Exploration of Naval Petroleum Reserve No. 4 and Adjacent Areas Northern Alaska, 1944-53

Part 1, History of the Exploration

By JOHN C. REED, CDR, USNR

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PART 1, HISTORY OF THE EXPLORATION

COMMODORE WILLIAM G. GREENMAN

Commodore Greenman was the Director of Naval Petroleum and Oil Shale Reserves from June 1944 to December 1950 and was the officer most responsible for the exploration for oil in Naval Petroleum Reserve No. 4. In many ways it was his project, and the outstanding achievements of the exploration largely stem from him.

FOREWORD

The Department of the Navy, through the Office of Naval Petroleum and Oil Shale Reserves, carried on explorations for oil in northern Alaska for 10 years beginning in 1944. The work was instituted to determine whether or not petroleum exists in commercial amounts in that part of the great Arctic basin in which Naval Petroleum Reserve No. 4 is located. It resulted in a partial appraisal of the oil possibilities of approximately 70,000 square miles of Arctic wilderness. Specifically, the program resulted in the discovery of 1 medium-sized and 1 small oil field, a gas field of major proportion, and other gas fields of apparently less but as yet unknown size.

The possibility of additional discoveries within the area is believed to be good. The Navy, at the present time, has suspended its search for oil in Alaska. The search will be resumed in the future if resumption of such exploration by the Navy is in the best interests of the Government.

The exploration program benefitted the oil industry by developing methods for large-scale oil operations under difficult, and sometimes hazardous, Arctic conditions. It also led to the gathering and interpretation of tremendous amounts of scientific and technical information concerning northern Alaska.

The United States Geological Survey, by agreement with the Office of Naval Petroleum and Oil Shale Reserves and with funds provided by that office, participated in the exploration program throughout and has undertaken to correlate and publish the results of the program in a series of five professional papers dealing with the history of the project, the regional geology, areal geology, geophysics, and subsurface geology of the area explored.

This is the first of the five professional papers. It was prepared by CDR John C. Reed, USNR. Commander Reed had an active part in the exploration program as an official of the Geological Survey. He completed this narrative while on temporary duty with the Navy, and, in part, on his own time. His enthusiasm and interest in the project are reflected in his presentation. The Navy is indebted to the Geological Survey and to Commander Reed personally for this factual and detailed report of the operation known as Pet 4.

A. S. MILLER
Captain, U. S. Navy
Director, Naval Petroleum and Oil Shale Reserves

GLOSSARY

Many abbreviations are repeatedly used in this report. For the most part these are the abbreviations commonly used in the Navy Department. The following glossary is for use in understanding the abbreviations:

AACS—Airways and Air Communications Service, U. S. Air Force.
ACS—Alaska Communication System, Signal Corps, U. S. Army.
ADM—Admiral.
AFB—Air Force Base.
AGB—Icebreaker.
AKA—Attack cargo ship.
ANS—Alaska Native Service, Bureau of Indian Affairs, U. S. Department of the Interior.
AO—Fleet oiler.
AOICC—Acting officer in charge of construction.
APA—Attack transport ship.
Arcon—Arctic Contractors, the prime contractor for the exploration of Naval Petroleum Reserve No. 4.
ARL—Arctic Research Laboratory, Office of Naval Research, Department of the Navy.
Arctic slope—Area north of the Brooks Range divide.
B29—A World War II 4-engine-type bomber aircraft.
Barchange—Barrow exchange expedition; the Barrow ship expedition in 1953.
Barex—Barrow expedition, the annual ship resupply expedition to Naval Petroleum Reserve No. 4.
BuAir—Bureau of Aeronautics, Navy Department.
BuDocks—Bureau of Yards and Docks, Navy Department.
BuShips—Bureau of Ships, Navy Department.
C46—A Douglas twin-engine freight aircraft.
C47—A Douglas twin-engine passenger aircraft. Equivalent to the Navy R4D, and the civilian DC3.
C54—A Douglas 4-engine aircraft. Equivalent to the civilian DC4.
C82—A twin-engine freight aircraft—the "flying boxcar."
CAA—Civil Aeronautics Administration.
CAB—Civil Aeronautics Board.
CDR—Commander.
CEC—Civil Engineer Corps, U. S. Navy.
CINCAL—Commander in Chief, Alaska.
CINCPAC—Commander in Chief, Pacific.
CNO—Chief of Naval Operations.
CNR—Chief of Naval Research.
CO—Commanding Officer.
COM-13—Commandant, 13th Naval District, Seattle, Wash.
COM-17—Commandant, 17th Naval District, Kodiak, Alaska.
COMAIRPAC—Commander, Air Force, Pacific Fleet.
COMALSEAFRON—Commander, Alaska Sea Frontier.
COMFIRSTSKFLT—Commander, First Task Fleet.
COMPHIBPAC—Commander, Amphibious Force, Pacific Fleet.
COMWESTSEAFRON—Commander, Western Sea Frontier.
Counterchange—Ship supply expedition to Barter Island in 1953.
CWO—Chief Warrant Officer.
D8—A large tractor.
DIRPACALDOCKS—Director, Pacific and Alaska Division, Bureau of Yards and Docks, Navy Department.
DNPR—Director, Naval Petroleum and Oil Shale Reserves.
LCDR—Lieutenant Commander.
LCM—Landing craft, medium.
LCS—Landing craft, small.
Linehaul—The regular contract flights in support of Pet 4 between Fairbanks, Umiat, and Barrow.
Loran—Long range radio navigation.
LSM—Landing ship, medium.
LST—Landing ship, tank.
LVT—Landing vehicle, tracked.
mcf—Thousand of cubic feet.
MSTS—Military Sea Transport Service.
NATS—Naval Air Transport Service.
NCBD—Naval Construction Battalion Detachment.
NOL—Naval Ordnance Laboratory.
NPR No. 4 or NPR 4—Naval Petroleum Reserve No. 4.
OICC—Officer in charge of construction.
ONR—Office of Naval Research.
Op 0303—Naval Operations, Polar Projects.
OpNav—Naval Operations, Office of the Chief.
PAA—Pan American World Airlines.
PAD—Petroleum Administration for Defense.
PB4Y—Navy version of the Liberator bomber, a twin-engine aircraft.
PBY—Twin-engine amphibious aircraft, Catalina flying boat.
PBY5A—Amphibious patrol bomber.
Pet 4—Naval Petroleum Reserve No. 4 or the Navy's oil-exploration program in Naval Petroleum Reserve No. 4 and adjacent areas.
PLO—Public Land Order.
Quonset or quonset hut—A curve-roofed prefabricated hut.
RADM—Rear Admiral.
R4D—*See* C47.
RCAF—Royal Canadian Air Force.
ROICC—Resident officer in charge of construction.
Seabees—The personnel of a Naval Construction Battalion.
SecDef—Secretary of Defense.
SecNav—Secretary of the Navy.
SIPRE—Snow, Ice, and Permafrost Research Establishment, Corps of Engineers, U. S. Army.
SPAMS—Special Alaska Magnetic Survey.
TAD—Temporary additional duty.
UDT—Underwater demolition team.
USAF—United States Air Force.
USCG—United States Coast Guard.
USNR—United States Naval Reserve.
VADM—Vice Admiral.
Weasel (M29C)—A light tracked gasoline-driven vehicle.
WO—Warrant Officer.

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EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944–53

HISTORY OF THE EXPLORATION

By JOHN C. REED, CDR, USNR

ABSTRACT

The exploration for oil of Naval Petroleum Reserve No. 4 in northern Alaska from 1944 through 1953 is known as "Pet 4." This is the narrative of that operation. This report outlines the background that resulted in the initiation of Pet 4. It describes the organization that was constituted to carry out the project, the administration of the exploration, the long-range planning that went into it, the progress that was made in each of the several parts of the project, and it finally discusses the overall effort in terms of accomplishment of the defined objective of Pet 4—"To appraise the oil possibilities of Naval Petroleum Reserve No. 4 and surrounding areas." Companion reports cover in detail the several segments of Pet 4, including regional and areal geology, geophysics, and subsurface geology and engineering.

The Brooks Range, which is around 150 miles wide, crosses Alaska from east to west somewhat north of the Arctic Circle. This report is concerned with the area, about 76,250 square miles in extent, that lies north of the Brooks Range divide. About half of that area constitutes Naval Petroleum Reserve No. 4.

The Brooks Range is rugged, especially in its central and eastern parts, and reaches an altitude of around 10,000 feet although the average altitude is much less. North of the range is a foothills province, which is about 20–80 miles wide, of moderate relief, and divided into southern, the more rugged, and northern parts. The altitude of the foothills province is about 600 feet at its northern edge and, in places, is as much as 4,000 feet along its southern border. North of the foothills lies an extensive coastal plain that ranges up to about 90 miles in width.

The area is cold—the highest summer temperature along the Arctic coast is often about 65° F, and the lowest winter temperature about —65°F. The annual precipitation is about 4½ inches at Barrow, and much of the precipitation falls as snow. Northern Alaska is windy—at Barrow the average annual velocity is about 11 miles per hour. Naval Petroleum Reserve No. 4 and surrounding areas is underlain by permafrost (permanently frozen ground) to depths of more than 1,000 feet. Permafrost causes many problems in activities such as oil exploration.

The report briefly outlines early explorations in the part of Alaska north of the Brooks Range, which began with the voyage of James Cook in 1778 when he sailed through Bering Strait and followed the Arctic coast as far as Icy Cape. A series of explorations by the Geological Survey began in 1923 when Naval Petroleum Reserve No. 4 was established. These explorations continued for 4 years, and they yielded much general geographic and geologic information.

The narration is broken down into years, and the years are divided by functional activities such as general planning and administration, transportation, construction and maintenance, drilling, geology, geophysics, and the support of other activities in the area.

On 5 February 1944, the Director of Naval Petroleum Reserves initiated the action that led to the exploration program of Naval Petroleum Reserve No. 4 by sending a proposal to the Secretary of the Navy for exploration and test-well drilling. By the middle of March competent technical advice had been obtained, coordination had been attained in both the executive and the legislative branches, and feasibility had been determined within the Navy Department. On 21 March the first reconnaissance party went to the Reserve by air and returned on 22 April. The report recommended the start of a full-scale petroleum exploration. Finally, on 2 June the President approved the project, and the exploration was launched.

By the end of 1944 the program was well underway. No drilling had been done, but much information had been assembled, and a camp had been built near Point Barrow and was occupied by a Seabee detachment. Air service was in operation, and the project was ready to proceed.

At the end of 1945 the program was reviewed by Admiral Moreell, the Chief of the Bureau of Yards and Docks. Much had been learned about operating problems in the Arctic. The practicability of tractor-drawn sled trains for hauling large tonnages long distances had been demonstrated. A ship expedition was successful. Air-support problems had been resolved. Information from surface geological surveys, geophysical investigations, and drilling was being accumulated and interpreted. In addition, progress had been made toward converting from a naval to a civilian-contractor operation.

Arctic Contractors took over the operation from the Navy in 1946 and completed more than twice the amount of winter freighting that had been estimated. During that year an airborne magnetometer survey was completed. Air photography and map compilation progressed. The work of five geological field parties was supplemented by office and laboratory studies. Two seismic and two gravity-meter parties completed their assigned tasks. The first test hole, Umiat test well 1, was drilled to 6,005 feet, and Umiat core test 1 was also completed.

Much progress was made in 1947. More than 15,000 feet of drilling was done. Winter freighting aggregated 749,000 ton miles. The ship expedition, Barex '47 (Barrow expedition, 1947), brought in 20,000 tons of supplies and equipment that were offloaded in 6 days. The understanding of the regional geology developed substantially.

Efforts expended in 1947 on projects other than the program itself was almost half the total effort. Chief of these was the construction by Arcon (Arctic Contractors) of facilities, including a large steel tower, related to an Army Loran (long range radio navigation) net. At the end of 1947 the operating committee, organized to advise on policies and procedures, recom-

mended continuation to at least 1952 and indicated that additional funds would be required.

By 1948 the results accumulating since the start of the program in 1944 were supplying an ever-increasing and ever-improving background of coordinated data for use in exploration. During the year a test hole, Simpson test well 1, was drilled to the basement rocks in the Cape Simpson area, and an encouraging stratigraphic test had been drilled in the Barrow area. The organization continued to support many other activities, largely on a repay basis, that otherwise could not have gone on.

About $7.5 million, including funds received for services performed for other activities, were expended in 1949. The average number of contractor employees during the year was 528. Among the notable accomplishments of the year were winter freighting aggregating 1.3 million ton-miles; much progress in the design of heavy-rig foundations; the completion of South Barrow test well 2 as a gas well, thus bringing gas to the Barrow camp; the establishment of bulk fuel storage at Barrow; and success in the use of LVT's (landing vehicle, tracked) and boat freighting within the Reserve.

In 1950, drilling aggregated 36,000 feet at 16 sites. Five seismic parties, one gravity-meter party, and seven geologic parties were maintained. Both Umiat and Simpson showed possibilities of major discoveries of gas and oil. In 1950 the program was executed more economically than ever before, and it was possible to carry on the work planned for about $900,000 less than originally estimated.

The program was hampered in 1951 for a considerable time because of doubt as to whether or not it was to continue, but finally the decision was made to go on. Freighting by sled train totaled 1,860,194 ton-miles, and drilling at 20 sites aggregated 47,710 feet. In 1951 a small oil field at Cape Simpson was proved; the Umiat field was better defined; and much was learned about producing oil from such an anticline. The field was estimated as containing between 30 and 100 million barrels of recoverable oil. The Gubik anticline was proved to contain large quantities of gas.

In 1952 only 15,142 feet of hole was drilled at 4 sites. The reduction in drilling was to conserve fuel for the drilling of two deep tests in 1953. Barex '52 brought 20,980 tons to Barrow in 4 ships. Winter freighting totaled 2,411,865 ton-miles at a cost of $709,000.

It was decided to recess the exploration in 1953, and selected equipment was moved to central points for inventorying, storing, and packing for return shipment. No drilling was done, but geologic and geophysical work was continued to logical stopping points. The recessing was accomplished satisfactorily.

It is estimated that in the 10 years of exploration the goal of the project was essentially attained in the western half of a broad coastal-plain belt along the Arctic Ocean and that the possibility of that area containing important oil accumulations is poor although it does contain a substantial amount of gas. The eastern half of the coastal plain is less well known and for appraisal would require a little more geologic work, geophysical surveying, and at least two test holes.

The western half of the lower foothills, which lie adjacent to the coastal plain on the south, is known to contain medium-sized and small oil and gas fields. More geophysical surveying and drilling are needed in that area before a reasonable appraisal can be made. The eastern half of the lower foothills is not well known. More geologic mapping, geophysical work, and at least three test wells would be needed for any reasonable appraisal of oil possibilities.

The oil possibilities of the higher foothills that lie still farther south are unknown. Geologic surveys, geophysical surveys, and drilling are needed for appraisal although some anticlines have been mapped geologically in some detail.

At the close of Pet 4 it was estimated by the contractor that 3–5 additional years of exploration would be required to attain fully the defined goal.

INTRODUCTION

This is the history of the Navy's exploration of the oil possibilities of Naval Petroleum Reserve No. 4, Alaska. It is a story of extraordinary integration and coordination between industry and a variety of Federal organizations. It recounts an important chapter in the history of oil exploration and in the development of the North American Arctic. Through planning, patience, and rugged determination, Pet 4 proved that the rigors of the Alaskan Arctic can be met and subdued at any season for indefinite periods by substantial numbers of men who, at the same time, can effectively carry on complex and difficult technical operations.

While the goal of the exploration was the gaining of all possible information on the oil possibilities of Naval Petroleum Reserve No. 4., an area as large as Indiana, the effort has also yielded a wealth of information and experience in arctic know-how that may well be of inestimable value to the military departments. The fact that an extensive program was going on and the presence of the facilities that were established to carry it on made many other activities possible in that region that otherwise would have been prohibitively expensive.

In the last analysis the exploration can, of course, be best appraised in terms of the men who carried it out. There were many of them, outstanding men for the most part, representing the Navy, the oil industry, and civilian Federal agencies. But among them all, whatever his station or position in the organizational chart, one man stands out for his burning enthusiasm for the project, for his courage and indomitable will to get on with the job, for his organizational and administrative ability, and for the loyalty and respect that he commanded from all connected with the program—Commodore William G. Greenman, Director of Naval Petroleum Reserves, from June 1944 to December 1950, throughout most of the span of Pet 4.

This is the first of a series of five general reports on the exploration. The other parts summarize special aspects of the program comprising "Part 2, Regional Geology"; "Part 3, Areal Geology"; "Part 4, Geophysics"; and "Part 5, Subsurface Geology and Engineering Data." This part attempts to integrate all of the diverse segments of the program into a sequential narrative not only of what went on, but also why, and

the implications of the results. Finally, it attempts to distill from the vast mass of material available an analysis of what is now known of Naval Petroleum Reserve No. 4 in terms of its petroleum potentialities.

So far as is known, the first white man to see the large oil seepages near Cape Simpson was Alexander Malcolm (Sandy) Smith, who is said to have "discovered" the seepages in 1917. A few years later, in 1921, Harry A. Campbell reached the seepages and examined them in the interest of a private company. Two groups of oil claims were staked at that time.

The oil age was approaching. World War I had shown that our Navy would require immense quantities of petroleum products; so, in February 1923, President Harding issued an Executive order establishing Naval Petroleum Reserve No. 4 (pl. 1) in Arctic Alaska in an effort to provide such products when and if needed.

According to Smith and Mertie (1930, p. 1):

> Oil had been reported at a few places near the coastal portion of this tract, but concerning most of the inland parts practically nothing was known. The responsible naval officials decided that for the proper administration of this newly created reserve the first thing necessary was adequate geographic and geologic knowledge of the tract. The Bureau of Engineering of the Navy Department therefore invited the Geological Survey of the Interior Department to examine and report upon the area and financed the beginning of this work.

During the following 4 years, 1923–26, the Geological Survey sent exploratory geologic and topographic parties into the reserve, and the broad outlines of the general geology and topography of the area were worked out in a reconnaissance fashion. That work formed the geologic base on which the exploration described in this report was built.

From 1926 until 1943 Naval Petroleum Reserve No. 4 received little specific attention in the Navy Department. The outline of the geologic pattern was known from Geological Survey Bulletin 815, which was published in 1930, but there was no shortage of petroleum products for either the Navy or the industrial economy, and northern Alaska, far away and fronting on the Arctic sea, was of no immediate concern.

However, World War II was in the making, and international unrest was growing. Finally, along with most of the rest of the world, the United States was plunged into the conflict both in Europe and in the Pacific. This was a different type of war—mechanized beyond previous imagination and requiring almost unbelievable quantities of petroleum products. Along with this came the shortening of global distances as better, faster, longer range aircraft were developed.

The whole pattern was such that there was need for a more complete knowledge of the petroleum potentialities of Naval Petroleum Reserve No. 4. Speculation about the Reserve and its possible petroleum resources took account of several possibilities—if the area contained large oil reserves, perhaps it would be possible to pipe the crude oil to the Pacific coast for shipment outside Alaska; maybe it should be refined in northern Alaska; possibly it could be used for Alaskan needs only, thereby saving the cost of transporting petroleum to Alaska; refining in the Reserve might provide products to supply bases in the Arctic; perhaps the oil would be refined in central Alaska or on the Pacific coast of Alaska and distributed from there.

In view of the general tightening of the petroleum situation in the early years of World War II, attention was turned toward Alaska and its possibilities for eventually contributing substantial quantities of oil. On 22 January 1943 the Secretary of the Interior issued Public Land Order 82, which withdrew from entry, subject to preexisting rights for use in the prosecution of the war, all the generally recognized possible petroliferous parts of Alaska including all of Alaska north of the drainage divide of the Brooks Range. (See pl. 1.)

Finally, on 30 March 1943 LT W. T. Foran, a Naval Reserve officer, a geologist in civil life, and a strong believer in the potential petroleum possibilities of the region, prepared a memorandum for R. W. Coghill, petroleum consultant for the Bureau of the Budget, in which he set forth some of the reasons for taking a more careful look at Naval Petroleum Reserve No. 4. Lieutenant Foran had been a member of some of the Geological Survey parties that had explored in the Reserve in the 20's and hence was familiar with the area and the broad outlines of its geology.

Late in the summer of 1943, the Bureau of Mines sent a party into northern Alaska to investigate the known petroleum seepages and to check on the existence and nature of other reported seepages. This expedition was dispatched because of the increasing interest in the oil possibilities of Arctic Alaska, including the Petroleum Reserve. The party traveled by bush plane, piloted by veteran Alaskan bush pilot Sig Wien, and in addition to an Eskimo guide, Simon Paneak, from the native group at Chandler Lake, included Norman Ebbley, Jr., of the Bureau of Mines; Capt. H. F. Thomas, of the Army Engineers; and H. R. Joesting, of the Alaskan Territorial Department of Mines. The group visited the known seepages, including those at Cape Simpson, and were taken to others apparently not theretofore seen by white men, including three small seepages near the present location of Umiat on what is now known as the Umiat anticline (U. S. Bur. of Mines, 1944).

Lieutenant Foran's memorandum to Mr. Coghill, as well as other recommendations, were carefully considered by the Navy Department; and after integration of plans with the Department of the Interior, the deci-

sion was made in the winter of 1944 to send a small reconnaissance party to the Reserve. That decision had the personal concurrence of President Roosevelt. Lieutenant Foran was placed in charge, and the party left Washington, D. C., on 16 March 1944 and returned to Seattle on 21 April 1944.

During the interval the party saw many parts of the Reserve. Lieutenant Foran's report was favorable and among other things concluded that "A petroliferous area of indicated major importance exists within the confines of Naval Petroleum Reserve No. 4." At the same time, the report recognized that the determination of the potentialities of the Reserve could not be of much, if any, assistance in the winning of the war in which the nation then was engaged. The departure of Lieutenant Foran's party in March 1944 was really the birth of the exploration program that soon came to be known to those familiar with it as Pet 4, the same abbreviation that is commonly used for Naval Petroleum Reserve No. 4.

Pet 4 continued from that time, March 1944, for almost 10 action-packed years of petroleum exploration. In recounting the progress of any long-range program in the far north, the normal way to divide the story is by years—each year being made up of what went on during each of the two totally different seasons. That method is used in this report. From freezeup through the long dark winter until breakup, conditions and methods of the whole pattern of living and working bear little resemblance to activities in the brief, welcome Arctic summer.

The story of Pet 4 is further divided by functional activities. Primarily, of course, Pet 4 was a petroleum exploration venture, and many of the activities are the normal subdivisions of any such exploration. Among these are geological activities, geophysical exploration, drilling, and recovery. Other activity subdivisions have to do with living and general operations; here belong such subjects as transportation, equipment, fuels and lubricants, food, airfield construction and maintenance, camp construction and operation, and clothing. Some subjects are included because Pet 4 was a Federal venture under the control of the Navy Department. In this group are treated the administrative organizational patterns, internal Navy Department relations, contacts with the Congress, relations of the Navy to the contractors and subcontractors and to other Federal agencies involved, fiscal affairs, and a variety of other matters.

Pet 4 started as a Naval Construction Battalion operation, but with the end of the war, followed by the general rush toward demobilization, it was decided to change as rapidly as possible to a civilian contract operation.

Pet 4 was recessed in the fall of 1953. The program had been successful in yielding a wealth of technical information sufficient for a partial appraisal of the petroleum reserves in large parts of the area. These reserves are substantial and under appropriate economic conditions may well justify eventual development. Furthermore, development and use may be justified if military strategy requires petroleum products in quantity in the North American Arctic. The facts of geography make this eventuality a definite possibility. It is apparent that the same factors that make both difficult and expensive the movement of petroleum from Naval Petroleum Reserve No. 4 to larger markets also make the taking of petroleum products to that area extraordinarily costly.

An outstanding product of Pet 4, as already briefly mentioned, has been the acquisition of a vast store of know-how in Arctic operations in many fields. Much has been learned, for example, about providing livelihood and livable working conditions for substantial numbers of men previously inexperienced in the Arctic and about transportation of personnel, equipment, and supplies in summer and winter by water, air, and land. Overall, the whole experience of Pet 4 was notably successful.

ALASKAN ARCTIC

To assist in understanding Pet 4, a brief summary is given here of the physical environment under which it was carried out. Pet 4 must be described against the background of location, terrain, and climate and some of their physical results such as salt- and fresh-water ice, vegetation, and permafrost. Methods of dealing with the environment in an oil exploration program were unknown before the program started. These things had to be learned as the project proceeded. In general, they were learned expeditiously and well, although at the expense of some efficiency, especially in the earlier years. To be sure, the area, especially the coastal regions, had been inhabited sparsely by the Eskimo. So too the Arctic Ocean had been partly known to explorers and traders since the early whaling days. A few traders had lived for short, and a very few for longer periods, along the Arctic coast. A handful of explorers, some of whom were trained scientific observers, had traversed the region of Pet 4, and their work had been well documented.

In general, though, the region was very little known, and nothing whatever existed as a body of facts on which to base the planning for the support of several hundreds of men and for carrying on drilling and other aspects of a major oil-exploration program.

From east to west across the main body of Alaska north of the Yukon River basin and north of the Arctic Circle stretches the Brooks Range. (See pl. 1.) This Arctic mountain chain is generally considered the northwestern extension of the Rocky Mountain System of Canada and the United States. The Brooks Range averages perhaps 150 miles in width and is succeeded in turn on the north by a broad foothills region, shown as the Arctic foothills on plate 1 and by a wide coastal plain, shown as the Arctic coastal plain on plate 1, sloping gently to the Arctic Ocean. The area north of the drainage divide constitutes about 76,250 square miles, about 37,000 square miles of which is included in Naval Petroleum Reserve No. 4. The Reserve includes parts of all three of the geographic divisions mentioned, but most of it is part of the Arctic foothills and the Arctic coastal plain.

The Reserve boundary extends due south from Icy Cape on the Arctic coast at approximately longitude 162° W. to the drainage divide of the Brooks Range at about latitude 68°30′ N. Thence it follows the divide eastward, and a little south to about longitude 156°10′ W., where the boundary turns due north and extends to the north bank of the Colville River and from there follows that bank of the river to its mouth at approximately 70°25′ N. latitude, 151°20′ W. longitude. Within these boundaries are about 37,000 square miles of Arctic terrain inhabited by some two thousand native Eskimos, most of whom live along the coast, with more than a thousand in the village of Barrow. There are only a handful of white inhabitants.

TOPOGRAPHY

BROOKS RANGE

The Brooks Range (see fig. 1) forms a great wall across northern Alaska and constitutes an effective barrier between the Alaskan Arctic to the north and the better known, somewhat more inhabited subarctic Yukon basin to the south. The Brooks Range, named for Alfred H. Brooks, former chief of the Alaskan division of the Geological Survey, is not a single, well-defined range but rather a group of mountain ranges and mountainous areas to some of which specific names have been given although these names generally designate broad areas without precise boundaries. (See pl. 1.) Among them are the DeLong Mountains toward the western end of the range, the Endicott Mountains in the vicinity of Anaktuvuk Pass, at about longitude 151° W., the Philip S. Smith Mountains east of the Endicotts, and the Franklin and Romanzof Mountains toward the east end of the range in Alaska.

According to Smith and Mertie (1930, p. 34):

> Scenically the Brooks Range is extremely attractive because of its sculpture, which has produced ragged mountain masses interrupted by steeply trenched or glaciated opened-out valleys, but when compared with many other mountain ranges the Brooks Range is relatively low.
>
> Taken as a whole, the average height of the summit of the Brooks Range from the meridian of the headwaters of the Aniuk eastward to the limits of the mapped area (the vicinity of Anaktuvuk Pass) is probably between 6,000 and 7,000 feet. From the Aniuk westward the highest parts of the range probably have an average elevation between 3,500 and 4,500 feet, and in the extreme western part, near the coast, the highest peaks stand less than 3,000 feet above the sea.

Eastward from Anaktuvuk Pass the range is somewhat higher, and the loftiest general area is in the Romanzof Mountains near the 144th meridian, not far west of the Yukon-Alaska border, where Mounts Chamberlin and Michelson rise probably to between 9,000 and 10,000 feet.

The main border of the range on the north side is rather abrupt, so that the mountain mass stands out conspicuously. East of Anaktuvuk Pass the northern front is progressively farther north; consequently, the foothills and coastal plain become narrower east of the Reserve. This northward progression is most conspicuous between the head of the Sagavanirktok River and the Canning River, and the coastal plain disappears entirely a short distance east of the area shown on plate 1, so that the narrower foothills province abuts the Arctic Ocean.

In detail, all but the western part of the range is extraordinarily rugged. Local relief is great, and the ragged and sharp crests and shoulders are accentuated by the absence, or at least, the sparseness of the vegetation.

The range is transected by low, rather open passes. The easternmost and best known of the passes is Anaktuvuk, at about the longitude of the eastern limit of the Reserve. That great trench, with several sharp bends or angles in its plan, connects the John River (a tributary of the Koyukuk) on the south with the Anaktuvuk (a tributary of the Colville) on the north.

ARCTIC FOOTHILLS

The Arctic foothills make up a belt of treeless rolling country and mountains of moderate relief, north of the Brooks Range and south of the Arctic coastal plain. The belt extends along the entire north side of the Brooks Range centering approximately along latitude 69° N. The foothills range in width from about 20 miles near the Canadian border to about 80 miles in the vicinity of the Colville River. The altitude of the foothills is about 600 feet along their northern edge and in places as much as 4,000 feet along their southern border against the north front of the Brooks Range. The

FIGURE 1.—Typical Brooks Range terrain near the head of the Itkillik River, east of Anaktuvuk Pass, showing steeply dipping Paleozoic rocks. View is westward along the range. Altitudes of higher peaks are about 7,500 feet. U. S. Army Air Forces photograph, 1947.

southern border is abrupt against the range to the south. The northern limit is less distinct, and in places the transition to the coastal plain must be drawn somewhat arbitrarily.

The Arctic foothills province is divided into a southern foothills (fig. 2) and a northern foothills (fig. 3) part. The former is more hilly, local relief is greater, and the general altitude is higher. In the northern foothills the local relief exceeds a thousand feet in only a few places. Both parts are characterized by long

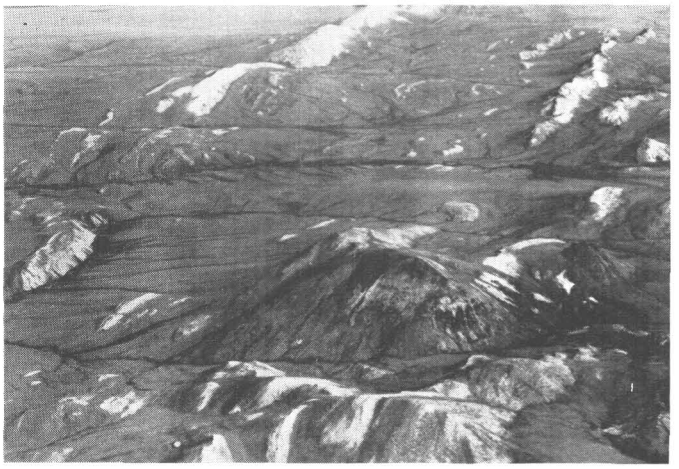

FIGURE 2.—Area of complex geology near the head of the Ipnavik River in the southern foothills part of the Arctic foothills province. Local relief is about 1,000 feet. Tightly compressed folds are cut by both thrust and normal faults.

parallel ridges and valleys roughly paralleling the mountains to the south. Extensive interstream plains and flat divides are common.

ARCTIC COASTAL PLAIN

The Arctic coastal plain is an extensive, monotonous tract (see fig. 4) between the Arctic foothills and the Arctic Ocean. (See pl. 1.) On the west it tapers and disappears at Cape Beaufort west of the Reserve, and on the east it narrows and virtually disappears a little east of the area shown on plate 1. Between its extremities the plain is widest south of Barrow whence it extends about 90 miles to the edge of the foothills. It narrows to about 50 miles in the vicinity of the Colville River along the eastern border of the Reserve and still farther east at the head of the Kuparuk River again widens to 70 or 80 miles.

As aptly described by Smith (1930, p. 48) and Mertie:

> Perhaps the most striking characteristic of the coastal plain is the uniformity and monotony of its landscapes. Except for minor details, its appearance is everywhere the same. Its slope is so slight that it appears to stretch away to the horizon as an endless flat. Prominent landmarks are entirely absent. Owing to its featurelessness even minor elevations such as sand dunes 10 feet high appear to be notable prominences * * *. Over these plains the winds sweep with unbroken severity, and the traveller caught in the sudden storms that are common in the winter finds it next to impossible to get any natural shelter. In summer the poorly drained tracts of upland afford only spongy footing, which makes travel laborious and slow, and lakes and deep sloughs necessitate circuitous deviations from direct courses.

DRAINAGE

In this section are described briefly some of the drainage features from within the Brooks Range northward across a part of the range, the Arctic foothills, and the Arctic coastal plain to the Arctic Ocean. This includes all of Naval Petroleum Reserve No. 4 as well as extensive tracts both to the east and to the west of the Reserve. An outline is included of some of the glacial history because of its profound effect on the character of the valleys, but no attempt is made to treat exhaustively the origin of the drainage, the geomorphic history, or the glaciation.

BROOKS RANGE

With the uplift of the Brooks Range, drainage was established down the slopes both northward and southward. This was across the dominant structural features, and concomitantly with the main cross-structure drainage, side drainages began to develop under the control of softer or more fractured layers in the rocks and along lines of structural weakness. The valleys are deeply incised. Valley slopes are very steep and rugged, and the divides are generally sharp and craggy. (See fig. 1.) The streams draining northward burst abruptly from the mountains to enter the Arctic foothills.

Major northward-flowing rivers that rise in the range include, from west to east, the Kukpowruk, entirely west of the Reserve; the Kokolik and Utukok, which drain large areas in the western part of the Reserve but enter the ocean west of the boundary; the Nuka, Kiligwa, Kuna, Ipnavik, Etivluk, Kurupa, Oolamnagavik, Killik, Okokmilaga, Chandler, Siksikpuk, Anaktuvuk, Nanushuk, and Itkillik, all tributary to the Colville River; and still farther east, the Kuparuk, Sagavanirktok, Shaviovik, Canning, and a few shorter rivers where the range is close to the Arctic coast not far west of the Canadian boundary at the 141st meridian.

Although the Brooks Range was extensively glaciated in Pleistocene time, the ice was never as widespread as it was in the Alaska Range, and some of the coastal ranges of Alaska much farther south. This was because of the sparse precipitation during Pleistocene time and continuing into the Recent. If there were enough snowfall, the Brooks Range today would be a glacial area indeed. As it is, there are only a few, relatively small glaciers in the whole range, and none of them extend into the foothills north of the range.

FIGURE 3.—View east over a large synclinal fold in the Utokok-Kokolik area of the northern foothills part of the Arctic foothills province near the western boundary of Naval Petroleum Reserve No. 4. Sandy layers, interbedded with shale, form ridges that describe the structure.

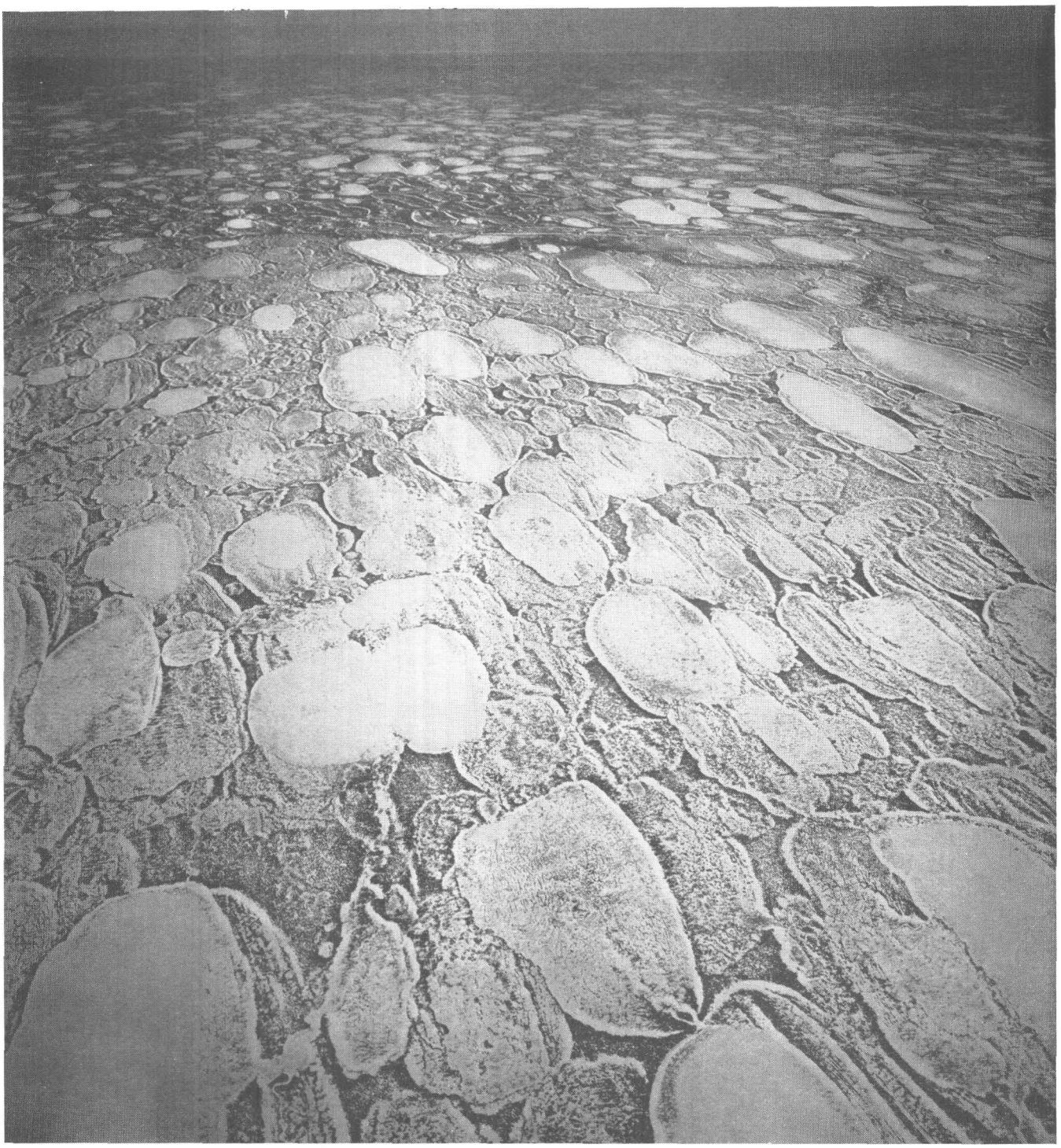

FIGURE 4.—The Arctic coastal plain near the head of Admiralty Bay and between the Meade and the Topagoruk Rivers. View is southerly. Note multitude of lakes and outlines of former lakes. Photography by U. S. Army Air Forces, 30 May 1943.

The Pleistocene glaciers had a profound effect on topography of the range, and the deposits left are important valley features both in the valleys within the mountains and in and near the valleys of the Arctic foothills. With the recession of the glaciers, the valleys that they had occupied were left with an assortment of glacial and glaciofluviatile deposits. Some of these deposits dam the drainage, forming extensive lakes both within the mountains and to some extent in the adjacent foothills. Among the more notable of these lakes are Chandler Lake, near the head of the Chandler River, and Lakes Peters and Schrader, on one of the tributaries of the Sadlerochit River near longitude 145° W. Within the range the glacial valleys are generally broad, flaring, and flat floored. Streams in unglaciated valleys have steeper gradients and much narrower valley bottoms.

The broad passes through the range, of which there are several west of Anaktuvuk Pass, are conspicuous glaciated trenches.

ARCTIC FOOTHILLS

Within the foothills the larger streams are incised a few hundred feet below the surrounding country. Those issuing from glaciated valleys in the mountains

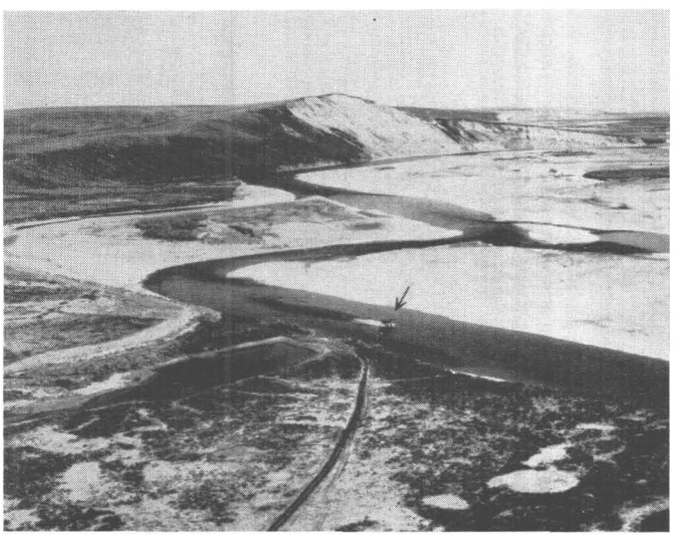

FIGURE 5.—View eastward down the Colville River from a point about over the Umiat airfield. Umiat Mountain is in center distance. Bush plane on floats is taking off from river near end of weasel road from the camp to the river. Photograph by U. S. Navy.

generally cross one to several moraines in series of bouldery rapids where for a few miles the gradients are somewhat steeper than elsewhere. The main streams continue to cross the major structural trends and in many places expose well the bedrocks where the streams impinge against the hills between tributaries. The tributaries are largely controlled by the structure.

The main valleys are broad and flat in cross section except in the occasional canyonlike narrows. The streams themselves have moderate gradients, are generally braided, and have a wide fluctuation in flow. Consequently, bare or willow-covered bars and islands are very common.

By far the most important river of the foothills is the Colville; in fact, it is the largest and most significant drainage feature north of the Brooks Range. (See fig. 5.) It rises in the southwest part of NPR 4 and flows generally a little north of east to a little below Umiat near the southeast corner of the Reserve where it turns abruptly northward near the northern edge of the foothills province. The eastward-trending part of the Colville basin is probably broadly controlled by the underlying structure. In that part of its course, it collects all the streams already mentioned that issue from the Brooks Range between the Nuka and the Chandler. Tributary to the Colville from the north are the eastward-flowing Awuna River and several smaller streams such as Prince Creek.

During the exploration the Colville and many of its major tributaries were traversed by small portable, sectionized, or other types of knock-down boats. Also the rivers, lakes, and bars were commonly used for landing small float or wheel-equipped planes.

ARCTIC COASTAL PLAIN

The streams are shallow and sluggish where they cross the Arctic coastal plain. They flow in contorted, complex channels among and through the thousands of shallow lakes. Northward from the foothills the Colville marks the eastern boundary of the Reserve, and two rivers that rise near the north edge of the foothills enter it from within the Reserve. These are the Kogosukruk and the Kikiakrorak. From the east enter the Anaktuvuk, the Chandler, and the Itkillik Rivers. The Colville flows into the Arctic Ocean across a broad delta, and the Itkillik joins it near the head of the delta. From the Anaktuvuk downstream to below Sentinel Hill, the Colville flows along a series of bluffs up to a hundred or so feet high on the west side, but eastward the flats extend for many miles. Major streams rising in the foothills and traversing the coastal plain in the Reserve include the Ikpikpuk, Oumalik, Topagoruk, Meade, and Kuk Rivers. Most of them have one or more named tributaries, and the Chipp River is a westward distributary of the Ikpikpuk.

Lakes are so numerous that in many places huge areas contain far more water than land. The lake shores are commonly low bluffs a few feet high, but many lake edges are indeterminate—so gradually does the water give way to swampy tundra. Over large areas the lakes are elongate and are markedly oriented

N. 12° W., or thereabouts. These lakes have been described by Black and Barksdale (1949, p. 110), but their origin is not clearly understood. It seems clear, however, that they are the result of lack of underground drainage because of the frozen ground, the almost complete flatness of the terrain, and the tundra vegetation. Explanations of their orientation include past and present prevailing wind directions, original slope, and the direction of the most direct sun rays during the summer. The largest lake on the Reserve is Teshekpuk Lake, near Smith Bay. The lake is approximately 25 miles long.

Within the Reserve, major indentations of the coast from east to west include Smith Bay, Dease Inlet and its wider head called Admiralty Bay, Peard Bay, and the estuary of the Kuk River, which is almost entirely blocked at its entrance but which is nearly 30 miles long and up to about 5 miles wide.

At many places the monotonous coastal plain passes very gently beneath the ocean, so that the profile is scarcely broken. Elsewhere the shore is marked by low almost vertical bluffs up to about 25 feet and in a very few places as much as 50 feet high.

Off much of the shore lie long and narrow barrier bars and islands made up of sand and gravel. Some of these are tens of miles long. Many of them are festooned from one headland to the next, and behind them, enclose wide, shallow lagoons and bays protected from the outer, rougher water and shoving sea ice. These inshore waterways are the first to open in the spring and offer a means of water transportation to natives in oomiaks and other small craft long before the ocean itself opens.

In general, the water off the Arctic coast of Alaska is rather shoal for considerable distances. There is virtually no tide along the coast of the Reserve; at most it amounts to a few inches. Of much greater significance relative to the ocean level is the effect of the wind, which sometimes changes the level more than 2 feet.

Mostly, the direction of ocean currents along the coast southwest of Barrow is northward, but the details are not yet known. This fact is of great importance to navigators because the currents control the movements of floating sea ice. It is often unsafe for ships to follow leads opening northward because of the ever present danger of the ice closing in behind, thus blocking escape. On occasion these currents are extraordinarily swift, sometimes several knots, and large floes and ice packs may change position rapidly.

The two outstanding annual events of Arctic Alaska are the opening and closing of the ocean. For a few weeks in late summer, the sea is open for navigation. After breakup, the sea can no longer be used for travel by dog sled or other over-ice vehicles. There is also a period when the sea is freezing during which the ice is too abundant to permit the use of boats and too weak for safe overice movement.

Commonly, the sea opens from the south toward the north and closes in the opposite direction. At no time is the main ice pack many miles off the coast although it may be out of sight for weeks. There is always danger of the pack moving in swiftly and unexpectedly. Ordinary ship navigation to Barrow is possible from early August to about mid-September, but there are wide annual variations. Shore leads are common over a larger span, during which times, with care, small craft may be used inshore especially in the lagoons and other stretches behind the barrier islands.

During Pet 4 the Barrow ship expeditions (Barex) reached Barrow early in August of each year, beginning in 1944, and departed by mid-August or as soon as unloading was completed.

CLIMATE

The climate of Naval Petroleum Reserve No. 4 is cold, but outdoor activities can be performed throughout the year, except for short periods of high wind or storm, providing a person is in good physical condition, well fed, and supplied with sufficient appropriate clothing. In fact, the temperature cutoff point for effective operations is frequently the effect of low temperature on equipment rather than on humans. Much has been learned about winterizing equipment for use in very cold weather.

The three principal weather factors at any locality, including Arctic Alaska, are temperature, precipitation, and wind. In considering each of these it is necessary, in order to gain a reasonably correct impression, to appraise not only averages but also maxima, minima, and distribution in time.

TEMPERATURE

The maximum range of temperature may commonly be about 130°F along the Arctic coast. Precise data are not available except for a very few localities such as at Barrow, but precise data are not necessary in this story of Pet 4. Generalizations are just as useful in giving a correct understanding providing, of course, that the generalizations are accurate.

The highest temperature in summer along the coast often is about the same number of degrees above 0°F as the lowest temperature in winter is below 0°; that is roughly 65°. The summers are short, however; and it is not unusual for the temperature to rise above the freezing point only occasionally from October through

May. The temperature is likely to drop below freezing at times during even the summer months.

The ocean has a somewhat moderating effect on the temperature, and extremes are believed to be both higher and lower only a short distance away from the coast.

PRECIPITATION

The area north of the Brooks Range is arid. At Barrow the mean annual precipitation is recorded by the Weather Bureau as about 4½ inches, and much of this falls as snow—in 1945 Barrow was recorded as having 28.6 inches of snow, and that year the total precipitation was 3.06 inches. During the summer months most of the precipitation falls as rain although snow may come at any time. In northern Alaska the high winds drive the light, dry snow easily, and accurate measurements of snowfall are difficult. Leffingwell (1919, p. 62) says, for example, "During high winds the air is full of driving snow for several hundred feet vertically, yet an open-top receptacle placed on the ground probably would remain empty, on account of the peculiar air currents." Observations of Leffingwell and other Geological Survey geologists are that in the mountains the snowfall is perhaps 3–4 feet (Smith and Mertie, 1930, p. 60). The following quotation (Smith and Mertie, 1930, p. 60) gives a vivid impression of the precipitation—

> Although the foregoing instrumental observations constitute the most authoritative and reliable data regarding the precipitation of the region, they suggest an aridity far more intense than other features of the region indicate. These apparent conflicts between facts and impressions can be recognized when it is realized that small precipitation is only one of the factors that determine the characteristics of arid regions such as the Sahara or the arid lands in the basin and range province of the western United States. A region of small precipitation is usually pictured as devoid of water, but in northern Alaska water is almost everywhere. The surface of the country during the summer is commonly wet and swampy, and water stands on the surface in ponds and lakes. The streams, unless they traverse a broad belt of limestone, show no marked diminution of volume but constantly increase in size toward their lower courses. All these features are due in large measure to the permanently frozen condition of the subsoil, which makes the removal of surface water by percolation and by underground migration impossible. Furthermore, the low elevation of the sun, even during the summer, prevents rapid evaporation. The rainfall or snowfall thus stands on the surface or collects in low areas where the slope is not sufficient to induce surface run-off. Then, again, the upper 6 to 18 inches of the frozen zone melts during the summer and thus produces wet, soggy footing that is most unlike any preconceived idea of a dry country. Furthermore, the precipitation does not come in deluging cloud-bursts, separated by long intervals of low precipitation, as in the countries most often referred to as arid, but comes in numerous light showers or heavy mists.

Smith and Mertie might have added that the dense, matlike but low tundra vegetation over the whole area and the very gentle gradient of the coastal plain both tend to slow down surface runoff very markedly even during the few months when the ground surface is unfrozen.

WIND

Everyone who has stayed for considerable time in northern Alaska remembers the wind, for it is windy 99 percent of the time, and there is very little shelter from the icy blasts. The average annual wind velocity at Barrow is about 11 miles per hour, and the winds are generally easterly or northeasterly along the coast and probably also on the coastal plain. The U. S. Weather Bureau reported the maximum wind velocity at Barrow in 1945 as 43 miles per hour, but much higher velocities are often recorded. Furthermore, the wind is very evenly distributed through the year. For example, the official Weather Bureau records for average monthly velocities for 1945 at Barrow are as follows:

Month	*Velocity (mph)*	*Month*	*Velocity (mph)*
Jan	12.2	Jul	9.3
Feb	10.0	Aug	11.9
Mar	9.9	Sep	13.0
Apr	11.3	Oct	11.4
May	13.2	Nov	8.8
Jun	9.7	Dec	12.5

Less is known about the wind inland than along the coast. Generally, it seems somewhat less windy away from the coast. In the higher and rougher parts of the Arctic foothills and in the Brooks Range the winds, according to reports of field parties, commonly seem to be largely controlled by the topography and blow in considerable part either up or down the valleys.

PERMAFROST

Permafrost or perenially frozen ground is a widespread geologic phenomenon in arctic and subarctic areas. Permafrost is defined on the basis of temperature as existing where the ground temperature is at or below +32°F. Thus, where no moisture is present as in solid volumes of bedrock or in loose material such as gravel, permafrost may exist without ice. Most of the water is frozen, but during the short summer months a thin surface layer thaws; in places the water moves through the ground too rapidly to freeze, and at other points the moisture may remain liquid because it is saline and hence has a lower freezing point or because it is in capillary openings where moisture may exist in liquid form substantially below 32°.

In a very gross way the southern limit of permafrost roughly coincides with the +32°F isotherm. Thus, it extends much farther south in higher, colder terrain.

Its southern limit is not sharp. Near its southern limit, permafrost is generally thinner and becomes discontinuous and patchy. Locally, permafrost is absent in areas far to the north of its general southern limit, for example, probably under the ocean, in recent volcanic areas where the ground temperatures are unusually high, possibly under certain deeper lakes and rivers, and elsewhere for a few other reasons. Unfrozen zones within perenially frozen ground are common, especially near the surface.

Much of this section on permafrost is taken from a paper by Black (1950) that is a compilation of the work of many authors as well as the results of Black's own investigations.

All of Alaska north of the Brooks Range is far inside the permafrost zone. The permafrost is thick, up to a little more than 1,300 feet, and is present almost everywhere. Recent observations by G. R. MacCarthy and others of the Geological Survey indicate that the coldest level is about 110 feet below the surface in most places and that from there on down the temperature rises about 1° for every 80 feet until temperatures above freezing attain and the permafrost zone terminates. The temperature at the coldest level may be as low as −10°C.

FIGURE 6.—Polygonal ground along the Arctic coast southwest of Wainwright. Photograph by U. S. Navy, 1949.

A common surface expression of permafrost is polygonal ground. (See fig. 6.) In areas of polygonal ground the surface is made up of a mosaic of polygons commonly several tens of feet in diameter. The polygon boundaries are either trenchlike depressions or ridges, and Black (1950, p. 263) has shown that the polygons go through a cycle "from flat surfaces with cracks to low-centered polygons and, finally, to high-centered polygons." Permafrost, especially in fine-grained material that is poorly drained, generally contains much ice in grains, films, fracture fillings, sheets, wedges, and irregular bodies.

Permafrost is far more than a fascinating scientific phenomenon. It is a large and frequently a dominant factor in devising ways of living and operating in the Arctic except in the most primitive fashion. It raises engineering problems in any activity of substantial scale, and Pet 4 was no exception. Space does not permit an exhaustive treatise either of permafrost as a phenomenon or of the means of dealing with it in the many ways that required attention during the program. A brief mention of some of the problems presented by permafrost will be helpful, however, as a background for a better understanding of Pet 4 as it progressed.

In the summer the wet, soggy tundra is difficult to traverse even on foot. For most ground vehicles the terrain is impossible. Tractors can operate locally but cannot cross the lakes or larger streams. Weasels and LVT's do fairly well if handled carefully and if facilities are available for maintenance.

Surface water is abundant in the summer, but there is no ground water within the permafrost zone except in unusual local situations. In the long winter, surface water is frozen to a depth of around 7–9 feet, and the only water available is from below the ice in deeper lakes or streams. It must be kept from freezing if moved any substantial distance. The Eskimos commonly melt ice for water in the winter.

Sewage disposal for large numbers of people is a problem. Sewage pipes cannot be laid in the frozen ground except at great cost of installation and maintenance. The pipes freeze because of the low ground temperature and, if warmed, cannot easily be held to grade because the supporting material is converted to soft mud.

Foundations are a real problem for anything except light, unheated structures. Structures may be supported on piles steamed into the permafrost and allowed to freeze in, provided the building is insulated sufficiently to prevent building heat from melting the ground below. Supports for heavy drill rigs that must remain stationary for months during the drilling of a deep hole are a special problem. The warm drilling mud from depth must not be allowed to thaw the foundation from beneath the rig and must also be carried well away from the structure at the surface to prevent melting of the permafrost and creating a mud hole around the rig.

Road locations must be carefully selected, and the grades must be built up because cutting into the permafrost only exposes deeper frozen zones to melting.

Apparently, the top of the permafrost zone is deeper below large deep lakes or even may be absent entirely. In a lake area like the Arctic coastal plain, serious problems are encountered in interpreting seismic exploration results correctly because the frozen material around the lakes transmits seismic waves differently than unfrozen material under the lakes; this gives data that may be interpreted as indicating geologic bedrock structures where none exist.

The extraction of petroleum from zones within the permafrost is not well understood, but it is likely that production through the permafrost zone will be extraordinarily difficult. If water is present the wells may freeze up; casings are difficult to maintain; and the effectiveness of artificial heating is not yet fully appraised.

The serious implications of permafrost relative to the activities mentioned above are obvious. Permafrost problems can be and are being solved, but the solutions are difficult and expensive and far more research must go on as to the origin, character, and habits of permafrost before the best solutions are found. Many other examples could be cited, but those mentioned have been selected so that the reader can always keep permafrost in mind and appreciate its importance as it pertained to Pet 4.

VEGETATION

There probably are no real trees, in the usual sense, within the boundaries of Naval Petroleum Reserve No. 4. Spruce grow along the main valleys of the range northward to approximately the divide into the Arctic drainage where their extent terminates abruptly. Willows, locally of considerable height and thickness, but still of shrublike character, grow abundantly along the river flats on the Arctic slope especially in the Brooks Range and foothills provinces and in many places are sufficient for fuel, tent poles, stakes, and other small, camp uses. The willows are either small and useless or entirely absent within a few tens of miles of the Arctic coast. Along the valleys in the foothills province grow stands of alder and cottonwood. Some of the latter in a very few places are treelike though rather small and insignificant in number. Some may reach a height of 35 feet and a thickness at the base of 10 inches.

Most of the area, excluding the major valley bottoms, is typical tundra. The vegetation, which is commonly a thick, spongy, matlike growth, is made up predominantly of grasses, sedges, mosses, lichens, and prostrate bushes. Here and there some areas, especially ridge tops, are almost completely bare of vegetation.

The flowers of Naval Petroleum Reserve No. 4 are a conspicuous and attractive summer feature. They blossom quickly in the continual summer daylight and are present in colorful profusion. Common flowers include purple and white anemones, poppies, mustard, saxifrage, roses, and asters.

Much recent work, some not yet published, has been done on the botany of the area, much of it through projects at the Arctic Research Laboratory of the Office of Naval Research at Barrow.

ANIMALS

No attempt can be made here to give a complete account of the numbers, habits, and distribution of all the animals of Naval Petroleum Reserve No. 4. Rather this section attempts to mention only a few of the more conspicuous animals with short comments about some of the easily observable ones. Much research still remains to be done on the zoology of northern Alaska.

Dall sheep, the white mountain sheep, are common in many parts of the Brooks Range, and the Eskimos occasionally travel long distances to hunt them. They range northward for long distances from the mountains and are present in substantial numbers among the ridges and hills of the foothills. Pet 4 field parties noted them as especially abundant along the front of the mountains from Chandler Lake eastward to and beyond the Canning.

A generation ago moose were reported as rare in the vicinity of Chandler Lake and farther north on the Killik River. Since then, moose seem to have increased in numbers, and their range has been extended much farther north. They now are common along most of the valleys of the northern slope occasionally almost to the Arctic coast. More than 60 were counted by the author in one airplane flight in the summer of 1950 along the Colville River between the mouth of the Killik and Umiat. The moose are confined to the valley bottoms and can not travel well or obtain forage in the interstream areas.

Caribou are still present in large numbers north of the Brooks Range. Adequate data as to numbers and as to increase or decrease are not available. During Pet 4, large concentrations of many tens of thousands were noted in the summers between the head of the Meade River, the Colville, and the Utukok and also east of the Reserve in the vicinity of the upper Shaviovik. Thirty or so years ago substantial numbers of reindeer were herded after a fashion by Eskimos at many places along the Arctic coast. These herds are now mostly gone. A small herd of a few thousand was maintained during the early part of Pet 4 around Alaktak or Half Moon Three

near Cape Simpson by the family of Tom Brower, of Barrow. It is reported that these are now gone.

The few bears that inhabit Naval Petroleum Reserve No. 4 and its environs are believed to be grizzlies. They are not numerous but are seen occasionally, and food caches are subject to severe destruction unless the food is stored in bear-proof containers such as 56-gallon steel drums. Polar bears live on the arctic ice and occasionally come ashore, but they do not range inland.

Red and cross foxes and the white arctic fox are common in many parts of the Reserve and are trapped for their fur by the Eskimo. Wolves also are fairly common, and the coyote is said to be increasing. The wolves seem to be especially abundant along the river valleys.

Although not in large numbers, smaller fur bearers such as the weasel, mink, and marten are present and are trapped. Wolverine also are widespread but not numerous. Wolverine and wolf fur is prized for its suitability in making ruffs for parkas.

An abundant inhabitant of the Reserve is a ground squirrel called sik-sik by the Eskimos. It burrows extensively in unfrozen places such as the bank selveges along the streams. A larger, marmotlike rodent called the sik-sik-puk is also rather common. The fur of these animals is widely used for parkas and other articles of clothing.

In some years lemmings are amazingly abundant, but the animal is cyclic, and very few are seen in the lean years of the cycle. Mice and shrews have also been recognized, but little is known about either the varieties present or their abundance.

The white arctic hare used to be an abundant inhabitant, but so far as is known, none were seen by anyone connected with Pet 4 or by the Eskimos in recent years.

The Eskimos, of course, own numerous dogs and use them extensively in the winter as draft animals. They are for the most part small and of mixed breed.

Sea animals are of wide variety. The whale, of several species, is much prized by the natives. Almost every year several are caught by the natives of Barrow and other villages such as Wainwright. A year of poor whaling can be disastrous for the Eskimos. The natives also hunt walrus, hair seal, and the large arctic seal called the ooguruk. Polar bears already have been mentioned.

Birds inhabit the Reserve in large numbers and in great variety. Only a few can be mentioned. Gulls, arctic terns, and jaegers are abundant, as are ptarmigan, plovers, and longspurs. Shore birds are conspicuous on sandy stretches of beach. Ducks, geese, and loons are widespread over the Reserve. There also are large numbers of hawks, including the rough-legged hawk, and the peregrine falcon. Canada jays are welcome companions in small camps, and the willow thickets and tundra abound in small song birds. The great snowy owl is often very abundant especially when the lemmings are numerous.

Special mention should be made of the mosquitoes. For a few weeks in summer, from about mid-June until early August, they are present in unbelievable swarms and can be a great nuisance in fieldwork. They do not carry malaria and are harmless so far as disease is concerned which is, however, little comfort to the fieldman plagued by them. A mosquito-proof tent and an insecticide to kill those inside are necessary for a worker to obtain restful sleep and to be able to carry on effective field operations. Gnats also may be present in plaguing myriads.

INHABITANTS

There are two permanent native villages in the Reserve: Barrow and Wainwright. The natives are all Eskimos. In addition, small settlements are occupied occasionally for rather short periods at many places along the coast. Some of these are occupied for a time each year for hunting purposes, others more rarely. Evidences of older abandoned settlements are common. The villages include a wide variety of dwellings—from the most primitive sod huts, tents, and various makeshift shelters to substantial dwellings. Barrow is now said to include more than a thousand natives. Many of them were attracted there by the better facilities and chance of employment in Pet 4. At Barrow is a school maintained by the Alaska Native Service, a Native Service hospital, a Signal Corps station, and a mission. There also is a school at Wainwright, which is a much smaller settlement of about 80 people.

A group of about 50 natives lived for years at Chandler Lake at the north front of the Brooks Range. They now have moved to Anaktuvuk Pass. These natives range widely in the summer, hunting sheep or following groups of caribou.

All of the natives live largely by hunting, fishing, and trapping. Reindeer herding has practically ceased. During Pet 4 about 80 Eskimos were employed by Arcon and attendant activities such as the Arctic Research Laboratory. The natives were paid the same wages as the whites for similar work, so that substantial cash was known in Barrow village. A serious socioeconomic problem was posed when Pet 4 terminated and the source of income with it. Unless the large number of natives now congregated there spread widely again, the local economy is likely to be insufficient to support them all.

The natives are especially susceptible to the common white man's diseases, such as measles, and appear to

have little resistance to them. Tuberculosis is rampant, and the living conditions do much to aggravate the seriousness of the situation.

A handful of whites live more or less permanently in Barrow and at Wainwright. These include teachers, nurses, Signal Corps employees, and a few others. There has been a white trader at Anaktuvuk Pass since 1950.

The only white settlements during Pet 4 were the contractor's (formerly the Navy's) camp about 4 miles north of Barrow village and the smaller camp at Umiat. (See pl. 1.) There normally were 300–500 men at the Barrow camp.

TRAVERSABILITY

Transportation of workers and the many kinds of supplies and equipment were a major problem in Pet 4. Much was learned—most important of all it was irrevocably proved that the problems, difficult as they are, can be, and repeatedly were solved. Also, it is generally agreed that large tractors were by far the most important pieces of equipment used in Pet 4. The subject of traversability will come up again and again in this story of Pet 4; therefore, it seems appropriate to outline very briefly here some of the factors that make up the general subject. This outline will serve as a background against which to appraise statements relative to traversability as they appear.

The most important point to keep in mind in regard to traversability is the vast difference between summer and winter conditions. The diagram shown on plate 2 has been adapted from a work-feasibility chart prepared by CDR P. W. Roberts, one of the officers in charge of construction on Pet 4. From November or December until April or May the surface of the tundra is frozen and therefore solid. It will support heavy loads after freezing penetrates to the permafrost surface. For the remainder of the year, traversability is a much more difficult problem. The ground is soft and wet down to the frozen material below. The more it is churned up, the more melting takes place. On the coastal plain the myriad lakes make the setting of straight courses almost impossible, and many of the rivers are deep enough to be substantial barriers.

Travel on foot is feasible on the sea ice in winter. Foot travel over the sea ice is not recommended for long distances because of weather hazards, difficulty of crossing pressure ridges, necessity of making long detours around open leads, loss of efficiency because of the heavy clothing necessary, lack of fuel, and difficulty of carrying sufficient shelter and food. The coastal plain is very difficult to travel on foot in summer; the soft ground, lakes, streams, mosquitoes, and roughness of the tundra vegetation all make progress slow and discouraging. The coastal plain can be crossed on foot in winter with less difficulty, but weather hazards are always considered. Travel on foot along long stretches of beach is possible summer or winter.

Foot travel in the foothills is easier than on the coastal plain, but wide areas of tundra vegetation are crossed only slowly and laboriously. Foot travel in the higher foothills and in the mountains is still easier. The footing is better except in the rugged mountains, and willows for fuel generally can be found in the valleys.

The traditional means of travel and hauling in the winter is by dog team. Dog teams and sledges can be widely used both on land and on sea ice, but the weights that can be transported are far too small for a project such as Pet 4, except for a few special chores. Sometimes dogs are used for carrying back-packs in summer, but that method is limited, and the weights that can be carried are small. Reindeer do not appear to be very useful as pack or draft animals.

The M29C weasel, a light tracked vehicle (see fig. 7), proved to be a very useful personnel carrier and

FIGURE 7.—Use of the weasel (M29C) in geological work. *A*. Weasels on the tundra in the Nuka River area. This is a typical geologic field project. Photograph by Geol. Survey, 1951. *B*. Weasels at a Geological Survey camp on a gravel bar in the Carbon Creek area. Photograph by Geol. Survey, 1950.

light land vehicle on the Reserve. In fact, it is believed that parts of the exploration program would have been impossible without the weasel or an equivalent vehicle. Careful driving is required to avoid damaging the carrier's two weak spots—the differential and the tracks. Nevertheless, weasels were used with marked success by geophysical and geological parties on long trips lasting on occasion for several months. Gasoline, supplies, and replacement parts were cached by tractor trains or planes in the winter or were dropped by free fall or parachute in the summer.

Where roadbeds sufficient to support them were maintained locally, wheeled vehicles such as jeeps and personnel carriers had important but nevertheless limited use around main camps such as Barrow and Umiat.

LVT's (landing vehicle, tracked) were used with considerable success for over-tundra transport and for use around and near camps in both summer and winter.

Tractors proved to be the most effective movers. They were the principal hauling elements of the winter "cat" trains by means of which most of the heavy moving was accomplished. It was found that as much heavy hauling as possible should be done over the ice of ocean, lagoons, and lakes, or along or parallel to streams. Cross-drainage hauling is more difficult, largely because of the hazards of even rather low cut banks that delay or stop both the tractor and sleds being towed.

Airplanes had a very important place in Pet 4. The so-called linehaul from Fairbanks to the Reserve employed several types of fairly large aircraft. Most of the freighting was by C46's, a military twin-engine Douglas aircraft, which in summer and winter effectively used both the pierced-plank airstrip at Barrow and the gravel strip at Umiat. Local plane service within the Reserve ranged widely depending on season and local conditions. Small aircraft (Norseman, a single-engine aircraft, and smaller) were used on wheels in summer using the strips at Barrow and Umiat, gravel bars along rivers, favorable ocean beaches, and improvised strips at such places as the Meade River coal mine and Half Moon Three camp (Alaktak).

In summer small planes on floats were widely used, and landings and takeoffs were effected on lagoons, lakes, and rivers. In winter the use of small planes was greatly facilitated by addition of ski landing gear. Larger aircraft such as the amphibious PBY, Catalina flying boat, were occasionally used for special tasks such as the airborne magnetometer survey and scouting of ice conditions for ship expeditions.

Helicopters were tried for certain geologic parties operating in the mountains but were abandoned after one fatal accident. However, they were very successful in gravity work on the coastal plain and in facilitating control surveys by the U. S. Coast and Geodetic Survey.

Plane use was greatly aided and rendered much safer by the lighting facilities, radio homing beams, and other navigational and landing aids at Barrow, Umiat, Bettles, and Fairbanks.

The annual Barrow ship expeditions, Barex, could reach Point Barrow for a short interval each summer. These expeditions were aided in some years by the assignment for at least part of the time of an ice breaker such as the U. S. S. *Burton Island*. Landing of material on the Barrow beach had to be accomplished as rapidly as possible when the ships arrived in order to reduce the ever-present danger of the pack ice. Ships and LST's (landing ship, tank) were used on occasion to ship eastward from Barrow along the coast as far as Barter Island, far east of the Reserve and not far from the Canadian boundary at longitude 141°. Small powerboats and sailboats, oomiaks (walrus-skin boats), and kayaks (small skin boats) are used by the Eskimos during the open season but were not employed in Pet 4 for freighting. Canoes and various types of collapsible canvas, wood, and plywood boats were employed successfully by survey parties on rivers during the summer. The use of larger, powered river boats on the Colville and other larger streams was often discussed but was not tried.

EARLIER EXPLORATIONS

Before proceeding further with the story of Pet 4, the reader should have at least a brief summary of the history of exploration of northern Alaska up to the time Pet 4 started in order to grasp the status of the information available on the area. This section, therefore, outlines the explorations that resulted in the factual foundation on which Pet 4 was built. (See fig. 8.)

It was a long time after many parts of Alaska, especially the Pacific coastal areas, were reasonably well known to the world that anything was learned about the area that now includes Naval Petroleum Reserve No. 4. So far as the record goes, the first white man to see any part of the Reserve was Capt. James Cook who in 1778 penetrated Bering Strait and sailed northeasterly along the coast as far north as Icy Cape, the point where the western boundary of the Reserve now reaches the Arctic Ocean.

It was nearly 50 years later in 1826 that Capt. F. W. Beechey, of the British Navy, commanding H. M. S. *Blossom*, pushed northeastward until blocked by the ice north of Franklin Point. Captain Beechey had been dispatched to cooperate with Sir John Franklin, who was working westward along the north coast from the

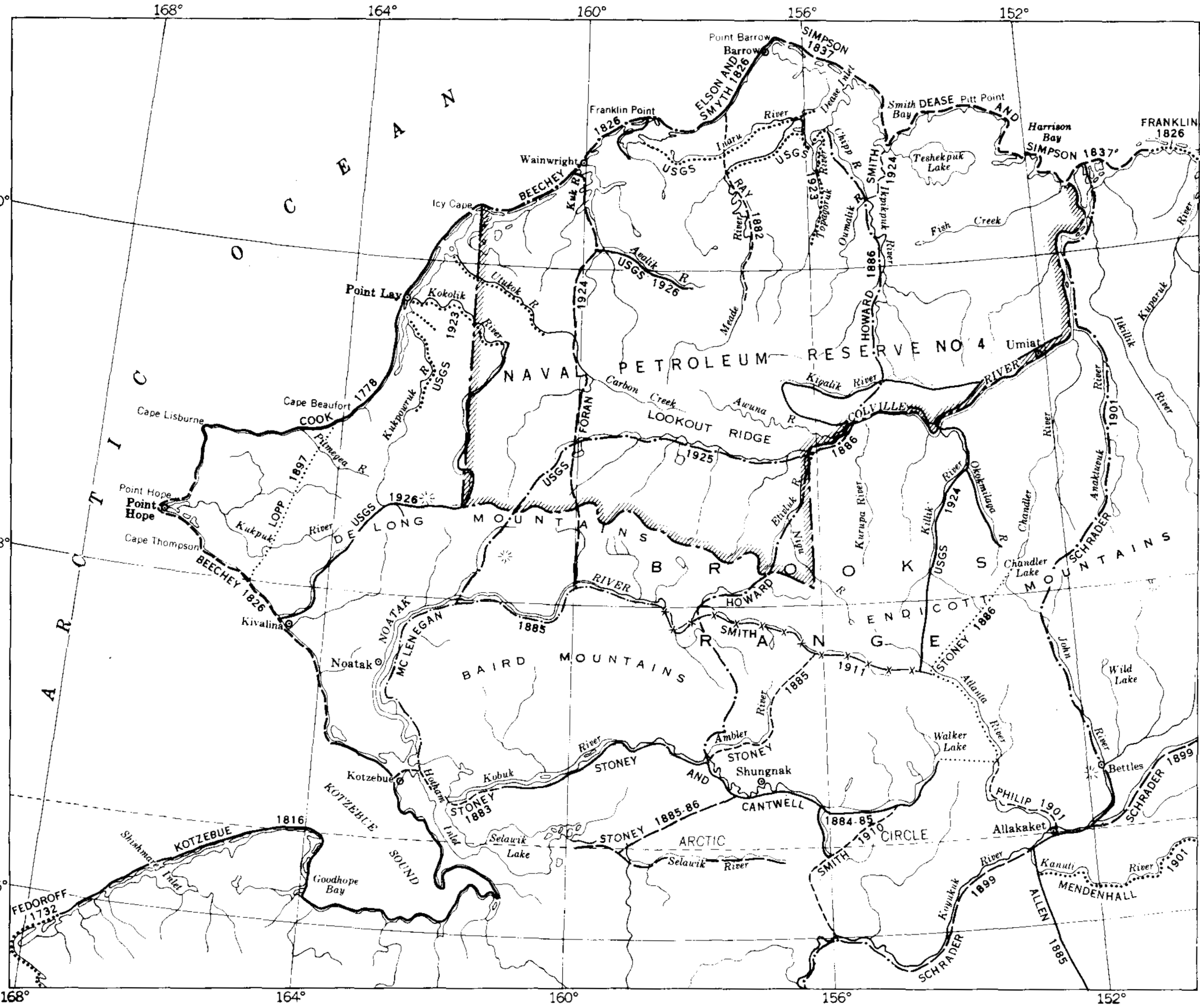

FIGURE 8.—Sketch map showing exploratory routes and progress of investigations in northwestern Alaska. (Map is modified from plate 3 of Geological Survey Bulletin 815.)

mouth of the Mackenzie River. Beechey's surveys were of extraordinary accuracy and have been much used. Beechey's mate, Elson, and one other man, Smyth, left the *Blossom* when it could proceed no farther and made their way in a small boat in the more open water near the shore as far east as Point Barrow. Meanwhile, Franklin, working westward from the Mackenzie reached a point near the eastern edge of the delta of the Colville where he too was stopped by the ice thus leaving some 150 miles of coast that had not yet been traversed.

This gap was filled in 1837 when P. W. Dease and Thomas Simpson were sent out by the Hudson's Bay Company. After descending the Mackenzie River, they pushed westward like Franklin. In their open boat they passed the Colville and reached a point a little toward Barrow from Cape Simpson where they landed and decided to proceed onward on foot. Simpson, with three others, finally reached Point Barrow from the east.

Between 1848 and 1853 much knowledge was gained by various expeditions sent out for the relief of Sir John Franklin, and the records left by the captains of the various ships are records of brilliant accomplishment. For example, in 1849 from one of the several relief ships in Kotzebue Sound, Lieutenant Pullen proceeded in a boat with a small party all around the Arctic coast to the Mackenzie and up that river to a Hudson's Bay Company post.

In 1848 an American whaler penetrated the Bering Strait into Arctic waters and whaling thereafter developed into a substantial industry that continued for many years.

By 1881, when Lt. P. H. Ray led the international polar expedition in the vicinity of Barrow, northern Alaska had been American territory for 14 years. Ray's work went on at Barrow for 2 years and included climatological and magnetic observations. Lieutenant Ray, among other things, explored up the Meade River to approximately latitude 70° N. near the southern limit of the coastal plain.

Starting in 1883 and continuing for several years, LT George M. Stoney, of the U. S. Navy, made explorations in the general Kobuk-Noatak area (the Kobuk River is a little south of the area shown on pl. 1) south of the Brooks Range and the western part of the Reserve area. In the winter of 1885–86 he stayed near Shungnak (south of area of pl. 1) and made explorations from there; one trip took him as far as Chandler Lake, and he apparently was the first white man to see that lake at the north front of the Brooks Range.

The most notable early inland journey within the Reserve area was by one of Stoney's officers, ENS, later RADM, W. L. Howard. According to Brooks (1906, p. 123)—

> He left the winter camp in April (1886) with two white men and two natives and proceeded northeast across the Noatak to the valley of the Colville, followed this downstream in company with a party of natives for about 20 miles, and then crossed to the headwaters of Chipp River. Here he discarded the dog teams used up to this point for transporting his supplies, and descended the Chipp River to the coast in native skin boats, arriving at Point Barrow on July 15, being the first white man to cross northern Alaska.

The second trip across northern Alaska, but far east of the present Reserve, was by J. H. Turner, of the U. S. Coast and Geodetic Survey, who established an astronomic position station where the Porcupine River crosses from Yukon Territory into Alaska and from there following in general the 141st meridian, made a winter dog-team journey northward to the Arctic Ocean (Brooks, 1906, p. 125).

In 1901 a Geological Survey party under W. J. Peters, topographer, and with F. C. Schrader, geologist, started in winter and went overland to the Koyukuk River (south of the area shown on pl. 1). When the open season arrived, they ascended the John River with canoes, portaged through Anaktuvuk Pass, and then went on down the Anaktuvuk to the Colville, which they followed to the ocean. From the mouth of the river, they followed in the shallow coastal waters westward to Barrow and on south to Cape Lisburne where they managed to meet and get transportation south on a vessel in which they reached Nome. Brooks (1906, p. 129) says that "Theirs was probably the most notable exploration which has been made by the Geological Survey."

In the period 1906–14, exploration by Leffingwell (1919) and Anderson in northern Alaska east of the Reserve added much pertinent geographic and geologic information. Stefansson's work in northern Alaska between 1908 and 1918 also was valuable. Similarly, in 1912 contributions were made to the information on the area east of the Reserve between the Porcupine River and the Arctic Ocean by parties of the International Boundary Commission.

With the establishment of Naval Petroleum Reserve No. 4 early in 1923, a series of explorations and geologic investigations by the Geological Survey began at the request of the Navy Department. These pulled together much of the information from earlier work and produced a large amount of new information, which together supplied a reasonably adequate but still very generalized picture of the major geologic features of the Reserve. This work went on through 1926, and the results were incorporated in Geological Survey Bulletin 815, Geology and Mineral Resources of Northwestern Alaska, by P. S. Smith and J. B. Mertie, Jr., which was published in 1930. Much of the information in that bulletin has been used in these earlier parts of the story of Pet 4. Limitations of space require that the record of those surveys be shortened for the most part to brief mention of the principal members of the parties and where they worked.

Three parties were sent out in 1923, all under the leadership of Sidney Paige, geologist. Paige and his topographer, E. C. Guerin, followed the coast from Wainwright to Cape Simpson where the petroleum seepages were studied and mapped. Subsequently, Paige and Guerin surveyed the east side of Dease Inlet and ascended the Meade River for about 150 miles. James Gilluly, geologist, and James Whitaker, topographer, proceeded along the coast to Peard Bay where they struck inland to the Inaru River, went down that river to Dease Inlet, thence upstream along the Topagorok River for about 80 miles. The third party, under W. T. Foran and with topographic engineer Gerald FitzGerald, left Nome in a chartered vessel, surveyed the coast from Cape Beaufort to Wainwright, and explored inland along the Kukpowruk, Kokolik, and Utokok Rivers for distances ranging from 25 to 40 miles. Smith and Mertie (1930, p. 9) state that "As a result of the work of these three parties about 2,150 square miles of hitherto unsurveyed country was mapped, and information was obtained that throws light on the geologic and physical features of probably 10,000 square miles."

In the winter of 1924, under the general supervision of Philip S. Smith, a joint party consisting of geologists P. S. Smith and J. B. Mertie, Jr., and topographers

Senator Walsh and Congressman Vinson, chairmen of the Naval Affairs Committees of the Senate and House of Representatives, respectively, were advised and kept fully informed of the development of the plans.

Finally, on 10 March the reconnaissance trip to the Reserve for the purpose of studying problems of access, transportation, and subsistence was approved by the President.

Thus, the preliminary plans were laid expeditiously but well. Competent technical advice was obtained. Coordination was attained with both the executive and the legislative branches, and feasibility within the limits of existing knowledge was determined within the Navy Department. Some of the original assumptions eventually required modification, and certain items in the plan had to be abandoned or changed; but, in general, Pet 4 was ready to be launched in a sound fashion.

PRELIMINARY RECONNAISSANCE, 21 MARCH TO 22 APRIL 1944

Appropriately, Lieutenant Foran, who was largely responsible for the idea of undertaking at that time an appraisal of the petroleum resources of Navy Petroleum Reserve No. 4, was selected to head the first reconnaissance party. His party was carefully chosen to include specialists in some of the various fields in which future work was anticipated. There were, for example, WO H. C. Gillen, waterfront and shipping; WO J. F. Connelly, general construction and earthwork; and WO W. W. Smith, oil-well drilling.

April is still a wintry month north of the Brooks Range, and, of the whole party, Foran was the only one who had been in the area before. It was therefore a considerable job that faced the group—1, to determine the most advantageous means for further geologic study, including geologic drilling and the application of geophysical methods; 2, to determine the operational difficulties that would be encountered in petroleum exploration; and 3, to gather information of a general nature concerning all phases of life in the Arctic.

Transportation from Fairbanks northward over the Brooks Range into the Arctic and to Barrow was by bush plane, as was travel within the Reserve. Impossible bush flying conditions forced considerable waiting in Barrow, but much was accomplished, and waiting periods provided time for gathering invaluable information from old-time resident-trader Charles Brower at Barrow and from the party's veteran Arctic bush pilot, Sig. (Sigurd) Wien. The party saw much of the Reserve, mostly from the air, before returning.

On 22 April the party returned and Lieutenant Foran prepared and submitted his report. The first small chapter of Pet 4 had been written.

The conclusions reached by the party were favorable for embarking on a full-scale petroleum exploration although in retrospect some of them seem based in part on optimistic assumption and some, such as No. 7 below were incorrect. Nevertheless, they contained much of value and were influential in guiding the earlier work of Pet 4. The conclusions were—

1. The unusually wide occurrence of seeps (Simpson to Umiat, Dease Inlet to Demarcation Point) suggested productive strata at comparatively shallow depths. The geologic work necessary for the location of an initial test on the Umiat anticline would require not more than 6 weeks surface structural study. To spot a location on the coastal plain would require several profiles of structure core holes.

2. In regard to transportation and disposition of oil, three plans were considered—the first, tankers to Barrow, and the second, pipeline to Nome, were rejected because of the storage and harbor facilities required; the third plan, a pipeline to Fairbanks was considered feasible. It was believed that neither the climate nor the topography would act as a barrier to the economic installation and operation of a competently planned pipeline system.

3. Since shallow production was expected, light drilling equipment was recommended. A timber-mat foundation on the permafrost was believed sufficient for the rig.

4. Concerning excavation and road building, it was estimated that working conditions would be no more difficult than those encountered in the Aleutian Islands and that costs would be approximately the same. The suitability of the beaches for use as temporary landing strips was observed.

5. The presence of pressure ridges and floating ice precluded the permanent or temporary construction of docks or floating docks. The shallow water required ships to stand offshore about three-fourths of a mile.

6. The Navy-issue clothing furnished fairly good protection. Diet should be approximately the same as for temperate zones.

7. Because of the prevalence of tuberculosis and the undependability of the natives as steady workers, no consideration should be given the procurement of local labor.

DECISION TO PROCEED

After a conference with Lieutenant Foran, RADM Ben Moreell, chief of the Bureau of Yards and Docks, prepared a memorandum dated 8 May 1944 in which he proposed that the reconnaissance of Naval Petro-

leum Reserve No. 4 proceed immediately with the drilling of core holes and exploratory wells and the dispatching of geologic and pipeline survey parties. Admiral Moreell chose to consider the recommended phase a part of the preliminary reconnaissance and suggested waiting until the data were all in before submitting a comprehensive report to the Secretary of the Navy for a policy decision and before calling in other interested Government agencies. Admiral Moreell also felt that it was just as important to determine whether or not it would be possible to get oil out of the Reserve economically as it was to determine the quantity and quality of oil available.

Admiral Horne, Vice Chief of Naval Operations, approved Admiral Moreell's suggestions but opposed reference of the matter to the Interior Department because of the delay imposed and the shortness of the Arctic season and wondered if the President's signature were again required. R. Keith Kane, Special Assistant to the Secretary of the Navy, recommended (1) that the President's approval be requested in a memorandum, (2) that Secretary Ickes be presented with the preliminary reconnaissance report and the notification that 2 or 3 exploratory wells would be drilled in 1944, (3) that copies of the reconnaissance report be sent to the chairmen of interested congressional committees, (4) that, on approval by the President, BuDocks proceed with the exploration project under the direction of the Vice Chief of Naval Operations. The recommended program was supported by DeGolyer and MacNaughton, Inc., and by A. F. Jacobsen, president of the Amerada Petroleum Corp.

By this time there was some enthusiasm in Congress for the exploration, $1 million having been earmarked for the program in the current Naval Appropriations Bill.

On 15 June Secretary of the Navy Forrestal asked the President's approval of a Bureau of Yards and Docks (BuDocks) party returning to the Reserve, investigating conditions more thoroughly, perhaps drilling 2 or 3 exploratory wells, and making a detailed report. Caution was to be exercised in all planning operations. On 26 June the President replied that he had no objections to the program.

Lieutenant Foran's recommendations, based on his preliminary reconnaissance, had been favorably received; and although the difficulties inherent in attempting to carry out such a program were well recognized, it nevertheless was believed urgently desirable that the program proceed.

Up to this point the final decision to proceed was yet to be made, but a great deal of preliminary preparation in anticipation of the proceed order had been made. Bart W. Gillespie, one of the principals in Pet 4, has elaborated the advance preparation for which he was largely responsible (Gillespie, Bart W., personal communication).

> . . . However, once the Chief Bureau Yards and Docks sensed that there was a good chance of the Secretary of the Navy being instructed to carry out such a plan he instructed me to proceed without delay to lay out the personnel and equipment outline all to a point just short of activating the unit and issuing the purchase orders for the equipment required. Had the Chief of the Bureau not possessed this foresight and courage no move could have been made toward the Arctic Ocean during the year 1944. The entire program would therefore have been delayed one year, or until the summer of 1945. With Sea Bees in such great demand in the Pacific during the year 1945 I doubt very much that the expedition would have been sent out and therefore in my opinion, the entire idea would have been dropped with the coming of V–J day.
>
> . . . we dispatched Lt. Commander Ivan Wilson and Chf. Warrant Officer Ralph Bell to Camp Peary, Virginia, to screen the Sea Bee personnel for officers and men capable of carrying out the many arduous tasks which would confront an expedition of this type, entering the Arctic for the first time in history. . . .
>
> The nucleus of the Sea Bee detachment which was later to be designated Naval Construction Battalion Detachment No. 1058, were the members of my original group, the 12th Battalion of Sea Bees who were the first to land at Kodiak Island and later assisted in the landing at Attu when the last of the Japanese were cleaned out of the Aleutians.
>
> The commanding officer, William Rex, who had served under me at Adak as executive officer of the 66th Battalion and several other officers were brought in from other units in the Aleutians. Specialists such as geologists, petroleum engineers, drillers, toolpushers, roughnecks and so forth were screened from the many other units then at Camp Peary.
>
> No movement of personnel was made at the time but a SecNav (Secretary of the Navy) freeze order was placed on the screened personnel thus selected and they were held at Camp Peary pending the final orders to activate the detachment.
>
> Other personnel in very limited number, at the time on active duty in the Atlantic and Pacific theaters were earmarked and the Bureau of Personnel prepared for their "proceed" orders on receipt of final activating orders signed by the Secretary of the Navy.
>
> The logistics for the support of a two drilling rig operation with safety for approximately the first eighteen months was worked out primarily by those of us who had on occasions done the same for long operations IN TROPICAL SURROUNDINGS. Somewhere in the files of the Bureau of Yards and Docks will be found the first general outline of materials and supplies earmarked to form the basis for more detailed procurement for the Arctic Expedition.
>
> This activity embraced most of the month of May 1944—the period during which we knew nothing for certain yet feared that any lack of reasonable action on our part in anticipating the needs might result in a fiasco should we be ordered to get the Expedition under way at the last possible moment.
>
> During this period of uncertainty we were not spinning our wheels awaiting information relative to the Arctic to drop into our laps. From the Army Northwest Command, the Imperial

Oil Company, and from several other agencies we were able to collect much of value—and sad to say, much of no value whatsoever. Our final loading was all but complete before we learned that Admiral Byrd did have something on record in Washington of value to anyone attempting a trip into the Arctic. Stefansson was, of course, under contract with the Army and was hardly available at the time. Thus we went as far as we could during the period of uncertainty. Afterwards it fortunately resulted that our preparations were reasonably good.

The period of uncertainty was brought to a sudden close on the morning of 2 June 1944. The Expedition was approved by the President and SecNav (Secretary of the Navy) ordered the Chief of the Bureau of Yards and Docks to get moving. Commander Wilson at Camp Peary was notified at once and orders were requested for the movement of the Detachment when activated to the Naval Station, Seattle, there to board the ships later to be selected to enter the Arctic.

On the same afternoon we moved in on the Advance Base Division's Executive officer, Commander John R. Dallerup in Chicago and set up a procurement procedure completely clean of red tape and based on emergency, bid-free purchasing wherever necessary.

It was during this period that such men as Wallace Pratt, Paul Lambright, Imperial Oil, Lloyd Noble, Noble Drilling Company and his excellent staff, gave of their time and advice to such an extent that the procurement was made safer and much more adequate for the work to be done in the Arctic.

It should be borne in mind at all times that we procured with one thought uppermost in our minds. We would not disrupt the production line which was keeping the petroleum industry operating at full capacity to supply war needs. We would cut corners and some way make certain that we protected our personnel in the Arctic and permit them to work reasonably well during the first twelve months of their stay in that region.

ADMINISTRATION

Arrangements were made for the firm of DeGolyer and MacNaughton, of Dallas, Tex., to act as consultants on geology and for the Noble Drilling Co., of Ardmore, Okla., which had supervised the work at Norman Wells, to act as drilling consultant.

On 8 June 1944 Naval Construction Battalion Detachment 1058, consisting of approximately 15 officers and 190 men, was assigned by the Chief of Naval Operations the mission of the exploration of Naval Petroleum Reserve No. 4. LCDR W. H. Rex, CEC, USNR, was placed in command and thereby became the first of a series of officers in charge of construction for Pet 4. Each officer in charge (OICC) had his strengths and his weaknesses, but it was largely through them that the program was able to accomplish all that it did. The Civil Engineer Corps can well be proud of this fine group of officers, who, throughout the program, maintained the best traditions of the Navy and of the Corps to which they belonged.

CDR Bart W. Gillespie, assistant to the Chief of the Bureau of Yards and Docks (BuDocks) for petroleum matters, on 11 July delivered by hand the basic orders of the expedition to Lieutenant Commander Rex. These orders read:

The purpose of this mission is to carry out exploratory work in NPR 4 (Naval Petroleum Reserve No. 4) with a view toward determining the presence of oil in commercial quantities and if so to establish methods by which it may best be produced and transported to a point of greatest usefulness. This mission, therefore, includes detailed geologic study, core hole drilling, deep well drilling, and overland and aerial pipeline survey. This region being virgin exploratory territory, you will be required to do your utmost to complete your task with the greatest possible amount of information of every type. Everything down to the most insignificant item should be recorded for future use. It is of utmost importance that one of the products of this task be a complete record of not only the success but the failures of this first Seabee petroleum venture.

The U. S. S. *Spica* (AKA–16, Attack Cargo Ship 16) was designated to transport personnel and equipment to Barrow and LT John Backlund was detailed as Arctic pilot. The SS. *Jonathan Harrington*, a Liberty ship of the Alaska Steamship Co. and a Catalina flying boat (PBY5A) for reconnaissance of ice conditions in the Arctic Ocean were also assigned. CDR F. M. Kiley, USNR, was placed in charge of the ship expedition.

If possible, landing of the expedition was to be made at Cape Simpson, where Lieutenant Foran would have taken soundings and secured information for anchorage in advance. On landing, the base camp would be built, a 150- by 5,000-foot airstrip constructed, and radio facilities put in operation as soon as possible. Core drilling for structural information would then be conducted in the Barrow-Simpson area in the hope of uncovering a structure that would warrant testing with a large drilling rig. Otherwise, the big rig would be freighted to Umiat during the winter and a test well started there in the summer of 1945. Concurrently, a preliminary pipeline survey was to be in progress.

The expedition was to receive instructions from the Bureau of Yards and Docks only; but within the scope of the mission, the fullest cooperation should be extended to the Director of Naval Petroleum Reserves and to representatives of the U. S. Geological Survey.

OPERATIONS

SEA TRANSPORTATION

CAPT W. G. Greenman, who in June had replaced Rear Admiral Stuart as Director of Naval Petroleum Reserves, pointed out that the short time available for procurement of materials and supplies for the first ship expedition had a very real effect on the program as a whole. The time factor and the inadequacy of information on the area made this initial job of procurement a difficult one. Nevertheless, a remarkable job was

done. Drilling equipment was especially difficult to obtain because of the large amount of steel involved and the shortage of steel at that time.

Barges with equipment from the Canol project (an oil development project) in Canada were started down the Mackenzie River for a planned rendezvous with Navy ships at Herschel Island and thence for towing to Barrow. This became unnecessary and was halted when BuDocks was successful in obtaining drilling equipment in California from the Army Corps of Engineers. Bart W. Gillespie (personal communication) has described this incident as follows:

> Working closely with the Army Engineers and with Imperial Oil we learned that there were two drilling rigs at Ft. Smith which could be made available to the Arctic Expedition if needed. They would of course have to be barged thru the Slave Lakes down the Mackenzie to Norman Wells and there transferred to ocean going barges for the trip down to Aklavik at the mouth of the river and thence out into the Arctic for the trip of four hundred odd miles to Point Barrow.
>
> Meanwhile, word had come that there was a possibility that the drilling equipment then stock-piled at the Mira Loma, California Depot might not be used in the South Pacific. Immediate action was taken to verify this rumor and when it appeared as though it was well founded we requested release of drilling rigs and as much more as could be used in the arctic from those items at Mira Loma.
>
> The procedure required for making the transfer of materials was slow and time for the departure of the Expedition was getting closer. Therefore, we dispatched officers to Norman Wells with instructions to stand by for the arrival of the drilling equipment then steadily moving across the Great Slave Lakes toward Norman Wells. If no word was received from California by the time of the arrival of the rigs at Norman Wells they were to be transferred at once to the sea barges and the journey continued toward Pt. Barrow, Alaska.
>
> Meanwhile we flew to California to do all possible to clear the necessary equipment thru proper channels, see it loaded on cars for Seattle and thus assure ourselves that we would have required machinery on the expedition. The deadline date for getting this material away saw the loading of the last pieces on the cars.
>
> An urgent dispatch was sent to Norman Wells halting further movement of the drilling rigs. The rigs arrived almost simultaneously with the dispatch and were taken over by Imperial for use at Norman Wells.

The original cargo estimate was 5,000 tons, but it actually totaled 8,448 tons, or 13,388 measured tons (hold volume), with a personnel of 196 Seabees and 235 stevedores. By 20 July 1944 everything was ready, and the ships departed Tacoma, Wash. This was the first of the ship expeditions that therafter made the long journey to Barrow annually and which later came to be referred to as Barex (Barrow Expedition).

On 5 August 1944 the expedition rounded Point Barrow, and on 6 August the ships stood off Cape Simpson, under conditions of fog, rough weather, and floating ice. After a reconnaissance the beaches were judged unsatisfactory for landing and unloading purposes. The search for a suitable landing site continued during bad weather and floating ice until 10 August, when the idea of a Simpson landing was abandoned. The ships then returned to Barrow, which was the most favorable site observed along the coast.

The decision not to make the ititial landing at Cape Simpson near the site of the largest and best known oil seepages was the first major departure from the original plans. Although at one time deplored by many as a serious mistake, it actually was a most fortunate decision. The whole course of the program would likely have been vastly different if the original plan had been carried through, and the many advantages that accrued through the choice of Barrow as the main base of operation would not have been realized. Water depths off the shore, the beaches, ice conditions, and foundation conditions on land all are much better at Barrow than at Cape Simpson.

Unloading with LCM's (landing craft, medium) and pontoon barges was started on 12 August and continued until 16 August. By that date storm and rough water as well as abundant ice forced the ships to seek protection east of Point Barrow. During the storm the PBY which was used for ice patrol and which at the time was lashed down on the shore of a lagoon behind the spit was literally torn apart by wind and water. The main part sank, but fragments were scattered for a long distance over the tundra. Unloading was resumed and continued between 17 and 21 August, but a wind, reaching a velocity of 35 knots, forced suspension of the work on the 22d. The U. S. S. *Spica* was completely unloaded on 23 August, and by 27 August the S. S. *Harrington* had discharged its cargo.

On 30 August Commander Kiley, thinking a hurried departure necessary because of the movement of the ice, ordered the stevedore units back to the ship. One unit of 66 officers and men did not respond immediately and was left stranded by the *Spica's* departure.

The SS. *Waipio*, of the Matson Co., at the urging of Governor Gruening of Alaska and of the company officials, made a run into the Barrow waters with supplies for the native village of Barrow (see fig. 9) long after the period of safe open water in the area was considered past. The help of the stevedore unit was of major importance in the rush of the unloading of the *Waipio* during 16–18 September. The SS. *Waipio* with a small amount of cargo remaining on board was then forced to leave because of the report of ice closing in around Franklin Point. The stevedore unit returned aboard the *Waipio*.

FIGURE 9.—Supplies from the SS. *Waipio* being unloaded for the Eskimo village at Barrow. Photographs by U. S. Navy, 17 September 1944.

AIR TRANSPORTATION

Before Seabee Battalion Detachment 1058 was well established in the Reserve and had constructed landing and other air transportation aids, air travel into the area had to be entirely by bush plane, mostly from Fairbanks, hundreds of miles to the south in the heart of Alaska. In this early flying the skill and experience of Sig. Wien and his group of young pilots was of inestimable value. There were no navigation or landing aids. Near the coast, especially around Barrow, the notoriously changeable weather is frequently foggy and windy. Winter flying with ski-equipped planes would have had many advantages, but much flying had to be done before winter came, and by that time some facilities had been installed. Ordinarily, small aircraft entered by way of the Anaktuvuk Pass and then landed on the rivers, lakes, or lagoons, if on floats, or on gravel bars along the rivers, if on wheels. Small aircraft also could, and did, land on ocean beaches in a few places, such as at Barrow. These planes were commonly refueled with additional gasoline from cases carried in the planes, from small supplies of gasoline at Barrow, or from small caches left at a few strategic locations such as at Chandler Lake on the north edge of the Brooks Range and on the Colville River near the present site of Umiat.

This early flying was hazardous work, but it was carried out without serious mishap and soon seemed almost routine. In addition to the Barrow beaches, a favorite landing spot was the Prince Creek bar, on the Colville a few miles upstream from Umiat. That was the landing strip for the 1944 geologic work of Lieutenant Foran on the Umiat anticline and for the Geological Survey party that worked along the Colville that summer. Both of those activities are described later. A highlight of that early flying was the first trip to Barrow in midsummer of an old Boeing aircraft belonging to Wien Alaska Airlines. On the return trip to Fairbanks, it was unable to fly over the Brooks Range on several tries because of icing, and it eventually, because of gasoline shortage, was forced to land on the Prince Creek bar. It was several days before the trip to Fairbanks was finally completed, with the last gasoline available at the bar, which was painstakingly transferred from drums to the plane's tanks.

Bush flying within the Reserve was handled by Wien Alaska Airlines. But because of Wien's obligations to the Eskimos of the area, the flying time allotted to the Seabees was insufficient for the needs of the unit.

With the construction of some facilities at Barrow, the responsibility for air support fell to the Naval Air Transport Service (NATS). Pan American Airlines, under contract to NATS for Alaskan service, undertook the linehaul (Fairbanks to Barrow) runs. As the NATS contract with PAA (Pan American Airlines) expired on 31 July 1944, negotiations were initiated for continued PAA air support for the Reserve.

Although reluctant to assume the obligation because only one plane was available for the service, PAA continued the linehaul flights. In spite of the helpful cooperation of the Army unit at Ladd Field (now Ladd Air Force Base) in hauling supplies, the backlog of goods at the Fairbanks station steadily increased. Fairbanks was the take-off locality for Pet 4 and soon became the headquarters of the exploration project.

BUILDING THE CAMP

Even before completing unloading of the ships, which, as has been mentioned, was largely at Point Barrow rather than at the selected campsite about 6 miles farther south along the beach, the shore personnel began the task of moving the material to the campsite. In this work the contingent left stranded by the departure of the ships was invaluable. Lieutenant Commander Rex immediately started the construction of a substantial camp, the preparation of an airstrip, and other improvements. Another activity was the erection of the drilling rig and the start of drilling what was vainly hoped would be a water well and at the same time would serve as a test of the drilling equipment.

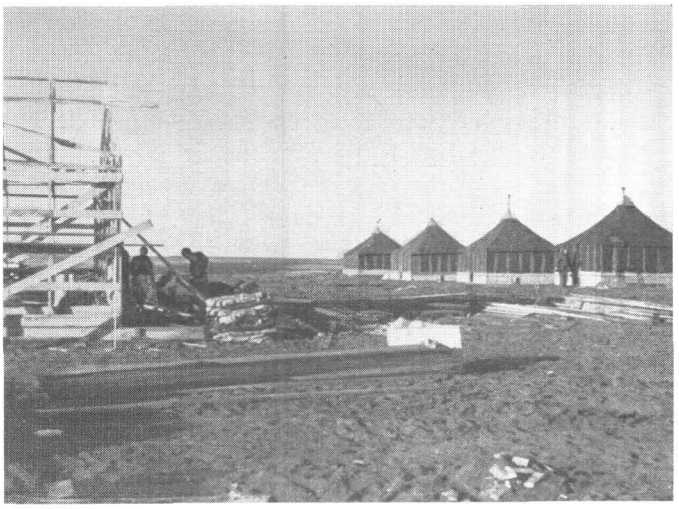

FIGURE 10.—Part of the Seebees tent camp at Barrow in the fall of 1944. Photograph by U. S. Navy.

From 23 August to 14 September, until the permanent camp was made ready, the personnel occupied a temporary tent camp. (See fig. 10.) Quarters were 16- by 16-foot tents over a timber framework and floor. A tarpaulin-covered 40- by 100-foot wood-beam structure housed the messhall and galley, which doubled as a movie theater. The administration building, an 18- by 36-foot frame building, was later moved to the center of the permanent camp and winterized with asbestos clapboard siding. Warehouses and shops consisted of tarpaulin- and tent-covered frame structures. Woodburning stoves were installed in living quarters but were replaced by diesel-fuel space heaters as soon as practicable. Electricity for lights and power was supplied by a 50-kilowatt diesel generator with a 75-kilowatt generator as a standby. Fresh-water facilities consisted of a pump-fed 1,300-gallon pontoon storage tank, a chlorinating unit, a purification unit, and piping to the galley. Water consumption averaged 3,000 gallons per day.

The permanent camp area was drained and graded. Twenty-four 20- by 56-foot steel-arch-rib huts (quonset huts) were erected including 10 barracks, 4 mess huts, 4 warehouses, 3 hospital and dispensary huts, 1 ship's store and photographic laboratory, 1 engineering office and radio communication room, and 1 recreation hall. Alterations were necessary to make the quonset huts suitable for the rigors of the arctic climate. Bulkheads were installed near the ends of the huts to provide for storm entrances. To the standard ½-inch plywood flooring was added a layer of ½-inch sheetrock insulation and 1-inch flooring. Smoke stacks and ventilators were made in the shop and installed. To equalize the sharp temperature gradient from floor to ceiling, electric fans were installed in quarters and food warehouses. Railroad ties laid on the gravel served as foundations. The galley, located centrally between the messhalls, was an insulated frame structure with concrete flooring. The utility building, a 31- by 56-foot noninsulated frame building, housed one 40-horsepower Munds boiler, one 50-kilowatt and one 75-kilowatt generator, two 2,500-gallon steel water tanks, a water-purification unit, a laundry, and a portable fire-fighting unit. The peak load of the camp was 45 kilowatts. Water was hauled by sled from the fresh-water lake east of the camp. A 12- by 18-foot sheet-rock-insulated frame building housed showers and washbasins. The latrine was a 16- by 16-foot tent over a timber frame. A 60- by 62-foot frame building insulated with asbestos clapboard shingles served to house the carpenter shop, machine shop, heavy-equipment-parts warehouse, and garage.

CAMP STORAGE

Supplies were assembled and grouped in storage areas (see fig. 11) with as much care as the package

FIGURE 11.—Early days of Pet 4. Equipment temporarily stored outside. Photographs by U. S. Navy, 8 November 1944.

markings and limited time would allow. Items that could not be found and that constituted important losses included 3,500 feet of drill pipe, 90 bottles of oxygen, and 2,500 sacks of cement. Other estimated losses were 600 barrels of gasoline and diesel oil, 50,000 board feet of lumber and dunnage. Part of the food became frozen and ruined because of insufficient warm storage.

ROADWAY TO BARROW AND AIRSTRIP

A roadway nearly 4 miles long to Barrow village was graded generally along the beach.

In early September, work was started on a permanent airstrip. A well-drained site was selected just north of the main camp. The main strip was 150 feet wide and 5,000 feet long, had a bearing of approximately N. 50½° E., and was completed in 3 weeks. A cross strip 150 feet wide and 4,300 feet long joined the main strip and was oriented about N. 3½° E. The tundra vegetation was bulldozed out in areas away from the beach and mixed with the sand and gravel in the strip area to act as a binding agent. After being graded and dragged the airstrip was packed by a roller constructed of oil drums full of sand. The natural tundra cover on the cross strip was left intact, and gravel fill was added as necessary to grade the strip.

Planes landing before the freeze did not break through the upper crust on the strips, and after freezing, the airstrips were in almost perfect condition. By 31 December 1944, 162 flights had been completed successfully thus indicating the adequacy of the construction. By that time Bartow landing lights (permanent airstrip markers) had not yet been received, but fusees (flares) were used satisfactorily.

PIPELINE SURVEY

The problem of getting oil out of the Reserve was continually kept in mind during Pet 4. Some early speculation concerned the possibility of shipping it out by tankers from some point on the Arctic coast, but this generally was not considered practicable. A good deal of attention was given also to the possibility of refining oil in or near the Reserve. This possibility seemed largely a strategic one and would depend on the possible requirement for petroleum products in northern Alaska. By far the most serious thought, however, was given to the plan for a pipeline from the Reserve to Fairbanks where access would be had not only to Alaskan military and civilian markets but also to the Alaska Railroad and to the highways—the Alaska Highway to the States, linking a series of major airfields and the Richardson Highway to the Pacific coast at Valdez on Prince William Sound. Connection could be made also to the existing pipeline connecting Whitehorse and Fairbanks.

As early as 1944 it seemed wise to make some preliminary studies relative to this proposed pipeline. It was generally believed that the pipeline, if it were built, would pass out of the area near the southeast corner of the Reserve and extend through Anaktuvuk Pass to Bettles where it would cross the Koyukuk River. It would probably cross the Yukon near the lower end of the Yukon Flats and thence to Fairbanks by way of Livengood.

Starting from Fairbanks on 10 September 1944, a small crew under LT Paul G. Daubel ran a location survey with levels as far as Livengood about 80 miles away, which was reached on 9 November. In general, the suggested pipeline route followed the Fairbanks-Livengood road but was located in the valleys, whereas the road mostly follows the ridges.

The conclusion from this preliminary survey was that pipeline construction and maintenance would involve many major difficulties, principally because of the terrain, and climate.

In October F. E. Waterfield, Jr., vice president of the Plantation Pipe Line Co., was requested to consider the problem of a pipeline from Umiat to Fairbanks. On 20 December he made his report on pipeline design which provided for various types of crude oil and for various operating conditions. Further studies were postponed pending the discovery of oil.

COMMUNICATIONS

Communication to areas outside the Reserve was somewhat rudimentary in 1944. A field-telephone line was laid to the old station of the Alaska Communications System (ACS) in Barrow village which provided contact between the camp and central Alaska or the States. At the permanent base a new station of the Army Airways Communications System (AACS) afforded another channel in case of emergency. The men of the ACS and AACS quickly provided the expedition with some degree of flight security. The assistance was largely on their own initiative without official orders, and occasionally they seemed to be depriving themselves to assist Pet 4. Offices and airport at the permanent camp were connected by a telephone system.

EQUIPMENT MAINTENANCE

Because the operation and maintenance of heavy mechanical equipment under the specialized climatic and other conditions of the Arctic was such an important part of Pet 4, it seems appropriate to mention some of the major problems as they arose and were solved during the course of the program.

The key heavy equipment unloaded from Barex '44 (Barrow Expedition, 1944) included 6 tractors, two 20-ton and one 10-ton cranes, and one 9-ton crane. The tractors were modified principally by the installation of oak blocks in place of the top carrier rollers because it was found that the rollers became inoperative because of icing, the cutting of 3- by 3-inch-square holes in the tracks to facilitate the cleaning of snow from the tracks, and the welding of additional grips or grousers on the tracks for better snow traction. In very cold weather some of the tractors were of little use as they had no starting engines. Athey wagons were satisfactory for hauling on the coarse-sand beach and were used to move about 2,300 tons of equipment over the 6-mile stretch from the unloading beach at Point Barrow to the campsite.

Radiator curtains and plywood side panels were installed to enclose all fuel lines and tanks, and cabs were added to provide comfort for the operators. With the advent of cold weather, lubricating oil was diluted with 15–30 percent of kerosene or diesel oil to facilitate its flow at low temperatures. No opportunity was afforded to thoroughly test the weasel (M29C) in 1944 although four had been unloaded.

GEOLOGY

During his brief reconnaissance of the Reserve in March and April, Lieutenant Foran had observed evidence of a major anticline in the Umiat area approximately 180 miles southeast of Barrow in the extreme southeast part of the Reserve. This was the location of some of the small seepages that had first been visited by the Bureau of Mines—Territorial Department of Mines party the year before. Foran considered that the most important next step was to obtain further information on that structural feature in the hope of determining structural closure at some point along the axis of the anticline; if closure was indicated he would consider Umiat a justifiable drilling site.

Therefore, Lieutenant Foran, assisted by Lieutenant (jg) Woodward and six additional party members, returned to the Colville River, landed on the Prince Creek bar above Umiat, and on 8 June started structural geologic mapping on the anticline. (See pl. 3.) Lieutenant Foran also made some observations on the stratigraphy and began to compile a stratigraphic section of the rocks in that area. Altogether, the Foran party spent 7 weeks mapping and studying the anticline which at that time was called the Prince Creek anticline but which since has come to be known as the Umiat anticline. (See fig. 12.) He found and mapped in a general way a closure of about 750 feet.

Meanwhile, the Geological Survey had also dispatched a small party to the same general area. The party consisted of Robert R. Coats, chief, George Gryc, geologist, and a cook-camphand. The Survey felt that stratigraphic information would be most needed in the early phases of an intergrated program of petroleum exploration, and the party was instructed to concentrate on the stratigraphic section which was exposed along the bluffs of the Colville River from above Umiat to 40 or 50 miles below Umiat. The Survey's opinion was based on the fact that the structural character of the Reserve was already generally known from the geologic expeditions of the '20s and before and that there were many generally eastward-trending structural features that were progessively less intense northward from the Brooks Range. Accordingly, the Survey party studied intensively the stratigraphic section from the Prince Creek syncline downstream across the Umiat anticline and the then unnamed Gubik anticline north of it for a total distance of about 40 miles. From that study the general scarcity of good porous sands in the part of the section studied became evident.

On 2 August the Foran party moved to Cape Simpson and began a hydrographic survey designed for use during the proposed imminent landing of the ship expedition. An attempt was made also to delimit a geologic structure in the oil seepage area near Cape Simpson, but this was unsuccessful because of the absence of bedrock outcrops in that vicinity.

DRILLING

The drilling equipment landed from Barex '44 consisted of 1 Model 1–42 portable Sprague and Henwood Core Drill, 2 Failing 1500 units which could drill a 4⅞-inch hole to 1,000 feet, and 1 National 50 rig.

Three experimental holes were attempted in the fall of 1944 in order to determine operating conditions and to familiarize the drilling personnel with the operation of the equipment. (See pl. 3.) Drilling was directed by LT J. S. Hagestad, petroleum engineer, and Lieutenant Commander Rex.

Core test 1, using the Sprague and Henwood drill, was a short distance south of the camp. Slush ice plugged the eyes of the core bit. If circulation were stopped for an hour or so, mud would freeze to the walls of the hole, so that reaming was necessary on going back in. This situation was alleviated somewhat with the use of an immersion oil burner in the mud tank to heat the mud. The hole was drilled to 344 feet, but coring was not successful. Reaming was necessary to enter the hole and jarring to get out. The crew be-

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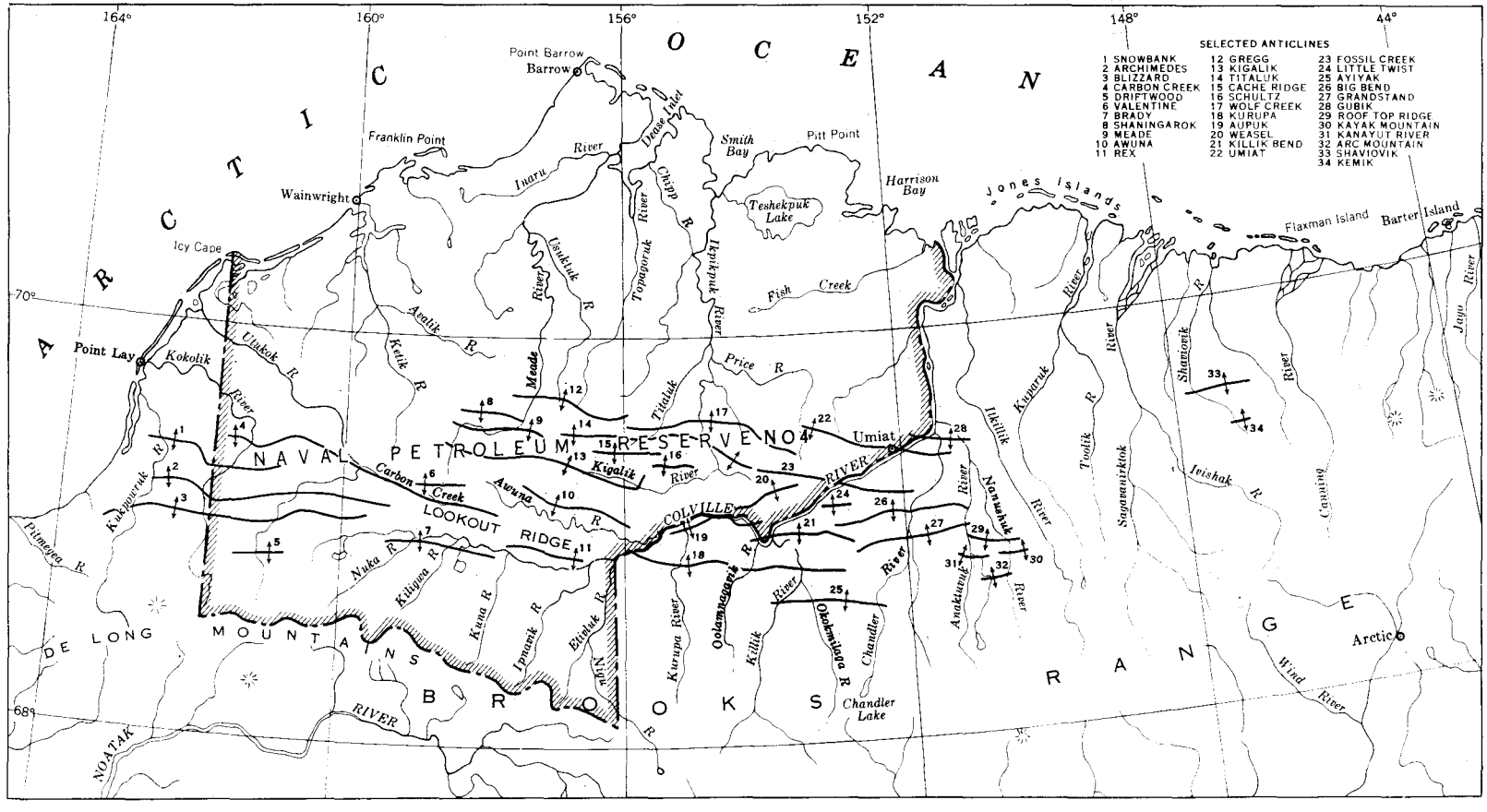

FIGURE 12.—Index map of northern Alaska showing general locations of selected anticlines.

lieved that a larger mud pump and continued heating of the mud would have solved most of the difficulties.

At core test 2, near No. 1, the diesel-fueled heating stove exploded, at 236 feet, the rig caught fire, and in the high wind the fire was uncontrollable, and the rig was destroyed.

The test of the National 50 was more successful. The big-rig test 1 was at the northeast edge of the campsite. The hole was drilled to 685 feet between 13 and 22 October although the rig was unhoused. Icing of lines was something of a problem, and a flame thrower was used to thaw lines, standpipe, and hose while making a connection or coming out of the hole. Except for these problems, the equipment was believed to have perfomed satisfactorily.

SUMMARY OF 1944

By the end of 1944 Pet 4 was well underway—although drilling for oil had not yet started, much information had been assembled, a substantial camp had been built and the Seabee detachment was well housed and well fed, and an air service system was in operation.

In 1944 the beachhead had been firmly established; in 1945 the exploration of the Reserve was ready to proceed. Key positions were held by Lieutenant Commander Rex, officer in charge of construction; LT A. G. Smith, executive officer; LCDR Saul Mackoff, medical officer; LTJG H. F. Corbin, chaplain; LT William T. Foran and LT James Brazil, geologists; LT Leonard Berlin, procurement and liaison officer in Fairbanks; LT B. D. Goodrich, procurement and liaison officer in Seattle; and above all CDR Bart Gillespie, in Washington, D. C., who exercised overall control and gave all possible authority and responsibility to the field personnel.

Lieutenant Berlin took charge in Fairbanks on 4 October 1944. He was responsible for procuring fresh food and emergency supplies for the detachment, dispatching of priority freight by chartered plane, the billeting of men on leave, consulting on the pipeline survey, and liaison with the Army unit at Ladd Field.

The record of accomplishment of the detachment under Lieutenant Commander Rex had proved his organizing and operating ability beyond question. Work had proceeded on camp and airfield maintenance; a strict accounting system had been installed; and preparations made for the winter freighting and drilling season ahead.

Many of the highlights of the first year have been summarized by Bart W. Gillespie (personal communication), who is quoted below at some length because he has managed so well to capture the enthusiasm and accomplishment of the early days of Pet 4.

The setting up of any expedition of importance particularly one involving ship movement into the Arctic seas is not a simple matter. The Chief of Naval Operations, when advised of the need for such an expedition to be ready to move from Seattle not later than 25 July required much information on which to base his selection of ships and personnel familiar with arctic conditions.

It was our responsibility to grind out the necessary logistics data in time to permit CNO (Chief of Naval Operations) to release its directives covering the ships to be selected and the personnel to man the ship or ships. CNO had this information in hand by 25 June and directives were released in record time. Two AKA (Attack Cargo ships) Liberty ships were selected for this trip. Troop accommodations, proper refrigeration to accommodate the large quantities of perishable meats and foodstuff had to be installed on board. Loading of different types of cargo which ranged from highly inflammable petroleum products and dynamite to last minute food and water required exact loading points and dates.

The vessels selected had to be rerouted from their present duties and given certain last minute inspections and radar installations prior to their entering the iceberg infested Bering Sea and Arctic Ocean. Highly specialized Naval personnel such as Arctic Ice Pilots, Weather men and Arctic Coast veterans were drawn in from all parts of the globe.

* * * * *

Less than two weeks before departure of the ships 128 officers and men designated as NCBD (Naval Construction Battalion Detachment) 1058 arrived at the Seattle Naval Station. Lt. Comdr. Ivan Wilson, who had been instrumental in selecting the group, was temporarily in charge. His excellent selections and later his proper setting up of the Detachment contributed much to the later success of the Expedition.

On 25 July 1944, the two ships set out for Dutch Harbor without benefit of convoy, escort or publicity other than that which apparently will always leak out where there are those who must keep their contacts with the press. * * * Dutch Harbor was entered on the fifth day.

After topping off with fuel and water the expedition started its slow journey into the Bering Sea. Radio contact with the destination did not exist. The exact position of the ice mass, wind and weather conditions now so carefully reported day and night were then unknowns to be figured when and if possible. Fortunately, the Expedition Commander, himself a stranger in the arctic, had at his side two veterans of the Arctic Coast plus a real amount of information previously collected by the U. S. Coast Guard.

Preliminary inaccurate information obtained in Washington led us to plan a beach landing off Cape Simpson. For this purpose Pontoons and LCM's were deck loaded to make possible beaching the cargo and personnel. The final decision was made on the spot when it was discovered that a sand bar off shore eliminated any such landing. The ships then moved back to a point approximately one half mile off the extreme point of land known as Point Barrow. The choice of landings was not the best since it could have been vastly improved had the ships moved into the protected anchorage nearer Barrow Village. However, this observation may be classed as an after thought. The important point is that no attempt was made to carry out the original plan to land and make camp on Cape Simpson. That region short of drinking water and devoid of sand and gravel was and is unsuited for campsites without expenditure of much money and time.

SECOND YEAR—1945

GENERAL PLANNING AND ADMINISTRATION

With the opening of 1945 all hands were looking forward to an outstanding year of accomplishment. It was not possible, of course, at the beginning of 1945 to anticipate that both of the major enemies with which the Nation was engaged as the year opened would be defeated during the year and that as a result it would be necessary to determine major policies as to the continuation of Pet 4 under a civilian contractor. The transfer to a contract operation became one of the outstanding features of Pet 4 in 1945. The transition was not fully completed until the spring of 1946.

On the basis of the carefully laid plans for continuation, estimates had been made of a fiscal requirement of $1,620,000 to carry on Pet 4. After approval by Under Secretary of the Navy Ralph A. Bard, this item was included in the Naval appropriation bill for fiscal year 1946 under the recurring item for operation and conservation of naval petroleum reserves.

As Pet 4 began to settle into its stride and in view of the plans for 1945, it became urgent that the various fields of responsibility in the rather complex operating organization be clearly and specifically defined. This was done on 13 December 1944 by the Chief of Naval Operations as follows:

1. The Director of Naval Petroleum Reserves will advise the Secretary of the Navy as to the establishment of general policies.

2. The Bureau of Yards and Docks will have cognizance over procedures and scope of the project; over equipping and outfitting of the personnel of the construction battalion; over provision of construction materials; over supervision of personnel; and over contracts with airlines.

3. The Commandant, 17th Naval District, will have military cognizance; general cognizance over personnel, communications, radio, air (except Naval Air Transport Service schedules), and ship transportation within the area.

4. The Commandant, 13th Naval District, will be responsible for assignment of priorities to the Naval Air Transport Service; provision of air and ship transportation as supplied by Naval Air Transport Service and Naval Transport Service; and coordination of loading and dispatching of ship expeditions and issuance of orders to ships involved.

A general plan for 1945 operations was first prepared and submitted by Lieutenant Commander Rex in October 1944. It provided essentially for the transportation of the National-50 rig to Umiat between January and April and the spudding in of Umiat test well 1 on 1 June, for the procurement and freighting of two Failing drills to the Cape Simpson area during the winter and for core drilling in that area between 1 June and 15 September, for the completion of the pipeline survey by three field parties, for necessary geologic parties to start working out of Umiat starting about 1 June, and for certain other necessary supporting activities.

After an inspection of the Reserve by Captain Greenman, Commander Gillespie, Lewis MacNaughton, of DeGolyer and MacNaughton, Commander Koon, of the Alaskan Division of the Bureau of Yards and Docks, and LT James Brazil, geologist, the recommendations of Lieutenant Commander Rex were somewhat modified and substantially expanded. The most far-reaching recommendation of the group called for the drilling of the first test well on the Umiat anticline in 1945.

Other provisions of the plan as developed by the group included the drilling of shallow core holes at Simpson to determine structure, Schlumberger surveys of the holes drilled in the hope of reducing the necessity for coring, and a seismograph survey of that area. The plan also included a gravity-meter reconnaissance of the Umiat anticline to provide additional information on that structure and to test the usefulness of gravity surveys on the Reserve. In addition, the plan visualized the burning of local coal for steam at Umiat. Further investigation later showed that the use of northern Alaska coal in the program was not practicable anywhere on the Reserve. Still another provision of the plan was the obtaining of vertical aerial photographs of the area embraced by latitudes 69° and 70° N. and longitudes 151° and 155° W.

Commander Koon felt that the first test well should be at Cape Simpson, and this view was supported by RADM C. A. Trexel, Director of the Alaska Division, Bureau of Yards and Docks, in a letter to Admiral Moreell. Commander Gillespie could not support this view and urged that the first test well be drilled at Umiat, for that was the only location that could be justified with the information available. Commander Gillespie felt that the opinion of Commander Koon and Admiral Trexel was influenced greatly by the supposed greater feasibility of drilling in the Simpson area. Eventually, it was decided to proceed with the Umiat hole first.

At about that time the shortage of tractors in the Reserve began to be felt seriously, and it was necessary to ration their use between the Umiat and Simpson parts of the program.

Some question was raised as to the need for sending certain heavy-equipment items such as steam boilers and rig housing to Umiat. The winter freighting would be much easier if they were not sent. Commander Gilles-

pie felt that the first hole could not be expected to be completed at least until January 1946, and he instructed that the required materials be sent and that all facilities, especially the airstrip, be in proper condition to insure unimpeded activity during the drilling of Umiat test well 1.

The plans for the drilling and related activities at Umiat and Simpson also resulted in some limitations on the support that could be afforded the surface geological and geophysical parties. Lieutenant Foran urged that these activities be more adequately supported. Commander Gillespie pointed out that everyone realized the importance of the work of the surface parties but that some inconveniences resulting from the high priority of the drilling of Umiat test well 1 must be accepted.

The wisdom and foresight of Commander Gillespie in his stand, and the general validity of developing a carefully considered plan and then sticking to it, have been demonstrated many times since 1945.

The overall plans for 1945 outlined a well-rounded exploration program using all applicable standard methods of both surface and subsurface exploration; and it was proportioned and directed toward obtaining maximum information on the potentialities of the Reserve. The program was cognizant of, and provided for, a priority of steps to the end that information would become available as nearly as possible as needed for subsequent steps. An inherent and unavoidable problem in 1944 and 1945 was the inadequacy of basic factual information on general geology, structural geology, and stratigraphy for choosing drilling sites.

The long-range planning, of which each year's plan was a carefully determined part, in general was devised to locate and map structural features and to obtain stratigraphic information in the Brooks Range and Arctic foothills by surface geologic methods and in the Arctic coastal plain by geophysical methods, largely seismic surveys, and by core drilling. Test-hole drilling would, of course, provide additional specific information wherever done, and no effort was to be spared to obtain maximum information from all holes drilled. Some holes, especially in the coastal plain part of the Reserve were to be located primarily to obtain subsurface geologic information.

Captain Greenman had been advocating an agreement whereby the Geological Survey would carry out a large part of the geological studies that would be required in and near the Reserve as part of Pet 4. This resulted in the exchange of several letters between Secretary of the Navy Knox and Secretary of the Interior Ickes. Finally, in January 1945 the two Secretaries reached substantial agreement, and the Director, Naval Petroleum Reserves, and the Director, Geological Survey, were authorized to deal directly in developing a working pattern to accomplish Captain Greenman's desire.

While the war was in progress, information about Pet 4 was classified, mostly as secret. The project was declassified in October 1945 thus making possible the public showing of a rather complete moving picture in color of the operations to that date. It also permitted a short trip to Barrow on 10 November 1945 of a group of 17 newspaper correspondents to see for themselves the difficulties being encountered and the progress being made by NCBD 1058.

The assigned complement for the operations in 1944 had been 15 officers and 204 enlisted men. Food, fuel, and proper clothing were somewhat short as the end of 1944 approached, and it was becoming apparent that some men were not fitted for arctic assignment at all and still others had difficulty adjusting themselves during idle intervals. Therefore, all men not absolutely required for the winter work as planned were returned to the States. As of 7 January 1945 the detachment had been reduced to 13 officers and 126 men. Of those sent back to the States, 35 were returned as being unfit for arctic work.

The plans for 1945 called for substantially more work than had been done in 1944, and Admiral Moreell on 7 March 1945 requested that the Chief of Naval Operations accordingly expand the detachment to 25 officers and 635 enlisted men. In addition, in anticipation of the demand for labor during the ship expedition (Barex '45) planned for the fall, 220 stevedores were requested for unloading, 100 of them to remain at Barrow for 60 days to assist in warehousing the supplies and materials that would be coming in.

With the coming of V–J day in September, an item of high priority became the discharge of those eligible for release. It shortly became apparent that continuation of Pet 4 as a Seabee operation would be impracticable, and attention was directed toward ways and means of converting the exploration program to a civilian contractor operation.

On 21 September John L. Sullivan, Assistant Secretary of the Navy for Air, and Commodore Greenman, Director of Naval Petroleum Reserves, who by then had been promoted to flag rank from captain, jointly addressed a memorandum to the Secretary of the Navy in which it was recommended that—

(1) the exploration be continued on a contractual basis;

(2) funds already appropriated for the program be used;

(3) the geological work be done by the U. S. Geological Survey;

(4) a contract be negotiated with a competent firm to proceed with the geophysical work, drilling, and maintenance of facilities and equipment; and

(5) the Navy continue to provide air and water transportation along with associated facilities.

The recommendations were approved by the Secretary of the Navy on the same day.

The recommendations were based on the favorable indications resulting from the program through the summer of 1945 and on a study that had been made of the cost of developing and producing oil in the Reserve including the transportation of the oil to west coast refineries. At about that time came the first estimate that the potential production required to support development of the Reserve should be in the order of 100,000 barrels per day from reserves of about 500 million barrels.

In arriving at his decision to recommend continuation of Pet 4, Commodore Greenman stressed his conviction that only the development of the Reserve in peacetime could assure its use in war or other emergency. He pointed to the Navy's need for knowledge of the Reserve for planning purposes, to the strategic location of Naval Petroleum Reserve No. 4, and to the fact that many engineering and economic problems would have to be solved even if oil was located in large quantities.

After the approval of the recommendations by the Secretary of the Navy, Commodore Greenman on 29 November requested BuDocks to take full responsibility for the letting and administration of contracts having to do with Pet 4. He suggested that any contracts, subject to the availability of funds, include work through the summer of 1949.

The proposal was studied by the Bureau's Board of Contract Awards, which found that three companies collectively included all the elements necessary for carrying on the work and recommended that a contract be negotiated with them. The companies were Hoover, Curtice, and Ruby, Inc.; the C. F. Lytle Co.; and the Green Construction Co.

The board had determined that a contracting organization was required that had had experience in northern Alaska, that had technical qualifications to explore for petroleum and analyze petroleum possibilities, and that was competent to manage and supervise drilling operations.

The C. F. Lytle Co. and the Green Construction Co. had operated jointly in Alaska for 5 years, had constructed 14 airfields for the CAA (Civil Aeronautics Administration), had built the Alaskan portion of the Alaska Highway, and had constructed substantial housing facilities. It had had experience in the winter sledding of large tonnages of freight.

Hoover, Curtice, and Ruby, Inc., had had wide experience in engineering, management, technical analysis, and supervision in the petroleum exploration field, and some members of the staff had northern experience. In the summer of 1945, as will be described later, the United Geophysical Co., which was closely associated with Hoover, Curtice, and Ruby, had done seismograph work in the Reserve under contract.

At a special hearing on 4 December 1945 before the Naval Affairs Committee of the House of Representatives, Commodore Greenman appeared, with other supporting witnesses, to justify the proposed continuation of Pet 4 operation under a civilian contract and to obtain the committee's support in seeking appropriations for carrying on the program on the basis of a negotiated contract with a competent civilian contractor.

The principal witnesses at the hearing were Commodore Greenman, Director, Naval Petroleum Reserves; W. E. Wrather, Director, U. S. Geological Survey; Lewis MacNaughton, DeGolyer and MacNaughton, advisor to the Secretary of the Navy in oil matters; and CAPT Bart Gillispie, CEC (Civil Engineer Corps), USNR, who had been in charge of the Seabee battalion and initial exploration in the Reserve.

After thorough questioning of all witness, the chairman moved that the Naval Affairs Committee reaffirm its approval of this project and recommend to the Appropriations Committee that sufficient funds be appropriated for the continuation of the program on the basis of a negotiated contract with a competent civilian contractor.

By a letter of intent dated 17 December 1945, the coventurers (Arctic Contractors) were authorized to begin work while the definitive contract was being prepared. CDR P. D. Koon, CEC (Civil Engineer Corps), USNR was designated officer in charge of construction under the intended contract.

Meanwhile, Commander Rex had been relieved as OICC on 26 September and was replaced by Lieutenant Commander Davis. The release of the personnel, which had begun in August, proceeded rapidly and by the end of October the last man of the original detachment had left the Reserve. Only a skeleton crew was left, scarcely enough to man maintenance and repair details and perform routine duties.

The Chief of Naval Operations on 17 December, the date of the letter of intent mentioned above, directed the Bureau of Naval Personnel to deactivate NCBD 1058 and to arrange for the disposition of its personnel.

Plans were laid for the OICC to maintain his skeleton crew to perform necessary duties until 1 January 1946, at which time responsibility was to pass to the contractor. Actually, the changeover required a longer time, and it was not until February 1946 that the Navy withdrew completely, except for such continuing responsibilities as were required in connection with the contract. In spite of the very serious personnel situation, the remnants of NCBD 1058 were able to maintain both the Barrow and the Umiat facilities and to perform as well some work preparatory to the winter freighting.

As soon as the letter of intent was signed, Arctic Contractors began to organize for the job. Arthur F. Daily was appointed project manager, and Herman Reichman, project superintendent. Mr. Reichman arrived in Fairbanks on 26 December. A contractor's employment office began to function in Des Moines, Iowa, on 24 December, and on 28 December the project manager moved into temporary Navy offices in San Francisco, Calif.

OPERATIONS

LAND TRANSPORTATION

During 1944 it had become increasingly apparent that one of the major tasks of Pet 4 was to find some means of freighting large tonnages many miles over the Reserve. The Arctic tundra presented almost insurmountable difficulties to such operations in the summer. The profusion of lakes and streams made heavy hauling extremely difficult, but an even greater problem was posed by the surface thawing of the frozen ground. The tundra surface becomes an untraversable quagmire if torn up by heavy motorized equipment. It was apparent by 1945 that the bulk of the heavy hauling would have to be done in the winter. The way in which this extraordinary problem was so effectively solved has become one of the outstanding triumphs of Pet. 4.

Winter freighting for 1945 was assigned to Lieutenant Hugg. Preparations that were begun in 1944 were continued through January 1945 and consisted, in addition to careful planning, of the building of wanigans (living and eating quarters, which were mounted on sleds), bobsleds, and welded-pipe sleds. This building, repairing, overhauling, and servicing of equipment continued for the next 3 months. The work was so painstakingly done that there was no major failure on the trail during the whole winter.

In the planning for the 1945 winter freighting, it was estimated that 1,000 tons would go to Umiat and 150 tons to the Simpson area.

The first sled trip was to Simpson, 75 miles from Barrow, and the tractor train started on 22 January. On that initial trip were learned the great advantages of freighting so far as possible over ice rather than over tundra. The first half of the trip was attempted over the tundra. Travel was very bumpy because of the rough surface of the tundra, snow drifts, and the low banks that had to be negotiated at stream crossings. The sleds frequently burrowed deeply into snowbanks, and the drums of fuel constituting one load shifted so badly that the sled was abandoned. As a first trial, 2 large tractors were used to pull 10 sleds. This was found to be insufficient power, and after unhitching two sleds the expedition continued with 3 tractors and 8 sleds, 4 of which were payloads while the remainder were for eating, sleeping, and servicing.

The latter half of the trip was over the sea ice as was the whole return trip. Ice travel was found to be much easier, although some difficulties arose because of the leads (open or thinly frozen cracks in the ice). It was found that some leads could be crossed with care and that it was possible to detour most of them. The weasel (M29C) proved a very useful vehicle for scouting ahead, especially for dangerous leads. The performance of the tractors was excellent as was that of the welded-pipe sleds. Even a little experience showed that much rough travel was eliminated, and much wear and tear saved, by a bulldozer attachment on the lead tractor.

The first loads were cached near the house of Tom Brower, near the base of the peninsula between Admiralty and Smith Bays at a place called Alaktak and later Half Moon Three. The trains arrived back at Barrow after 4½ days.

The second trip was also to Simpson and left Barrow on 5 February. By sending ahead 1 tractor hauling 4 wanigans mounted on bobsleds and by following the trail of the return of the first trip as far as possible, it was found that better time could be made and heavier loads hauled. Three additional tractors were able to pull 15 pay loads, and the round trip was made in a little less than 2½ days.

The third Simpson trip started on 14 February. It was a smaller expedition; and on the return, 3 loads of pipe and lumber, as well as a propulsion unit, were salvaged from a barge that had been lost during the unloading during Barex '44. That trip required approximately 3 days.

After those three successful shakedown trips to the Simpson area, all was in readiness to attempt the first long haul to Umiat, a venture on which would hinge the success or failure of Pet 4. The route of that first Umiat freighting trip was from Barrow to the Simpson caches, thence up the Chipp River to the Ikpikpuk and its east fork to its head, thence 65 miles overland to

Umiat. The last overland leg was scouted and flagged with the use of dog teams by Sergeant Bagby and Cpl. A. A. Curtin, Eskimos of the Alaskan Scouts. The weasel was not suited to overland scouting, for it could not stand up under continued hard usage in rough terrain. It was found that scouting out an overland trail was a much slower and more painstaking job than scouting a trail over ice.

The loss of Corporal Curtin on that scouting mission was the first and one of the few fatalities of Pet 4. It was necessary for Sergeant Bagby to make a dogteam journey 40 miles to Umiat for supplies. He was delayed by a storm and, on his return to their little trail camp, Corporal Curtin was missing although his equipment and heavy clothing were in the camp. He has never been found although an exhaustive search continued through 11 March.

The first Umiat-bound train left Barrow on 24 February. It consisted of the lead tractor with wanigans followed by 4 tractors hauling 11 sleds and 2 carryall scrapers. Two of the sleds were dropped at the Simpson caches, and a crane was picked up for Umiat. After the easy trip to Simpson, the river hauling seemed especially difficult and slow. Deep snowbanks on the rivers gave much trouble as did sandbars hidden by snow, and the narrow, winding ice channel was hard to follow. The overland part of the trail was fair because of the careful scouting. The train returned to Barrow after a little more than 22 days, having covered 635 miles in the round trip. It was truly an epic trip performed in the heart of the Arctic winter.

The second Umiat freighting expedition departed Barrow on 28 March and followed approximately the route of the earlier journey. Although the wind filled the bulldozed trail with snow within a few hours, the trace remained marked for weeks by snow windrows. The scouting weasel broke down on that trip, and the remainder of the scouting was done by Sig Wien in a small plane. Several overland cutoffs were made, resulting in the round trip being shortened to 586 miles; but it was decided that the longer trail using ice as much as possible saved much on wear and tear on equipment and was shorter in time. One sled was overturned, on the trip, and some drilling equipment damaged; otherwise, the trip was uneventful and required nearly 18 days.

The fourth and final trip to Simpson was made on 17–19 April and delivered two Failing "314" core rigs (housed and sled-mounted) as well as a galley wanigan and pipe and drill rods. Only one tractor was used, and the trip required just over 2 days.

The final Umiat trip left Barrow on 21 April and followed the approximate route of the earlier trains. The trains covered the 307 miles to Umiat in a little more than 8 days.

The general pattern followed in hauling materials to such drilling sites as Umiat and Simpson was to take first, construction equipment, second, equipment for rigging up, and finally, drilling equipment. The final and best trail to Umiat used in 1945 was 307 miles long, of which 58 miles was over sea ice, 176 miles over fresh-water ice, and 73 miles over tundra. The morale of the men during freighting remained high. Two crews alternated 6 hours on and 6 hours off; meals were served every 6 hours.

Tractors at Umiat immediately began moving the equipment from the Umiat airstrip to the drilling site about 8 miles away. By July it was almost impossible for the tractors to make that trip because of the soft ground, and only one weasel was available for use between the two places.

SEA TRANSPORTATION

For Barex '45 it was estimated that 3 ships would be required to carry 14,000 long tons of cargo that would occupy 950,000 cubic feet. In view of the difficulty that had developed in the unloading of Barex '44, every precaution was taken to insure a smooth operation in 1945. CAPT D. B. Downer was designated expedition commander; LCDR John Backlund, arctic pilot; and LCDR John Gateby, beachmaster. Those three officers inspected the Barrow beach late in May in company with Commander Gillespie in preparation for the August landing. It was agreed at that time that the beachmaster, who would have control of landing boats and barges, would be responsible to the expedition commander, whose basic responsibility would cease at the beach. Unloading time was estimated at 20 days. Provision was made for an estimated 7 days standby time in order to use beach no. 2 at the camp instead of beach no. 1 at Point Barrow farther north.

A party of the U. S. Coast and Geodetic Survey under the command of Lieutenant Commander Woodworth charted the Barrow coast in the first part of August and sounded the inshore water. The data were flown to the expedition ships as they lay off Icy Cape waiting for the ice to move away from Barrow.

LTJG J. R. Bell was assigned to check the loading of the ships at Tacoma, Wash. More than 6 weeks was available for procurement and assembly of cargo, and it therefore was possible to do a thorough job of packaging and loading. Much of the cargo was palletized (loaded on pallets that could be easily moved for load-

ing, unloading, and storage). The load included a drilling rig capable of drilling to 6,500 feet with 3-inch drill pipe.

A jamesway hut was erected on the Barrow beach for the use of the beachmaster, and by the end of July 5 LCM's (landing craft, medium) and 3 barges were in condition and awaiting the ships' arrival. Other lighterage equipment came in on the ships. Six areas were marked off along the beach so that supplies and materials could be segregated and assembled. Crews were set up on two 12-hour shifts for 24-hour operations.

The ships assigned to Barex '45 included the U. S. S. *Spica* and the SS. *Jonathan Harrington*, both previously on Barex '44, and the SS. *Enos A. Mills*. Also included was a NATS (Naval Air Transport Service) R4D (a twin-engine, passenger aircraft) for ice reconnaissance. The expedition departed Tacoma, Wash., on 19 July.

On 27 July the ice began to move out from Barrow, but the wind soon drifted it back again. On 10 August three ships anchored in clear water off the Barrow camp, but on the 11th the ice drifted back and accumulated around the ships and the beach, so that all unloading operations had to be suspended for a few hours although no damage was done. On 13 August the ice threatened again, and all three ships sought shelter around the point east of Point Barrow. The *Harrington* was caught in the ice (see fig. 13) during that maneuver, and a propeller blade damaged. The *Spica* and the *Enos Mills* were able to move back to their positions off the landing beach on 14 August, but the *Harrington* discharged stern cargo near the Point in order to allow the propeller to rise high enough for repairs to be made.

The *Enos Mills* left on 20 August and stopped to unload some cargo at Wainwright. The other ships departed on 22 August but were driven back to Barrow by the ice on 24 August. The *Harrington* was again caught by the ice, and another blade damaged. She was freed and towed to open water by an LCM on 28 August. Repeated attempts to get through the pack near Franklin Point were unsuccessful until 3 September when both ships rounded Icy Cape and were in the clear. It is doubtful that the ships could have cleared Franklin Point without their ice reconnaissance plane.

The cargo unloaded actually totaled about 17,000 tons; it was all placed ashore in good order. (See fig. 14.) Except for the two brief periods of fog and ice during the operation, conditions were good. The sea was calm, and easterly winds prevailed and kept the ice offshore.

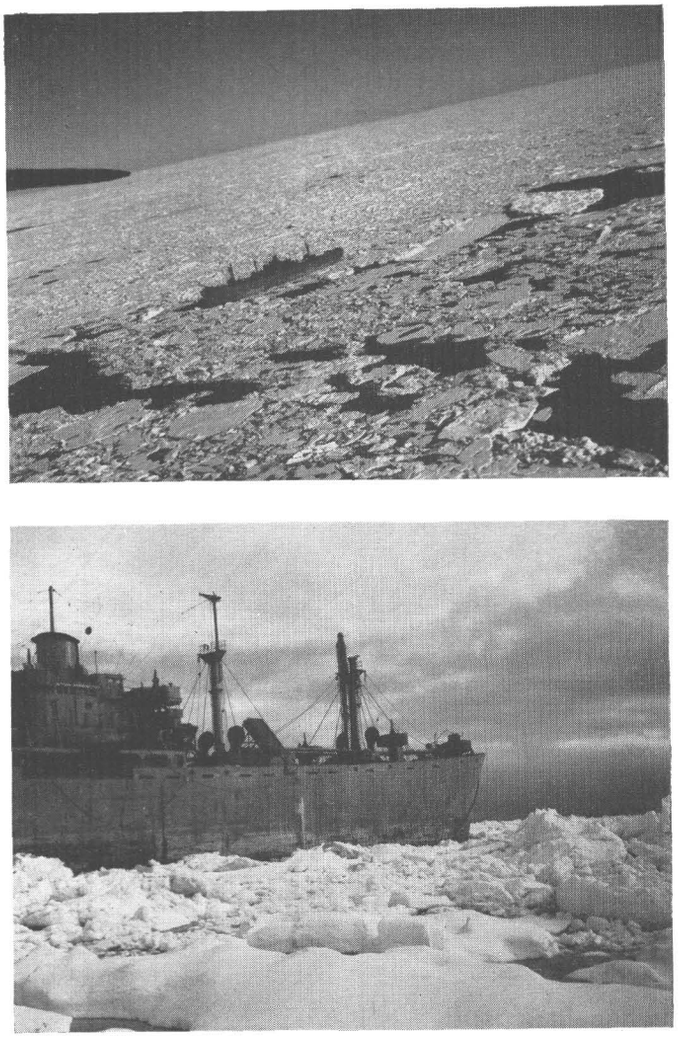

FIGURE 13.—SS. *Jonathan Harrington* caught in the ice off Point Barrow, August 1945. Photographs by U. S. Navy.

AIR TRANSPORTATION

The importance of adequate air support for Pet 4 became more and more apparent as the program progressed. Personnel and high-priority freight had to come in and out by air from and to Fairbanks. Regular mail service and just the knowledge that regular flights were being made was an important morale factor. Small planes were badly needed for reconnaissance, communication, emergency delivery of supplies or spare parts, and evacuation of ill or injured men at isolated camps or on sled trains.

It was evident by the end of 1944 that plane service would have to be substantially improved. On 3 January the Chief of the Bureau of Yards and Docks reported to the Deputy Chief of Naval Operations for Air that the arrangements with Pan American Airlines and Wien Alaska Airlines were inadequate. It was

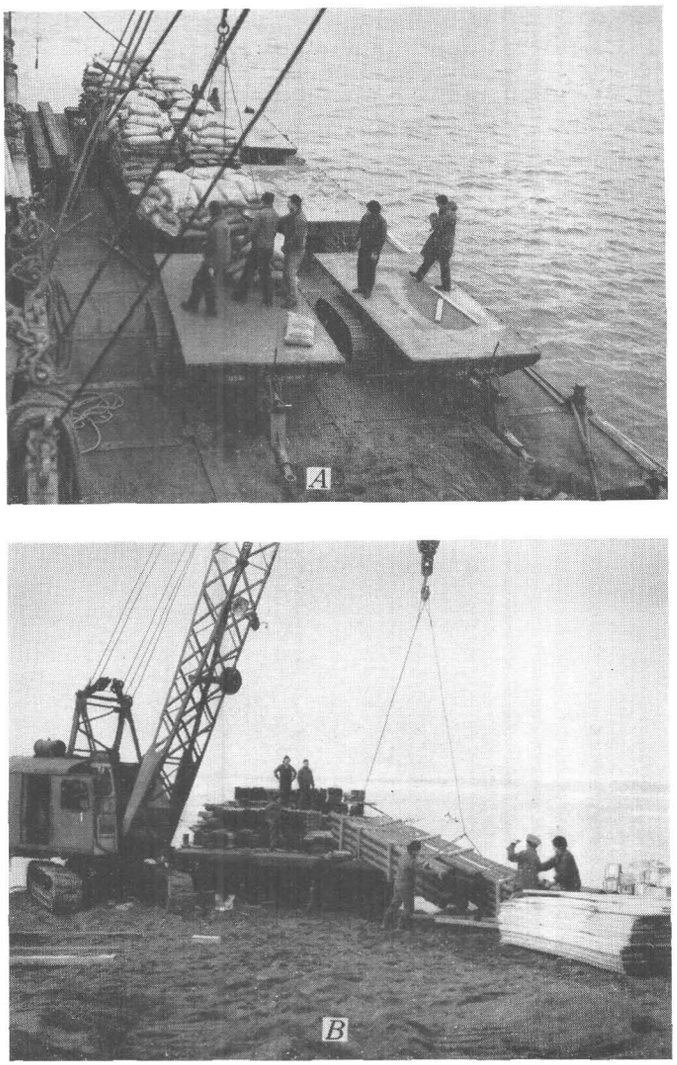

FIGURE 14.—Unloading operations at Barrow, Barex '45. *A*. Loading pontoon (barge) at ship's side. *B*. Unloading pontoon at beach. Photographs by U. S. Navy.

recommended that NATS take over the air support of Pet 4. On 9 February word was received from the Commander NATS West Coast that NATS had been instructed to take over. CDR Henry Hollenbeck, who had been assigned to direct operations, planned to put three R4D's on the job before 1 February to clean up the increasing freight backlog at Fairbanks. The first NATS flight into the Reserve was on 23 January, and at that time there were 295,000 pounds waiting in Fairbanks to be moved.

The extent of the air support required for an operation such as Pet 4 is illustrated by the following paragraphs that set forth some specific figures as examples. Up to 23 January, Pan American had flown 250,000 pounds of cargo; Army Cold Weather Test, 111,000 pounds; and the Air Transport Command, 67,000 pounds. For air hauling within the Reserve, Wien Alaska Airlines used a Bellanca and a Travelair.

In January and February NATS moved 298,000 pounds into the Reserve, and Wien's airline shuttled 46,000 pounds from Barrow to Umiat in 46 trips. In March 250,000 pounds went to Barrow, and 300,000 pounds was shuttled to Umiat. The large amount of freight to Umiat was made possible by supplementing Wien's planes with 2 Army Norseman planes and 2 Army pilots who had reported that month for temporary duty. In addition, as soon as the Fairbanks backlog was sufficiently reduced, the NATS R4D's were used on the Barrow to Umiat shuttle.

April was the peak month for air freighting. NATS made 72 trips from Fairbanks to Barrow with 347,000 pounds. The Army, on the same run, carried an additional 15,000 pounds. The NATS R4D's in 149 trips also carried 752,000 pounds to Umiat (see figs. 15, 16, 17), while Wien's in 109 trips hauled 230,000 pounds, and the Army Norseman planes, 27,000 pounds in 21 trips. By the end of April all required drillpipe, cement, drilling mud, rig housing, and spare parts were at Umiat.

Air freighting to the Simpson area began in May. The two Army planes were no longer badly needed and were returned to Army command although their departure was offset by the addition of one NATS Norseman. In May a total of 700,000 pounds was carried by NATS, 75,000 pounds by Wien, and 50,000 pounds

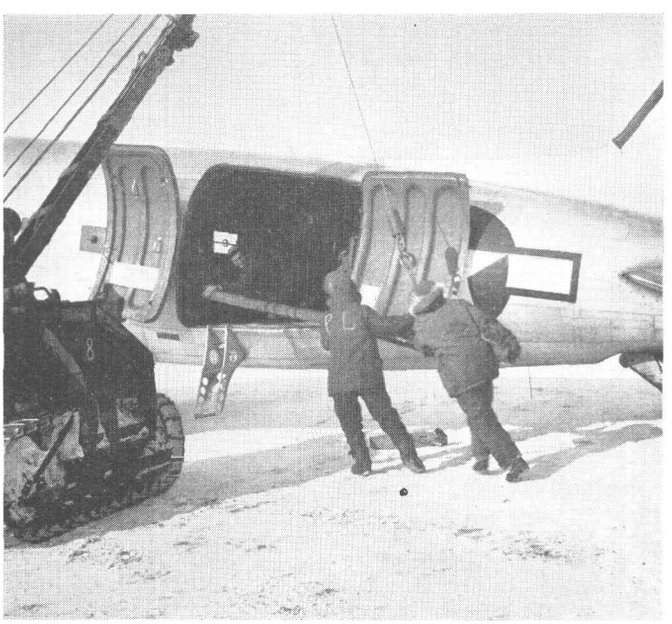

FIGURE 15.—Loading drill pipe in Navy R4D's for freighting between Barrow and Umiat in April 1945. Photograph by U. S. Navy.

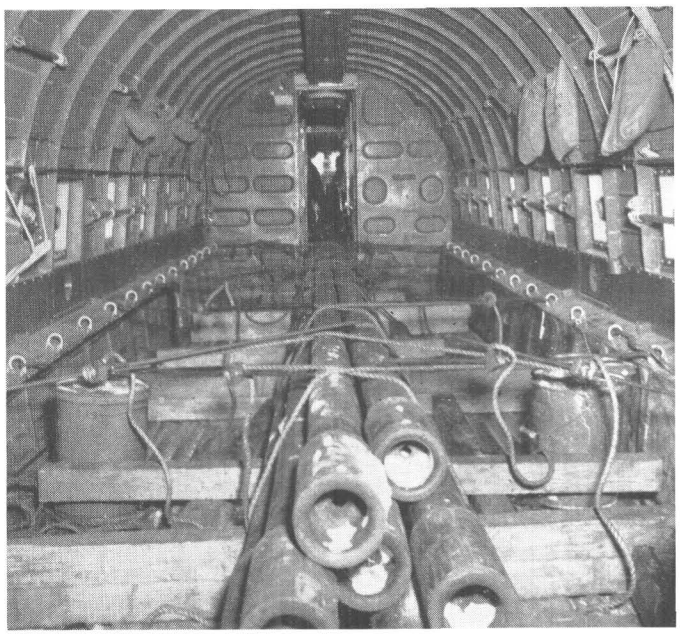

FIGURE 16.—Manner of carrying drill pipe in aircraft for freighting between Barrow and Umiat in April 1945. Photograph by U. S. Navy.

by the Army. In June, July, and August approximately 200,000 pounds in all was carried each month. The load continued to decrease, and in December was only 70,700 pounds.

In the summer field season of 1945, the geological parties were supplied out of Umiat by 2 Piper Cub planes, 1 on wheels and 1 on floats, belonging to Wien Alaska Airlines. One Cessna on floats supplied the Simpson operations from Barrow.

FIGURE 17.—Loading weasel at Barrow airfield for freighting between Barrow and Umiat in April 1945. Photograph by U. S. Navy.

AIRFIELD CONSTRUCTION AND MAINTENANCE

The airstrip at Barrow and attendant facilities were to be improved in 1945. A new strip was to be constructed at Umiat, and the small strip at Alaktak improved somewhat. As a safety measure it was planned to construct a strip at Bettles on the Koyukuk River along the route of the linehaul about halfway between Fairbanks and Barrow.

In the winter it is relatively easy to construct satisfactory landing strips on the frozen surfaces of lakes suitable for fairly large, wheeled aircraft. Two such landing strips, each 3,000 by 100 feet, were bulldozed out in February—one on a lake near Tom Brower's house at Alaktak and the other on a lake near the Umiat campsite. The latter strip was immediately used by the NATS R4D cargo planes as mentioned earlier. To maintain the runway, a small tractor obtained in Fairbanks was disassembled, flown to Chandler Lake in an old Boeing 247 belonging to Wien Alaska Airlines, and landed on the ice, and from there parts were shuttled by smaller aircraft to Umiat where it was reassembled.

FIGURE 18.—Laying of marston mat on main runway of Barrow airfield, 8 June 1945. Photographs by U. S. Navy.

Several improvements were made during the year at the Barrow airfield. In February, Bartow lights were installed along the runway, and a revolving beacon was placed on the utility building. To relieve the very critical tractor shortage on the Reserve, the tractor that was used in 1944 on the pipeline survey was flown to Barrow in June and used for airstrip maintenance.

The Barrow field became so soft in the spring thaw that it was necessary to cover it with marston mat (pierced steel plank). (See fig. 18.) The runway, 140 by 4,000 feet, was so covered as well as the 50,000-square-foot parking area. Tundra growth was mixed

with the coarse sand of the airfield to stabilize the surface before the mat was laid, and this provided a good base. Later an additional parking area of 31,500 square feet was graded and covered with marston mat.

A concrete turntable 175 feet in diameter was constructed in August at the south end of the runway. It was also necessary to level the landing strip by selectively raising the mat and placing sand and gravel under it. A hangar and a radio transmitter building were started at Barrow during the year.

Work began on the Umiat airfield in May even before the snow had disappeared. The three tractors assigned to the work were in fair condition although somewhat worn from the winter freighting. As the summer wore on, the maintenance of the tractors increased very greatly. Nevertheless, in May the snow was bulldozed aside, and 8,000 cubic yards of gravel placed.

The Umiat field is close to the Colville River and only a few feet above the river level. With the coming of the high water in June, the gravel pits were flooded, and the grading of the airstrip was slowed down. As the river subsided a gravel bar in the river was graded as a runway for small aircraft. A few landings were made by NATS R4D planes on that runway, but it was soon declared unsafe for aircraft of that size. By the end of July, in spite of delays due to maintenance time required for the tractors, a total of 40,000 yards of sand and gravel was on the strip. At the end of September 3,300 feet of the Umiat runway was complete, but work continued on through October.

Because of the shortage of Seabees it was determined to let a contract for the airstrip at Bettles. The contract was awarded to the C. F. Lytle Co. and the Green Construction Co. CDR Bart Gillespie was designated officer in charge of contract, and Lieutenant Litchfield, resident officer in charge of construction. The first landing was made on the strip by a contractor's plane on 26 May while the field was still soft and muddy. In September the strip was 100 percent operational. The complete installation, including auxiliary buildings and lights, was finished in October.

CAMPS

In January it was necessary to improve the insulation of the permanent quarters at Barrow. Another layer of insulation was installed on the inside, leaving an air space between the new layer and the original construction. In March a radio and light-control building was put up at the airfield, and work started on additional huts for quarters. Six of these were completed in June. Ten small quonsets and a larger one were completed in August, so that the entire personnel was out of tents by 25 August. Also in August, a site was graded for 17

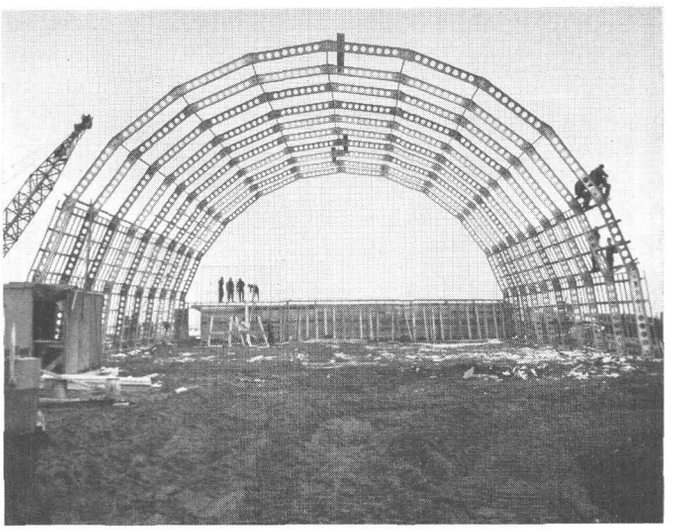

FIGURE 19.—Construction of hangar at Barrow airfield, summer of 1945. Photograph by U. S. Navy.

new buildings. In September, six more 40- by 100-foot quonset huts were completed. (See figs. 19, 20, 21.) Construction was finished on the hangar, generator house, and transmitter building. In October, a dry-cleaning plant was put in operation. An additional 40-horsepower Munds boiler was installed in the utility building in November.

Construction work started at Umiat in January, when a radio installation and housing, consisting of five jamesway huts, were erected. In May, seven 16- by 16-foot framed tents were set up at the Umiat well site about 8 miles by trail from the airfield. The next month a boiler house was built, and the righouse erected at the well site. Two quonset huts were completed at

FIGURE 20.—General air view of Barrow camp on 11 September 1945. Photograph by U. S. Navy.

the Umiat camp near the airfield, and the jamesway huts erected earlier had to be cribbed because of settling during the thaw. In September the gravel filling required to raise the Umiat camp out of the swampy surrounding land was finished, and a gravel road between the field and the camp was under construction.

A jamesway hut was erected at Alaktak (Half Moon Three) in March, and by May, nine framed tents were ready at the Simpson camp.

FIGURE 21.—Street scene in Barrow camp, 15 November 1945. Photograph by U. S. Navy.

PIPELINE SURVEY

The continuation on to the Reserve of the rather detailed pipeline survey that had been made in 1944 from Fairbanks to Livengood was believed to be unnecessary. However, some reconnaissance information was needed for planning and design purposes. Three parties of Alaskan Scouts were assigned the task which was accomplished in the winter and spring of 1945. The parties moved by dog team and were supported by L–1 planes. Party 1 covered the stretch from Livengood to Bettles; party 2, from Bettles to Anaktuvuk Pass by way of the John River valley; and party 3, from Umiat south to Anaktuvuk Pass after it had completed the flagging of the sled-train route to Umiat.

COMMUNICATIONS

The success of an operation such as Pet 4 requires a highly effective communications system. Every effort was made to expand and improve rapid means of communication between Fairbanks and the Reserve, between the main base at Barrow and outlying camps such as Umiat and Simpson, and between the main and subsidiary bases and mobile field groups of all kinds—geophysical parties, geological parties, sled trains, and others.

In 1945 the Airways and Air Communications Service stations in the Reserve provided radio navigational aids to aircraft and point-to-point communications. At Barrow this required 1 officer and 16 enlisted men, and at Umiat, 5 enlisted men. The communications were very satisfactory except for a weakness in point-to-point service caused by the lack of better antennae and more powerful transmitters. However, this situation was corrected when needed equipment came in on Barex '45. The equipment was completely installed by February 1946.

A radio installation similar to those in the sled trains was maintained at Alaktak (operated by Tom Brower) because of the strategic location for emergency landings and for reporting weather between Barrow and Umiat.

EQUIPMENT AND ITS USE

Some of the difficulties encountered in 1945 were due to the unavoidable rush in procurement and loading of Barex '44. For example, the small core drilling rigs were found to be unsatisfactory. Furthermore, some valuable cargo was lost overboard during unloading.

When warm weather arrived in April of 1945, the frost that had collected on the inside of the outer surfaces of quonset huts thawed and resulted in leaks. Plans for 1945 housing and warehousing were inadequate. There was a shortage of construction materials and electrical and plumbing supplies. Nevertheless, in spite of shortage of workers, warehousing and storage were accomplished within available means. All supplies, materials, and equipment were segregated and inventoried. All that could not be warehoused and that would not be damaged by exposure were placed in mapped outdoor storage areas.

It was found that wheeled vehicles in general could not be used effectively. This was contrary to advice obtained before the start of Pet 4 and was serious in that it resulted in unusable wheeled vehicles being sent and in an insufficient supply of tractors and Athey wagons. (See fig. 22.) Weasels were not sturdy enough for the rough terrain, but the service they rendered was invaluable. The outstanding importance of the tractor has already been mentioned. The sled trains were able to go up and down 15 percent grades successfully. Both the factory-built Micheler bobsleds and the welded-pipe sleds made at Barrow performed excellently; the latter were specially good on ice. By careful loading and by keeping the center of gravity low and either centered or toward the rear, the sleds withstood angular lists of 20° without damage to wanigans or loads.

Before heavy winter freighting by sled was practically demonstrated, it was believed that a well-constructed airfield suitable for heavy aircraft would be

a prerequisite to any deep drilling. Although the value of plane support must not be minimized, the advantages of heavy tractor-train transportation are obvious. Previous advice was to the effect that over-ice hauling would not be practicable. Pet 4 showed that the sheltered parts of the ocean and the larger rivers provided natural and easier winter routes, if care was taken in avoiding cracks. Overland freighting proved much harder on both men and equipment.

Before the loading of Barex '45, there was opportunity to have much of the winterization of equipment done in the States. This greatly relieved the facilities for such work at Barrow. Such winterization included the installation of heaters in tractors, cranes, and weasels; the building of cabs on tractors; the preparation of knockdown plywood cabs for weasels; the insulation of batteries and fuel tanks; the placing of frost shields on vehicle windows; and the factory installation of snow and ice grousers and roller blocks on tractors.

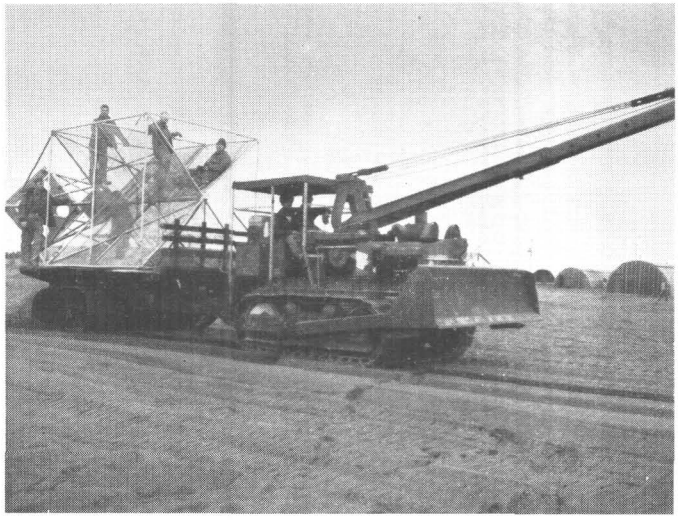

FIGURE 22.—Radar reflector being transported on an Athey wagon towed by a crane, 15 August 1945. Photograph by U. S. Navy.

Clothing for arctic use that was available for issue was too bulky and not durable enough for general use in Pet 4. Some standard articles were warm enough but had been designed for aviators and others whose duties did not require hard physical exertion. It was believed that a combination of suitable issue articles and items of Eskimo clothing would be required.

AERIAL PHOTOGRAPHY

The plans for 1945 called for additional aerial photography, especially of the areas to be studied by field geological parties, as soon as the snow had disappeared. The photographs were to be printed as rapidly as possible and supplied to the field parties.

Trimetrogon photographs of the Reserve taken from 20,000 feet had been available since 1943. That photography was not well controlled and was somewhat inferior otherwise, especially because of partial cloud and snow cover. In 1945 the 16th Photo Squadron of the 311th Reconnaissance Wing based at the Naval Air Station, Denver, Colo., made trimetrogon photographs of a large part of the Reserve from an altitude of 12,000 feet. Some ground control was supplied by the 7th Geodetic Control Squadron, but in general, ground control, both horizontal and vertical, was still inadequate. The 16th Photo Squadron also made vertical photographs of about 400 square miles in the Umiat area.

The 1945 photography was especially useful in making preliminary interpretation of geologic structures in the foothills belt. Both the 1943 and the 1945 photography added greatly to the information available from the geologic investigations in the 1920's in locating the positions and extent of the many anticlines in the foothills part of the Reserve.

GEOLOGY

The plan for geologic field investigations for the summer of 1945 provided for 8 parties, each including 2 geologists and several other members such as recorders, rodmen, boatmen, and cooks. (See pl. 3.) Five of the parties were operated by the Navy with Naval personnel and three by the Geological Survey with Survey personnel. Four of the five Navy parties worked in the Reserve in the general Umiat area and for considerable distances both upstream and downstream from there. The fifth Navy party studied the Umiat structure first and then the lower part of the Chandler River valley south of the Reserve and south and east of Umiat. The three Survey parties covered the valleys of the Anaktuvuk, Chandler, and Killik Rivers, all outside the Reserve but in locations where the information obtained was pertinent to the geologic interpretation of conditions within the Reserve.

The geologic parties arrived in the Reserve near the middle of May 1945. Equipment and supplies were distributed by bush plane to cache points, and all of the Geological Survey parties were in the field by the end of May. Travel was by foot, with attendant backpacking as necessary, and by collapsible or knockdown boats downstream along certain of the larger rivers. Radio communication with Umiat was erratic. All the parties completed their assignments and were picked up by bush plane by 13 September.

The three Geological Survey parties crossed belts of old rocks near the Brooks Range in the early part of the season and obtained significant data on the struc-

ture, stratigraphy, and lithology of the old rocks that are deeply buried in the vicinity of Umiat.

Emphasis was given throughout to stratigraphy and structure, and much information was accumulated to assist in the development of a better understanding of the geologic history of northern Alaska on which would rest eventually an interpretation of the petroleum possibilities. Of special interest was the stratigraphy and lithology as a start toward a basis for geologic correlation over large areas of the Reserve and adjoining areas. From the work of 1945 came the data that gave the first indication of the pattern of facies changes, the interpretation of which was developed later in large part by Thomas G. Payne, of the Geological Survey. Considerable effort was expended in 1945 in attempting correlations by the use of bentonitic layers. Also, the 1945 results began to focus interest on the possibility of stratigraphic traps for petroleum in addition to the more obvious importance of anticlinal traps. Also of special interest resulting from the geologic fieldwork of 1945 was the indication of the great abundance of shale in the stratigraphic section and the scarcity of clean-sand layers of large horizontal extent that might be expected to be sufficiently porous and permeable to be reservoirs of petroleum in commercial quantities.

In addition to the work of the field parties just described, some special geologic studies were made in 1945 and carried over into 1946 principally by LT Don Jopling and LTJG J. S. Templeton. Those men made lithologic, mineralogic, and paleoentologic studies of the top 1,816 feet of Umiat core test 1, and they divided that section into six zones. Such oil as was found in the test hole was interpreted as being residual from emanating gases, but that interpretation is now known to be incorrect. Some mineralogic and paleoentologic studies of drill and field specimens were attempted in Fairbanks in October, but both the literature and the equipment available there were inadequate for such studies. LTJG Templeton spent 3 months in the winter of 1945–46 in the U. S. National Museum, in Washington, studying fossils from Naval Petroleum Reserve No. 4 and comparing the faunal material with that from other areas.

GEOPHYSICS

The plan for geophysical investigations in 1945 included provision for an airborne magnetometer survey of the Reserve. That method had been of interest to the Navy as a possible method of submarine detection from the air and was being experimentally tried as a geologic tool by the Naval Ordnance Laboratory and the Geological Survey. The method was based, of course, on differences in the magnetic intensity of the earth. The operation was called SPAMS (Special Alaska Magnetic Survey) and was directed by J. R. Balsley, of the Geological Survey, and Homer Jensen, representing NOL (Naval Ordnance Laboratory). Air transportation for SPAMS was provided by the Navy, which supplied a PBY5A in which the equipment was installed.

Ground control was provided by a continuous strip camera; the photographs were then tied by an observer to the 1943 trimetrogon photography. A recording magnetic variometer was operated at Barrow during SPAMS and provided a record of the diurnal variation which was later used to correct the magnetometer readings.

The field survey continued from 22 July to 14 September. (See pl. 3.) Almost all of the Reserve was covered from an altitude of 1,000 feet along north-trending flight lines approximately 2 miles apart. The area around Cape Simpson was covered by additional east-trending flights. For greater detail, some tests were made at an altitude of only 100 feet, and the eastern half of the Reserve was flown at 12-mile intervals from an altitude of 5,000 feet. Magnetic-intensity contour maps were prepared in the fall and winter of 1945.

The magnetic anomalies that were revealed were of sufficient interest to merit testing by more conventional and more detailed geophysical methods. A magnetic anomaly in the southeast part of the Reserve corresponded closely to the Umiat anticline as known from surface geology. Anomalies elsewhere have been generally more difficult to interpret.

Plans for other geophysical investigations in 1945 called for a gravity-meter reconnaissance of the Simpson area to localize areas for core drilling and seismography work; a later gravity-meter study of the Umiat structure; Schlumberger surveys of the core holes planned for Simpson; and experimental seismic work using the same holes. It was hoped that the core holes would establish at least one key horizon. It was also anticipated that using the holes for seismic testing would yield information on optimum shooting depths, on tamping procedures, size of charges, and the best geophone spacing.

The gravity-meter and seismic parties started at Simpson in early June. One weasel was supplied to the gravity-meter party and was used for both surveying and recording. Another weasel was used by the seismograph party for transportation of personnel and for surveying. A tractor supported both the core-hole drilling and the seismograph shothole drilling. A Cessna on floats provided air support from Barrow.

All the activities in the Simpson area—core drilling and seismic and gravity-meter operations—were carried out from a summer tent camp. Wanigans left by the winter sled trains were used for working and messing.

The gravity-meter party went to Simpson on 9 June and worked until 1 September. LT Frank K. Fish was in charge, and the party included 12 other men. Because of the rapid rate of change of the magnetic gradient, precise location surveying was required. Eleven triangulation stations and 636 gravity stations were located. Some delay was occasioned by the necessity of replacing the gravity meter from Houston, Tex., which took from 23 July to the middle of August. Corrections for drift, latitude, and elevation were applied to the observed gravity values.

The work indicated a gravity high extending eastward all the way across the peninsula from Dease Inlet to Smith Bay. An anomaly north of the camp was selected to localize the area for the core drill and the seismograph.

The seismograph work was under the supervision and liaison of LT Ernest Marti. The party chief was J. A. Legge, of the United Geophysical Co., which did the work under contract NOy–11701. It was found that the drill could not make a large enough hole for the required dynamite loading, and another rig was required to drill the 5-inch shotholes. At the end of August the party moved to Barrow and made one refraction shot for basement control. The party had completed a reflection seismic study of the western third of the Simpson peninsula.

The seismic work demonstrated the applicability of the method to the coastal-plain area, and studies thenceforth were directed toward determining the most expeditious method of operation, the relation between seismic and gravity results, and obtaining as much subsurface information on the area as was possible. Shooting went on from 6 June to 30 August. Altogether 317 profiles were obtained for a total length of 26 miles. The best depth for the holes was found to be between 50 and 60 feet. Because the ground was frozen, almost all holes could be shot as many times as desired without damaging the hole and causing any appreciable loss of energy. Permafrost caused no special difficulty but did result in readings for high-velocity material at the ground level.

Three horizons were mapped, all of them showing a northeast-trending high. The seismic axis of this high corresponded closely to the gravity axis. The basement, at a depth of about 7,500 feet, appeared to dip southeasterly. This was consistent with the result of the refraction shot at Barrow that indicated the basement there to lie at about 4,300 feet.

Both the seismic work and the gravity-meter work demonstrated the need, if those types of work were to continue, of more adequate transportation facilities and portable camps. Oil was found in the Simpson area at a depth of 75 feet in shothole 53, and gas forced the abandonment of shothole 54.

At Umiat four electrical surveys were run on Umiat test well 1; one on 26 July when the hole was 564 feet deep and the last on 16 September when the hole was 1,816 feet deep. The results indicated the Schlumberger surveys would be valuable in Pet 4, but similar attempts at Cape Simpson modified this indication somewhat. The logs differentiated the various strata and distinguished the more permeable from the less permeable zones. In general, the resistivity values were higher than elsewhere in the world for similar strata, and the differences in potential, less than elsewhere. Permafrost apparently caused no difficulty, and there were no unusual electrical or magnetic disturbances.

Two Schlumberger surveys at core test 11 in the Simpson area—one when the hole was 440 feet deep and one after its completion at 580 feet—showed that permafrost included strata of both high and low resistivity and that electric logs did not reveal permafrost boundaries. The electric logs could not be correlated with the geologic logs. Attempts at electric logging of other core tests were unsuccessful because ice on the walls of the holes masked boundaries and damped the potential curves. The conclusion was that successful electric logging would require elimination of ice.

Temperature measurements, using electrical resistance elements, were made in Umiat test well 1 between 24 and 27 September. That was about a week after drilling had ceased. The hole was bailed dry to 800 feet and casing set at 685 feet had been cemented to the surface. It was concluded that permafrost extended to about 600 feet below the surface (later it was determined that permafrost actually extended to about 920 feet) although it was difficult to correct accurately for the heat released by the setting of the concrete. This was corroborated by Lieutenant Williams' observations of drilling-mud temperatures. Nevertheless, it was believed that the casing was set well below the base of permafrost.

It had been predicted that permafrost at Simpson would extend to about 130 feet. The obtaining of frozen cores from below 500 feet showed that the prediction was in error, but no additional temperature data were obtained.

DRILLING

Umiat test well 1 is a short distance south of the axis of the Umiat anticline and a short distance west of the high point on the structure. It is about 7 miles west of Umiat camp and airstrip. (See pl. 3 for locations of drilling in 1945.) A National 50 rig with a 96-foot cantilever-type mast was used for drilling. Rigging up

began in the latter part of May. The conductor hole was completed on 16 June, and a 24-inch conductor pipe, cemented by hand, and the hole was spudded in on 22 June. Water came by pipe from Seabee Creek about 1,800 feet away. Some difficulty was met in keeping circulation and cementing casing, partly because it was necessary to heat the mud with a steampipe while the cement was setting.

On 1 July drilling was suspended until a geologic check of the location was made. The location had been moved slightly to a spot more favorably situated topographically. On 14 July the location was confirmed, and drilling recommenced. Continuous coring and reaming proceeded to 685 feet where 11¾-inch casing was set on 4 August. At 1,213 feet the threads on the last drill collar were found to be faulty, and continuous casing was necessary thenceforth. A deviation of as much as 4½° was recorded at 1,600 feet. On 16 September the creek was nearly dry, and because 200 barrels of water per day was required for drilling, the drilling was terminated at 1,816 feet.

Continuous coring of the hole had been planned originally, but in August instructions were changed to require the coring of lithologic breaks only. Of the 1,816 feet of hole, 1,127 feet actually were cored. Advance experiments in cementing casing indicated the advisability of keeping the cement warm during its setting period and of waiting an unusually long period before drilling out the plug. LT Ralph Coleman, petroleum engineer on the well, recommended the use of a high early-strength cement in future drilling. The mud engineer on the well was LT Fred B. Williams.

Bedrocks are not exposed at the surface in the Simpson area. Therefore, all information on the rocks was from general geologic inference, from the presence and distribution of seepages, and from the geophysical investigations. The Simpson core-drilling program was designed to determine the underground lithology, stratigraphy, and structure, to test the geophysical results, and possibly to yield information on the presence or absence of petroleum accumulations.

CWO Don H. Meek was in charge of the drilling. LTJG J. S. Templeton was geologist on the first 6 holes, and LTJG G. O. Rolf, on the last 6 holes. A Failing rig was used. Permafrost gave a great deal of trouble, and much was learned about drilling in such permafrost areas.

Between 25 and 29 June, Simpson test 1 was drilled to 116 feet. Circulation was largely unsuccessful and the hole caved badly. The pipe was finally pulled, and the hole, abandoned. Core test 2 was drilled between 30 June and 2 July. Casing was carefully frozen in to 76 feet. At 226 feet the drill rods were frozen in, and fishing was unsuccessful. The hole was abandoned.

All remaining holes were drilled with a conventional core barrel. A great deal of ice complicated the drilling of core test 3. The drilling penetrated to 368 feet between 3 and 7 July. Ice bridges formed, and repeated reaming was necessary. Ice shavings clogged the pump. Three joints of pipe were lost and froze in the hole. The hole was abandoned because it was impossible to pull the pipe loose.

Simpson core test 4, drilled between 8 and 10 July, was 151 feet deep. At 120 feet a coal bed was found that, it was hoped, would constitute a key horizon. The coal bed was not found in core test 5, which was drilled on 11 and 12 July to 130 feet, or in test 6, which extended to 149 feet on 12 and 13 July. Core test 6 yielded some gas, but the cores contained a little oil.

Between 15 and 25 July, Simpson core test 7 was drilled to 532 feet, by far the greatest depth of any core test to that date. A great deal of ice formed in the hole, especially in the upper part, and ice shavings caused pump difficulties. After reaming at the final depth, which was determined by ice conditions, the hole was made available for Schlumberger and seismograph studies.

Icing problems were not as great in Simpson core test 8, which was drilled to 580 feet between 27 July and 3 August. Oil-bearing sands extended from 65 to 210 feet in the hole, but the oil did not drain into the hole. Ice conditions were very bad in test 9, and it was practicable to reach only to 320 feet, which point was attained on 7 August. Core test 10 was drilled to 500 feet between 8 and 15 August. Ice in the hole caused abandonment.

Between 17 and 26 August, Simpson core test 11 was put down to 580 feet. There was virtually no difficulty with ice, and the geologic section was different than in the other holes. The last core hole, test 12, was half way between tests 10 and 11 and was completed on 29 August at 460 feet. The geologic section could not be correlated with either test 10 or test 11. Few cores were taken in test 12, for there was urgency to complete the drilling program in order to get the personnel out by float plane before the lakes froze.

The locations of all the core tests are shown on figure 23.

Core tests 1, 2, and 3 were all in the same vicinity and represented an attempt to get one sufficiently deep hole. Nos. 4, 5, and 6 were in a triangular pattern to determine local dip. Lithologic changes between holes are so marked that the holes were largely unsuccessful in the purpose for which they were drilled.

Oil-bearing sands, believed to be correlative, were found in Simpson core tests 8, 9, and 10. Also shotholes 53 and 54 about 1½ miles farther west revealed

showings of oil and gas. It was believed that the oil had migrated from sands through faults and fractures only to become trapped beneath and in the permafrost zone. The presence of seepages seemed to be consistent with this concept. Attempts at correlations from hole to hole appeared to confirm the seismic indication of a general southerly dip of about 1°.

Simpson core test 10 was on a structural nose as indicated by the seismograph. It contained the best oil showings and appeared to have penetrated an oil trap caused by faulting. The fact that core test 11 could not be correlated with 10 was inexplicable and

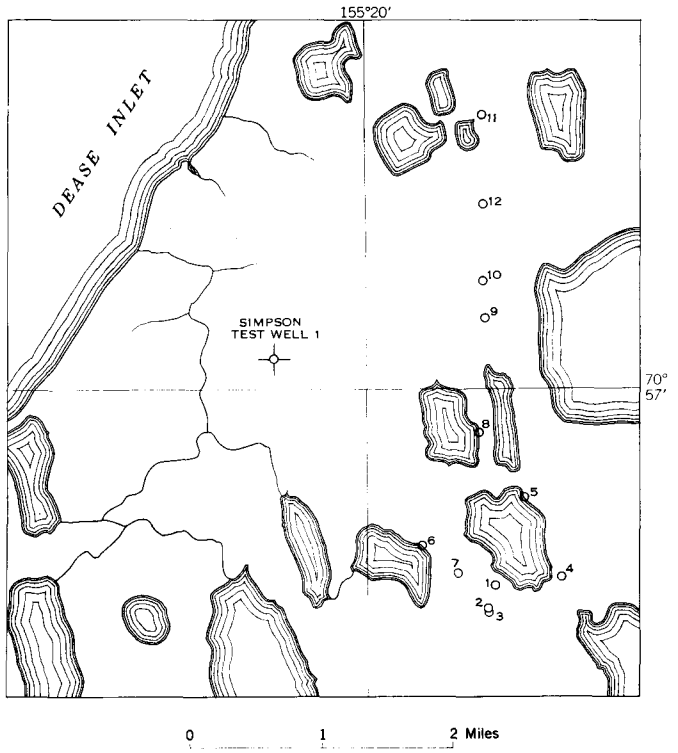

FIGURE 23.—Sketch showing locations of core tests drilled in the Cape Simpson area in 1945.

finally was interpreted as being the result of some rather unusual faulting. Test 12 gave additional credence to this special fault interpretation.

OTHER ACTIVITIES

Interest and collaboration in other activities going on in Arctic Alaska were always a part of Pet 4. Some of those other activities had no relation to Pet 4, but others, such as hydrographic and control surveys by the U. S. Coast and Geodetic Survey, were rather closely related. The additional activities became substantial enough to note in 1945 and increased rapidly after that year.

A Coast and Geodetic Survey party under Lieutenant Commander Woodworth charted the Barrow and Dease Inlet coasts from June through September 1945. The results were valuable in planning and carrying out the annual ship expeditions.

On 31 July 1945 the Royal Canadian Mounted Police supply vessel *St. Roch* rounded Point Barrow close in and continued on eastward. Most of the ice on that date was several miles off shore but not far enough to permit passage of large ships.

A station of the U. S. Weather Bureau was in operation at Barrow village in 1945, but local weather differences between the village and the airstrip at the Navy camp were great enough to require a Navy aerological station at the camp on a 24-hour basis. In May a similar station manned by 5 enlisted men under 1 officer, was installed at Umiat.

The U. S. S. *North Star*, the ship of the U. S. Bureau of Indian Affairs used for supplying native villages along the Alaskan coast ran aground in attempting to reach an anchorage off Barrow village. After discharging cargo the ship floated free and departed for Wainwright on 14 September. The previous year the Navy had helped in unloading the *North Star* thus assisting in alleviating a serious food shortage at the village.

In 1945 help was given to the Bureau of Indian Affairs, which was sponsoring the mining and hauling of coal to the village of Barrow from a small mine on the Meade River. The principal assistance was in upkeep and repair of mechanical equipment. A serious influenza epidemic struck the native village in February 1945—Eskimos are especially susceptible to such communicable diseases. At one time almost all of the inhabitants of Barrow were ill. The Navy assisted in equitably distributing the limited fuel oil available to the village. In addition, surplus food at the Navy camp was cooked, frozen, and distributed in the village. An oil burner was installed by the Navy in the native hospital at the village, and the NCBD 1058 medical officer, Lieutenant Commander Mackoff, contributed his personal services unstintingly.

SUMMARY OF 1945

At the conclusion of the 1945 season, the status of Pet 4 was reviewed by Admiral Moreell. An extraordinary amount of information had been gained on arctic operations. The practicability of tractor-drawn sled trains for hauling large tonnages long distances in midwinter had been demonstrated. Much had been learned about the special problems of drilling in the far North. The ship expedition had been very successful, and the air support problems had been largely worked out. The pattern of the bedrock geology as revealed by surface work, geophysical investigations, and drilling was be-

ginning to fit together. And, in addition to the physical accomplishments, great progress had been made toward converting from a Navy to a civilian-contractor operation.

Errors had been made, but most of them were corrected. Especially important was what had been learned about ice conditions at Simpson and how to drill successfully in spite of those conditions. Extensive and careful records had been kept so that advantage could thenceforth be taken of the knowledge gained.

Another quotation from the reminiscences of Bart W. Gillespie (personal communication) summarizes his recollection of the second year of Pet 4.

> When the final score is added up and someone has the curiosity to ask just HOW things happened during the period from August 1944 to August 1945 much space must be taken to detail the great contributions made to this job by the Alaska Communications System, AACS, Army Transport Command, Army Air, Cold Weather Test, Ladd Field, the Alaska Scouts, Naval Air Transport Service, and Civil Aeronautics Authority.
>
> The Alaska Communications group under Col. Andrews, was responsible for communications between Barrow Camp and Fairbanks almost immediately and this same group with CAA and AACS at Ladd Field and Anchorage combined to install the first radio aids to air navigation almost as soon as the Sea Bees had laid out a runway and planes were coming in for landings on the steel matted surface.
>
> The Army Transport Service moved emergency equipment to Barrow and soon Cold Weather Test was making Barrow on almost scheduled flights, training its pilots and at the same time doing a great service for the Sea Bees. In less than six months these various services had added a great amount of security to the long flight from Fairbanks to Pt. Barrow. By May of 1945 Pt. Barrow was equipped with radio beacon and range station with light beacon and the runway which had been equipped with very weak temporary side lights was changing over to powerful Bartow lights.
>
> Naval Air Transport Command VR5, under direction of Cmdr. Henry Hollenbeck, rushed the winterizing of twin engined Douglas transport cargo planes, and supported the operation during the winter months between Fairbanks and Pt. Barrow.
>
> Then in May, to assure success of the first operation at Umiat, planes shuttled 1,400,000 pounds of materials from Pt. Barrow to Umiat making landings on an ice covered lake kept smooth by use of a tiny tractor the story of which should become a legend of the north.
>
> Again I repeat, nothing is impossible in the north. Planes today properly winterized can, if necessary, take off with ground temperatures at 50° below zero and fly with no particular difficulty under such conditions. But NATS of 1944–1945 and ATC (Air Transport Command) for that matter, had yet to learn that which today permits such flying.

THIRD YEAR—1946

GENERAL PLANNING AND ADMINISTRATION

With the change of Pet 4 from a Seabee to a contract operation, Commodore Greenman, DNPR (Director, Naval Petroleum Reserves), wisely concluded that for proper planning and administration of such a highly technical operation, and one in which such a variety of specialized interests was involved, it would be desirable to organize an advisory group of eminent specialists in petroleum development problems to assist in charting the course of Pet 4. Following his recommendation, the Acting Secretary of the Navy, John L. Sullivan, on 4 January 1946, approved the establishment of an operating committee to develop policies and provide plans for Pet 4. The committee and the organizations they represented were as follows: Commodore W. G. Greenman (chairman); W. E. Wrather, Director, U. S. Geological Survey; L. W. MacNaughton, representing the firm of DeGolyer and MacNaughton, petroleum advisors to the Secretary of the Navy; LCDR F. A. F. Cooke, Bureau of Yards and Docks; and A. A. Curtice, Arctic Contractors.

The operating committee met for the first time on 5 January. Several other interested officers and civilians attended in addition to the committee members. The principal agenda items were (1) to familiarize the committee with the general plan of exploration as approved by the Secretary of the Navy, (2) to review the geological and geophysical data accumulated to date by the field parties, (3) to map a plan of procedure for the continuation of Pet 4 with funds available, and (4) to map future plans contingent upon the appropriation of additional funds.

Thus was initiated the guidance of Pet 4 by the operating committee, a pattern that, although not entirely without criticism from time to time, did result in a sound and practicable program.

At its first meeting and after carefully reviewing the information available, the committee came to the conclusion that there was sufficient favorable evidence to justify the continuation of Pet 4 along the lines approved by the Secretary of the Navy. The committee recommended that the contractor maintain and operate the Barrow and Umiat camps, complete the landing strip at Umiat, finish drilling Umiat test well 1, move the rig at Barrow to Cape Simpson, continue seismic work in the Cape Simpson area, make a gravity survey near Point Barrow, make seismic observations in a line over a supposed structural high then called the Meade-Inaru arch, run another seismic line from the Simpson area to Umiat, and provide logistic support to three Geological Survey field parties in the summer of 1946.

The committee recommended that the Geological Survey continue fieldwork, undertake the interpretation of aerial photographs and ultimately produce an aerial mosaic of the Reserve, initiate the study of well cores and cuttings, start and maintain an interpretation of geologic information including the correlation of all geologic data, and establish and maintain a laboratory in Alaska to supplement fieldwork.

The contractor, after the operating committee meeting, was instructed to proceed along the lines recommended by the committee under the authority of the letter of intent until such time as the contract could be signed and put into effect. The Survey, under the agreement between the Secretary of the Navy and the Secretary of the Interior, was authorized to proceed, and the required funds were transferred.

Under the letter of intent as prepared by the Bureau of Yards and Docks and accepted by the contractor, obligations could be incurred with the approval of the officer in charge of construction, and reimbursements could be made just as if the contract had been signed on 17 December 1945, the date of the letter. This authority was until 1 April 1946 and was later extended to 1 May, then 1 June, and eventually to 1 August. Actually, the contract was signed on 20 June 1946. It was a cost-plus-fixed-fee negotiated contract as authorized by the First War Powers Act, 1941. The contract provided for the expenditure of approximately $2,125,000, of which $1,175,000 was in government-furnished material and equipment and which included a fee of $120,000.

Following the acceptance of the letter of intent of 17 December 1945, Arctic Contractors began to set up its organization to do the job. Arthur F. Daily was appointed project manager and Clarence Moriarty, assistant project manager. Herman Reichman became project superintendent and Ted C. Mathews, assistant project superintendent. Many of the key positions were filled with recently discharged Navy men including LCDR Baxter Goodrich, chief engineer and supply supervisor; LT Ross Nelson, assistant engineer and assistant supply supervisor; LT Ralph Coleman, chief petroleum engineer; LT Don Jopling, geologist. Bart Gillespie, now a captain, was scheduled to become project manager on his anticipated release from the Navy.

The project superintendent arrived in Fairbanks on 26 December 1945, and on 17 and 18 January 1946 he inspected the Barrow facilities in company with Mr. Mathews.

When it became apparent that the resolution of problems of wage and salary schedules and other matters would delay the signing of the contract, the contractor decided to proceed with an employment program so as not to inhibit the necessary winter activities, principally the winter freighting. Personnel required in the preparation for the sledding began leaving for Barrow in late January; they were closely followed by the camp-maintenance personnel. The contractor established a procurement office at the naval station in Seattle on 7 January, and on 28 January the home office of Arctic Contractors was activated in Fairbanks, Alaska.

Between 19 and 21 January, conferences were held in Pasadena, Calif., through which it was decided that a lump-sum subcontract would be awarded to the United Geophysical Co. for the geophysical work required as a part of Pet 4.

On 26 January a conference was held in Fairbanks, Alaska, between the contractor and the Navy to discuss fully the broader phases of Pet 4. Both Arctic Contractors and the United Geophysical Co. were represented. The Navy representatives included Rear Admiral Trexel, Commodore Greenman, Commander Koon, Lieutenant Wolfstein, Commander Bettens (NATS), and Captain Fitzgerald, the Chief of Staff for the Commandant, 17th Naval District. On 28 January the party went to Barrow, inspected the facilities, and discussed the change over to a contractor operation with Lieutenant Commander Davis.

By this time NCBD 1058 had been reduced to 5 officers and 107 men and was scheduled for deactivation by 1 March. However, a small force of NCBD 1058 remained after 1 March to straighten out technicalities regarding transfer to the contractor of materials and supplies, and it was not until 14 March that the naval unit actually was deactivated. On that date, Lieutenant Commander Davis, OICC, was relieved by Lieutenant Wolfstein, who became resident officer in charge of construction on Naval Petroleum Reserve No. 4. On 1 March the contractor force included 120 persons, 3 of whom were in Seattle and 9 in Fairbanks. By the end of March the number had increased to 159, including 18 men for gravity-meter work. Bart W. Gillespie, after his release from the Navy, reported on the job in March, and on 8 April he replaced Mr. Daily as project manager. On 1 April CDR P. W. Roberts relieved Commander Koon as OICC.

By 28 April Assistant Project Manager Moriarty had finished his work, and his employment was terminated. Chief Engineer Goodrich was relieved in May by John Dallerup. E. D. Spaulding became assistant chief engineer. Stewart Folk was appointed technical advisor to the officer in charge of construction.

The second meeting of the operating committee was held in Washington, D. C., on 28 May. Two main problems were considered—a review of the plans made at the January meeting in the light of what had transpired through the winter, and consideration of a long-range plan for continuation of Pet 4. The latter problem was urgent as a $9.6 million appropriation item was under consideration. The item at the time of the meeting had passed the House of Representatives and was before the Senate.

Final reports of the 1945 activities were presented to the committee. Mr. Gillespie, the project manager,

reported that the field operations, except for a few suggested modifications, were ready to proceed in January as planned. The committee approved the procurement of a rig capable of drilling to greater depths than either of the two larger rigs then on the Reserve. There was substantial interest in the committee in expanding the geological and geophysical programs beyond the work planned in January, but Mr. Gillespie showed that it would be impossible because of logistic limitations. He pointed out that anything except minor changes in the program would generally have to be known a reasonable time in advance to permit adequate preparations. This kind of advance planning, by experience, soon became routine in the operating committee. The obtaining of seismic profiles of the Umiat anticline, over the "Meade-Inaru arch," and of the Simpson-Umiat line was described as impracticable and was canceled by the committee for the time being.

On 6 May change order A was added to the contract. It provided for the procurement of oil-field materials, supplies, and equipment for the 1947 operations at an estimated cost of $150,000 of which $750 was the contractor's fee. Meanwhile, materials for Barex '46 were being procured principally from the Seattle office. Market conditions were difficult, and the badly needed additional tractors were especially hard to obtain.

Already, after only a few months operation, Arctic Contractors had become a well-knit operating organization. The process of development was speeded, no doubt, by the previous rugged experience of the Arctic winter.

An inspection of the Reserve and of the operations in the field was made by the operating committee between 18 and 20 June, inclusive, and a few modifications of plan were suggested. The first of these modifications was for an additional gravity-meter party to operate in the general region between the lower Ikpikpuk River and the Colville in two areas designated as east Ikpikpuk and west Sentinel Hill. The second was for the Geological Survey party on the Meade River to map folds near the gas seepages near the head of the river in detail and then study the outcrops along the river northward. Following that suggestion, a rapid reconnaissance by George O. Gates, who had been designated as the head of the Geological Survey activities in regard to Pet 4, indicated its impracticability, and the project was carried through as originally planned. The third modification proposed by the committee was that a seismic survey of the east end of the Umiat structure be made in the fall of 1946. That end of the Umiat anticline is obscured by the river and extensive gravel terraces, and only by geophysical means could the nature of the anticline there become known.

On 26 June contract change order B provided for the purchase of more supplies and equipment in the estimated amount of $300,000 including a $1,500 fee. Later, change order C in the estimated amount of $200,000 was required to cover additional expenses over the estimates. This change order did not alter the scope of the contract.

Early in the summer of 1946, E. H. Farrar, former LCDR in the Civil Engineer Corps, was engaged as procurement agent in Seattle as it was becoming apparent that this would be a full-time job. Employment conditions generally were good in Fairbanks, but there was a serious shortage of housing for employees, and especially deficient were accommodations for persons passing through Fairbanks to and from the Reserve.

As the contractor was unsuccessful in obtaining a physician for Pet 4, medical services in the Reserve were rendered by a Navy corpsman and periodic visits of an Army doctor. An attempt was made to employ Eskimos applying for work, but tuberculosis among them was very common, and only 13 were found physically fit—they were employed.

By August there were 175 men at Barrow, 60 at Umiat, and 30 at the site of Umiat test well 1. About 75 men in addition made up the geophysical crews. Contractor personnel comprised about 250.

At the end of August the buildings on Garden Island, at the edge of Fairbanks, were transferred to Pet 4 by the Army and became the Fairbanks headquarters of the program. The facilities were occupied by Navy, Arctic Contractors, United Geophysical Co., and Geological Survey personnel. In the Reserve at that time between 6,000 and 7,000 meals were being served weekly.

On 18 September change order D was signed. At an estimated cost, including fee, of $30,000 it provided for the purchase of 30 jamesway huts and incidentals.

During the summer it became generally agreed that a coordinator of all exploration data would be a desirable addition to Pet 4, and Walter A. English was engaged in that position and as an advisor to the DNPR. Mr. English attended the fifth meeting of the committee that was held in Washington, D. C., between 6 and 8 November. By that time the requested budget of $9.6 million had been appropriated for Pet 4 for the period from 1 July 1946 to 1 July 1950. At that meeting Mr. Gillespie reviewed the operations and stressed arctic working conditions. The OICC, CDR P. W. Roberts, reviewed the financial status of Pet 4. Geological Survey party chiefs, and special-study workers described the results of their projects, including the airborne magnetometer survey. Gerald FitzGerald, chief topographic engineer of the Geological Survey, outlined the status of aerial photography of the Reserve and the mapping from those photographs. John Legge, of the United

Geophysical Co., summarized the seismic and gravity-meter work of his company.

After careful consideration the committee recommended that in 1947 the Geological Survey send 4 field parties to various parts of the Reserve and surrounding areas and 1 air-supported party to the east Ikpikpuk area. Greater emphasis was to be placed on stratigraphy and lithology and less on detailed structural mapping. The compilation of planimetric and topographic maps from aerial photographs was to be continued, and the needs of the field parties were to determine priorities.

The United Geophysical Co. was to check by gravity-meter survey the Skull Cliff vicinity, where an oil seepage had been reported, and the magnetic anomalies near Smith Bay, west Sentinel Hill, and Fish Creek. Two seismic crews would operate in the Smith Bay and Ikpikpuk areas.

The contractor would maintain camps and facilities and would support all field projects. Drilling would include a deep test on a location determined by seismic means near Cape Simpson, and core holes would be drilled at Skull Cliff, Point Barrow, Smith Bay, south Sentinel Hill, Umiat, and east Ikpikpuk.

The committee recommended the appointment of a chief technical advisor to the OICC. Change order E was dated 2 December 1946 and covered the planned program of the contractor at an estimated cost of $4.5 million including a $200,000 fee.

At the end of 1946, the principal administrative officials for Pet 4 were—

For the Navy:
- Commodore W. G. Greenman, DNPR, Washington, D. C.
- Walter A. English, advisor to DNPR
- CDR P. W. Roberts, OICC, Fairbanks
- LCDR A. N. Wolfstein, ROICC, Barrow
- CDR R. F. Duelfer, ROICC, Seattle
- E. B. Evenson, chief Navy auditor, Fairbanks
- Stewart Folk, technical advisor to OICC, Fairbanks

For the Geological Survey:
- George O. Gates, geologist in charge, Geological Survey, Navy Oil Unit

For Arctic Contractors:
- Bart W. Gillespie, project manager, Fairbanks
- E. C. Peterson, chief accountant, Fairbanks
- Herman Reichmann, project superintendent, Barrow
- Ted Mathews, construction engineer, Barrow
- Ralph Coleman, chief petroleum engineer, Barrow
- Don Jopling, chief petroleum geologist, Barrow
- Don Meek, drilling superintendent, Barrow
- John Wood, office manager, Barrow
- John Dallerup, chief engineer, Seattle
- Drex Spaulding, assistant chief engineer, Barrow
- William Fackler, office engineer, Fairbanks
- Emory Farrar, purchasing agent, Seattle

For the United Geophysical Co.:
- John Legge, geophysical supervisor, Fairbanks and Barrow

OPERATIONS

WINTER FREIGHTING

The inspection of facilities on the Reserve by Reichman and Mathews in January had disclosed that considerable repair and conditioning of equipment would be necessary in preparation for the winter sledding that had to get underway shortly if the plans were to be carried out. Some of the tractors at Umiat could not make the trip to Barrow under their own power and had to be hauled back for overhauling. Parts were scarce because some badly needed replacements had not been included in Barex '45. Required lubricating oils had to be flown in to supplement the supply on hand.

The first group of the contractor's employees reached Barrow by Army plane on 23 January, and some of them were immediately assigned to conditioning equipment. By 7 February a sled train of 5 sections was made up for Umiat and departed. This was almost on the eve of one of the worst storms in years which caught the train on the Ikpikpuk River on 9 February. The gale, which lasted a week, reduced visibility practically to zero, piled up large drifts of sand and snow, and made progress impossible during the storm. Even after the storm, bulldozing the drifts was difficult all the way to Umiat.

The first section opened the trail and carried the living and messing quarters and the shop wanigans. The remaining sections carried the payload of fuel oil, and each sled carried between 30 and 60 tons. In spite of their violent introduction to the Arctic, the physical condition of the men was good, and their morale was high.

An early innovation of the contractor was the scouting of a winter hauling route to Umiat via the Arctic Ocean to Teshekpuk Lake, across the lake to the mouth of the Colville River, and thence up the Colville to Umiat. This scouting, justified on the experience of 1945 that overice hauling was easier, was done by an Eskimo guide and two men in a weasel. A much easier route was found with very little overland hauling.

Overhauling and conditioning of equipment went on rapidly at Barrow during February in preparation for hauling to Simpson and the sending of a second train to Umiat. Preparation of wanigans for geophysical operations was also started at Barrow. The freighting problem had been greatly intensified by the substantial raising of the requirements for Cape Simpson and Umiat. Therefore, it was decided to attempt hauling to Simpson with trucks rather than with tractors, supplemented by M4 tanks pulling Athey wagons.

This operation was started on 20 February and was reasonably successful although the maintenance cost was very high—far in excess of tractor hauling. Bull-

dozers and a motor patrol kept the trail open. On 25 February two Athey wagons broke through fresh ice covering a crack in the ice of Dease Inlet. The ice was nearly 5 feet thick over 5 feet of water. A tractor sent to help also broke through but was finally able not only to extricate itself but also to pull out the Athey wagons. Two days later other Athey wagons broke through a similar crack off Christie Point and had to be unloaded before they could be pulled out. It also was necessary, in order to keep the trucks running, to lay 100 feet of pierced plank over an especially bad section of trail. All the required fuel and gasoline were at Simpson by 21 March, and subsequently, oil-field equipment and supplies were hauled.

After the first train for Umiat was on its way, the few available men rapidly assembled a second train, also of five units and including a 250-ton fuel payload. The ocean part of the new trail via Teshekpuk Lake had been flagged by weasel, and the new train left Barrow on 22 February. The weather was still adverse; nevertheless, the second train reached Umiat in less than 9 days and a few hours ahead of the first, which had required 24 days. In spite of the fact that the mapped distance by way of Teshekpuk Lake is much farther than by way of the Ikpikpuk, it was found that not only was the going easier but the traversed distance was actually 20 miles shorter because the Ikpikpuk trail was so crooked.

Both trains returned to Barrow, were repaired and reloaded, and again set out for Umiat by way of the Colville River on 13 March. The trains on that trip, which was in excellent weather, averaged 50 miles a day. Again the trains returned to Barrow and within 3 days were loaded and off on the third trip which left Barrow on 26 March. The good weather held, and the fourth trip reached Umiat on 15 April and returned on 20 April. The fifth and last Umiat trip of the season left Barrow on 22 April and reached Umiat on the 26th. One train returned to Barrow, and the other was disbanded at Umiat.

The winter freighting of 1946 also included the transfer of miscellaneous supplies to the Meade River area both by truck and by tractor.

The winter was an unusually hard one, and the pressure cracks in the ocean ice were larger and more abundant than in more normal years. Nevertheless, largely owing to the pioneering experience of NCBD 1058 in 1945, the freighting was outstandingly successful. In all, 2,530 tons of freight went to Umiat; 1,695 tons, to the rig site, seismograph camp, and Half Moon Three in the Simpson area; and 450 tons, to the Meade River area. The total payload freighting was 826,220 ton-miles. About two-thirds of the tonnage was diesel oil, gasoline, and lubricating oils.

Radio communication with the trains was unsuccessful, but a ski-equipped Wien plane made almost daily flights to check the trains' locations, deliver mail, and scout trail. Time lost on the trail for equipment repair was negligible. Some time was lost, especially in the early part of the season, because of poor visability caused by darkness and blowing snow.

AIR SUPPORT

The principal linehaul support during the winter of 1946 was by NATS using R4D planes. NATS averaged about 4 trips a week. This support was supplemented by flights from Ladd Air Force Base, principally planes of the Army's Cold Weather Test group planes. It was expected that NATS would be replaced by a commercial carrier under contract by 1 July. Bush flying in the Reserve, including contact with the sled trains, was by Wien Alaska Airlines assisted by one NATS Norseman stationed at Barrow. By the end of February, the backlog of freight and personnel at Fairbanks had been eliminated. By March, negotiations were in progress for air support by a commercial carrier.

During April the geological supplies were cached by Wien, assisted by E. J. Webber, geologist of the Geological Survey, using a ski-equipped Bellanca.

NATS R4D planes made many shuttle trips between Barrow and Umiat in May. At Umiat, landings were made on the frozen airstrip. This frozen runway was satisfactory until 15 June when it was closed to R4D's. Then was begun the task of extending and raising the level of the Umiat strip. It was estimated that this work would have the strip ready for large-plane use by 15 July, or at the latest 1 August, but it actually was completed ahead of schedule, and R4D's were using it again by the end of June.

During August, bush plane hauling reached a peak when Wien Alaska Airlines moved 60,000 pounds in 1 week from Barrow to Umiat. Ordinarily, the plane freighting within the Reserve was much less and generally intermittent.

The linehaul contract eventually was awarded to Wien Alaska Airlines in August and that company started operations between Fairbanks and Barrow on 29 August. At that time NATS withdrew. Cargo flights from Fairbanks to Barrow by Wien averaged about 15,000 pounds a month.

On 24 September a linehaul flight into Barrow by Wien's airline, using a chartered Lyle Airlines plane, was thrown out of control by violent winds during landing and was wrecked near the airport warehouse. The plane was so badly damaged that it was junked, but parts were salvaged in April 1947. There were no injuries.

BARROW EXPEDITION, 1946

As early as March, logistics studies were made and advance preparations for Barex '46 organized. In July began the work of carefully servicing the boats for use during the Barex landing operation. Six beaches for landing were laid out along the shore near the camp. The specific locations were selected for convenience to appropriate warehouses, storage areas, or place of use. On the south, beach 1 was for building materials; beach 2 was for food and commissary supplies; beach 3, near the center of camp, for general supplies; beach 4 for spare parts; beach 5 for oil-field equipment; and beach 6 for fuel oils and lubricants. Beach 7, several miles to the north at Point Barrow, was for emergency unloading in bad weather. Landing craft and propulsion units were checked, and electricians serviced all refrigerator units. During the loading of the ships, Mr. Mathews, who had been designated beach operations foreman for the contractor, was in Seattle. By early August all was in readiness at Barrow. The channel into Elson Lagoon had been deepened and widened to permit the passage of a fully loaded barge.

CAPT Leonard Frisco assumed command of Barex '46 on 27 June. On 17 July he inspected the beach and unloading facilities at Barrow, along with CDR Glen R. Whaley, beachmaster; CDR John Backlund and CDR William F. Hawley (U. S. Coast Guard), ice pilots. The party also observed the coast from Barrow to Point Lay, and the ice pilots predicted an early open season and favorable ice conditions.

From 8 July to 12 July, the U. S. S. *Muliphen* was loaded with 2,500 tons of drummed diesel oil and gasoline at Point Molate, Calif. She proceeded to pier 91, Seattle, Wash., and was virtually fully loaded between 16 and 23 July although miscellaneous items were loaded until the day of departure. Between 13 and 17 July, the U. S. S. *Algol* was loaded with 2,500 tons of petroleum products at Point Molate and then completed loading in Seattle between 22 and 29 July. Some commercial cargo was loaded to relieve the U. S. S. *North Star* of the Bureau of Indian Affairs of some of its overload. Some freight, deemed by the shipper to be essential, arrived late, and as a result both ships were loaded beyond normal draft and far beyond the limit for safe maneuvering at Barrow if ice movements required such measures. Loading was by commercial stevedores. John Dallerup had done an excellent job of procurement for the expedition. Also the port director's staff in Seattle was very cooperative in using all available space and in getting the ships loaded. Palletizing of the cargo had to be sacrificed to some extent.

On 23 July a conference was held and attended by representatives of all interested naval commands. Reports of Navy and contractor personnel indicated that all plans for loading, shipping, and unloading were fully coordinated.

The ships departed Seattle on 30 July and reached Dutch Harbor on 4 August. There the U. S. S. *Muliphen* loaded 21 tons of electronic equipment, and both ships took on some fuel. On 6 August the expedition left Dutch Harbor for Barrow with a total cargo of 11,600 long tons. No large ice was encountered until Point Lay was passed on 9 August, but by full use of the reconnaissance plane, passage was found without difficulty, and the 15-knot speed was retained until fog and much ice were met off Franklin Point. The plane was again used, and Barrow was reached on the afternoon of 9 August.

In maneuvering around Point Barrow in the advent of adverse ice conditions, a ship should not draw more than 20 feet, and 24 feet was the absolute maximum. The *Muliphen* arrived with a draft of 26½ feet, and the *Algol*, with 26 feet 2½ inches. Twenty-six feet was the maximum safe draft even in the safety area off the camp. Therefore, from an anchorage 1½ miles off shore, discharging was begun at once on a 24-hour schedule; within 3 days the ships had been lightened enough to safely negotiate these waters. A total of 19 LCM's, barges, and 1 LCS (landing craft, small) were used for lighterage. Only five of the beaches were needed for unloading.

Weather, except for heavy fog for part of the time, and ice conditions were exceptionally favorable. Large cakes of ice floated by but did not hamper operations. On the night of 12 August, the largest barges were ordered into the lagoon behind the beach because of rough seas which threatened damage to the barges on the beach as they were unloaded. Later they were put back into service by holding them broadside to the beach while they were unloaded. On 12 August both ships, without interrupting unloading, were moved in to the 7½-fathom line about a mile from the beach.

The job was done, and the ships departed on 15 August. The expedition was considered completed when the ships reached open water south of Cape Lisburne on 16 August. The overall unloading rate for the *Muliphen* was 39 tons per hour and for the *Algol*, 45 tons per hour.

The one serious accident that marred the expedition was the drowning of John Calvin Merritt, S2c (seaman, 2d class), USN, who fell from the sea ladder when boarding the *Muliphen*. He was recovered in 7 minutes but failed to respond to treatment.

The U. S. S. *North Star*, supply ship of the Bureau of Indian Affairs, arrived off Point Barrow on 8 Sep-

tember and unloaded 35 tons of frozen meat and butter consigned to the contractor.

AIRFIELD CONSTRUCTION

The muck and gravel runway at Barrow, overlain by pierced plank, had given good service and required little maintenance. At Umiat, the eastern 1,400 feet of the 3,300-foot runway had been laid on tundra and had to be abandoned. The remainder of the strip was extended westward 2,100 feet; and the grade of the whole strip, raised 1 foot above the old grade; and a 12-inch crown, added. This work was started in June and was completed by 1 August, with some time being taken out for the building of two small dams in Seabee Creek to impound water for drilling operations. During July the strip was used while construction was still going on. A total of 28,000 cubic yards of gravel was moved and placed to complete the job.

CAMP CONSTRUCTION

By 11 February the contractor had 60 men in the Reserve and 24 more awaiting transportation in Fairbanks. The contractor had taken over the power plant, boiler plant, water and fuel service, and other duties and had prepared five sections of a sled train for Umiat. Camp operations were handicapped by foul weather in the winter of 1946, especially by high winds between 9 and 16 February and by delays in arrival of freight and the personnel.

By 20 February, with the arrival of more employees, the contractor assumed additional duties. Every available man was required on airstrip maintenance at Barrow to remove drifts left by the recent storm and by continued formation of new drifts. On 29 March the machine and automotive equipment shop and adjoining carpenter shop were completely destroyed by fire. The loss was serious and included 8 weasels recently serviced for gravity-meter work, machine tools, and a portable machine shop. A temporary machine shop was set up in the heavy-duty-equipment shop, and the Bureau of Yards and Docks expedited the shipment of replacements by air from Port Hueneme. As a result of this serious fire, and other minor ones, a fire chief was appointed in April; water tanks with hose and pumps were placed in principal buildings; and a complete fire-alarm system was installed. In spite of these precautions, the transmitter building, beacon, and five transmitters were destroyed by fire on 6 June. The Commandant, 17th Naval District, immediately sent a radio-material officer, who installed temporary equipment. By fall a 24-hour fire watch was in effect and fire-fighting equipment consisted of a 2,500-gallon pontoon tank mounted on a tractor- drawn Go-Devil. Tanks holding 4,000 gallons, with hose and pumps, were at key points throughout the camp.

A system of warehousing and material control that had been recommended by the Bureau of Yards and Docks was put in operation in April and May. Later a usage history was initiated in warehousing for use in future procurements. In May, changes and adjustments were made in the electrical distribution system at the Barrow camp. This work was to improve radio reception and reduce electrical maintenance work. Electrical equipment and metal buildings were grounded to practically eliminate electrical interference to radios. During the year, radio buildings and antenna installations, according to CAA specifications, progressed at both Barrow and Umiat. The erection of antenna poles or tall poles for transmission lines, except on the beach sand, required the thawing of the permafrost with the use of a prospect boiler and steam point. Small poles were set in gravel-filled oil drums, and the drums were set in the ground to their tops in holes excavated by dynamiting.

At Barrow a complete fiscal inventory of material, equipment, and facilities was undertaken and scheduled for completion by 15 July. In August, work was postponed on a new bathhouse which was under construction in order to lay concrete slab foundations and start construction on four 40- by 100-foot warehouses that would be needed to house supplies to come in on Barex. After the expedition left, all haste was made to complete the warehouses. Much of the cargo lay on the beach in exposed positions, and it was rapidly inventoried and stored—some outside and some in warehouses. An underground refrigerator, excavated deep in the frozen ground, was under construction. Eskimos from Barrow had been employed in the beach unloading, and some were retained. A doctor, who had been flown in for the purpose, certified 22 additional natives as physically fit for employment.

At Barrow, in addition to the warehouses and bathhouse, an addition was built to the administration building. Foundation stringers were laid directly on leveled gravel. At Umiat a thick layer of gravel was present beneath the tundra. In some places foundations were laid on gravel and backfilled with moss to minimize thawing and settling. For large buildings at Barrow, concrete slabs were poured first, and foundation stringers were placed on them; or, for some buildings, the slabs formed the floor. Fortunately, gravel and coarse sand was abundantly available both at Barrow and at Umiat but not at most other places on the Reserve.

After Barex '46 winterizing and beaching of barges and boats was begun. Winterizing also proceeded on

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materials, equipment, and buildings, including further insulation of the messhall, and with special attention to winter freighting equipment and equipment for the planned extensive core-hole drilling. Drills and equipment were mounted on sleds and tractors, and sleds were overhauled and serviced. Material and supply stowage was completed in September, and the new generators were installed in the powerhouse. Items in outside storage that would be needed during the winter were blocked above ground.

Finally, both field camps and base camps were secured for the winter.

On 18 December the contractor's garage and warehouse in Fairbanks was completely destroyed by fire. The contents were a total loss. The Bureau of Yards and Docks moved immediately to provide replacements.

WATER SUPPLY AND SEWAGE DISPOSAL

Year-round water supply for the Barrow camp came from a fresh-water lake near the camp. A tank, equipped with a pump and hose, in a heated wanigan mounted on an Athey wagon was used to haul water to various points in camp.

At Umiat, water was originally obtained in a similar fashion from nearby lakes or from the Colville River. In the summer of 1946 a small spring was discovered close to the camp. A shallow well was dug, and thenceforth water was piped to the camp. It was believed that a water well could be drilled that would supply camp water most of the year.

At Barrow bulk sewage and garbage were collected in oil drums and burned on the seashore or dumped on the ice. The waste on the ice went out each year with the ice. Insulated sewer lines from the kitchen and bathhouse provided for disposal of liquid sewage to the ocean. Sanitation was not a problem because of low temperatures, absence of flies, and the small population.

EQUIPMENT AND ITS USE

One of the early innovations of the contractor when he took over from the Navy operation was the replacement of light-weight lubricating oils used by the Navy with normal-weight oil. This was found to be feasible because engine operating temperatures were practically independent of the outside temperature and only a thorough warmup period was required. The change resulted in a great improvement in operating performance.

The large tractor was generally agreed to be by far the best piece of equipment for arctic sled freighting. The weasel (M29C), although hampered by its light, fragile construction both in body and in engine was a most useful item. Herman-Nelson heaters were dependable and invaluable for preheating engines and use in emergency repair jobs. All the sleds used gave excellent service.

During March the heavy- and light-duty-equipment repair shops operated on a 2-shift basis in order to keep the freighting equipment rolling. Rush repairs needed by tractors increased as the season progressed.

COMMUNICATIONS

ACS (Alaska Communication System, Signal Corps, U. S. Army) continued to handle radio communications to Fairbanks and Barrow as before. All installations of ACS communications and navigational aids in the Reserve, as well as weather-station facilities, were scheduled for ultimate transfer to the CAA, although the Army personnel was relieved and temporary operation of facilities was begun by the Navy in March. The CAA personnel finally took over in August. Work continued at Umiat and Barrow on improved facilities, including receivers, transmitters, and a radio range. The work on the range and on the transmitter and antenna parts of the CAA installation at Umiat was completed in December. Also in December the Barrow operations building and antenna were completed, and the blind-landing equipment was in operation.

AERIAL PHOTOGRAPHY AND MAPPING

In 1946 additional aerial photography was done by the 4th Reconnaissance Squadron of the Army Air Forces from Ladd Field. Progress was slow, however, because of adverse weather conditions, and on 29 September the project was discontinued because snow was rapidly covering the ground. The project was unfinished, thus necessitating the provision for additional photography in 1947.

The preparation of maps from the aerial photographs by the Geological Survey proceeded throughout the year, and the larger part of the area covered by the more recent photography was compiled by the end of the year. The maps covered all the areas where further geophysical work was contemplated but only a small part of the areas where geologic work was planned.

GEOLOGY

At the first meeting of the operating committee in January 1946, the general responsibilities of the Geological Survey were outlined as a part of the integrated exploration program. That charter enabled the Survey to organize and staff a unit especially designed to carry out the responsibilities assigned. George O. Gates was placed in charge of the unit, and he began at once to build an administrative nucleus, provide for office and laboratory work in Washington, D. C., establish and equip the required petroleum laboratory in Fair-

banks, plan field parties in detail and arrange for their coordinated supervision, and provide for special geologic studies as required.

Five regularly organized geological field parties were sent out in 1946. (See pl. 3.) The period of fieldwork was approximately 1 June to 1 September. The parties reached Umiat between the middle and end of May; consequently, they could be flown to field sites in planes on skis. All had returned to Fairbanks by 12 September.

Food and gasoline caches were set out by air along the planned routes of all parties in order to lessen the loads that had to be transported overland. A total of 38 such caches were established at estimated 12-day distances. E. J. Webber, geologist, was in charge of the caching. He arrived in Fairbanks on 27 March and procured and assembled the supplies, dispatched them to Umiat and Barrow, via NATS, and carefully planned the caching operation itself. A total of 17,000 pounds was involved, 9,000 pounds of which was food and the rest mostly gasoline.

Between 17 and 27 April, all supplies went out from Umiat and Barrow in a ski-equipped Bellanca, piloted by Sig. Wien, to prearranged locations. Mr. Webber accompanied the pilot and charted each cache on an aerial photograph. Preseason caching proved very effective and was employed every year after 1946.

Much was learned the first year about caching operations. Supplies should be packed in strong metal containers, such as gasoline drums, to protect the caches from bears. In 1946, 4 out of 7 caches on the Sagavanirktok River were completely destroyed by bears. Care must be taken to place caches high above the flood levels reached by the streams during the spring breakup. In 1946, 2 caches on the Meade River about 16 feet above normal river level were lost in the spring flood.

Bush-plane support during the season was supplied in a limited way and was found to be so effective that such support of geological field parties was continually expanded each following year. That sort of support permits occasional mail collection and distribution, provision of emergency or additional supplies, coordination of geologic effort by the supervisor, visits of specialists to parties as desirable, and the quick and efficient gathering of spot geologic information from widely scattered localities. Reconnaissance flights over an area were found to be especially advisable before the area to be studied in detail was finally chosen. Aerial photographs are very helpful but can be misleading as to the number of outcrops present. About a month of fruitless effort in 1945 could have been saved for the Anaktuvuk River party if the river could have been examined first from a plane flying at a low altitude. Reconnaissance flights can greatly increase the flexibility of operations. As originally planned for 1946, party 4 was to be flown to Kurupa Lake, at the head of the Kurupa River, after reaching the mouth of the Oolamnagavik River. A flight up the Kurupa at the time of the move showed that the river for about 20 miles downstream from the lake was too shallow for the boats. The party, therefore, was transported to a place below that stretch of shallow water.

The weasel was found to be a very useful means of transportation for geologic parties. In 1946, 1 party was furnished by Arctic Contractors with 1 weasel and a driver, and another party had 2 weasels. At the end of the season, it was pointed out that 1 weasel was not enough, there should be at least 2. One should be driven by a contractor employee who should serve as mechanic. The other could be driven by one of the Geological Survey personnel. It was recommended that emphasis be placed on caching sufficient gasoline for the operation of weasels for about 75 percent of the party season and also on the caching of sufficient spare parts.

PARTY 1

Party 1 systematically studied and mapped the Umiat anticline. The party was made up of two geologists, one of whom, Karl Stefansson, was the chief of the party; a topographer; a recorder; a cook; and a weasel driver supplied by Arctic Contractors. A closure was indicated of at least 500 feet, and probably several hundred feet more.

Much was learned about the stratigraphic column which, with the data from Umiat test well 1, permitted structural contouring. The base map was controlled by field triangulation and compiled by photogrammetric methods. Aerial photographs proved useful in the surface mapping.

PARTY 2

Party 2 was led by LT R. G. Ray, geologist of the office of Naval Petroleum Reserves on detail to the Geological Survey. The party included another geologist, an instrument man, a cook, and 2 contractors' weasel drivers, 1 for each of the weasels.

The party worked in the general vicinity of Maybe Creek, a headward tributary from the east of the Ikpikpuk River in an area bounded roughly by longitudes 153°30′ and 154°10′ west and latitudes 69°10′ and 69°25′ north. In most parts of the area, outcrops are sparse.

Three eastward-trending anticlines were mapped in part. The crest of the most southerly of the three structural features, the Maybe Creek anticline, is about 2½ miles south of Maybe Creek. The most northerly structural feature is a dome about 4½ miles north of Maybe Creek. It was named the Maybe Creek dome. The

third anticline, the Wolf Creek anticline (see fig. 12), lies between the dome and the Umiat anticline.

The same area was traversed by J. B. Mertie, Jr., of the Geological Survey, in 1924 and detailed work was begun there by a Navy party in 1945. The 1946 work involved a main weasel traverse route of more than 100 miles. As time ran short, the detailed work was dropped, but the stadia traverse was continued to the Kigalik River and structural and stratigraphic determinations made by the study of aerial photographs. Sandstone samples sent to the laboratory in Fairbanks had porosities ranging from 3 to 18 percent. The Maybe Creek anticline is 6 to 8 miles wide, but the length is unknown.

The Maybe Creek dome was found to be about 5 miles broad. It is on a major anticlinal axis on which at least two other structural highs were recognized but not studied in detail. Some coal was found north of Maybe Creek.

The Wolf Creek anticline trends N. 65° W. to N. 70° W. The north flank is better exposed. In general, surface data are very scarce, but aerial reconnaissance and aerial photographs indicated a closed structure 7–8 miles long and about 6 miles across.

PARTY 3

Party 3 was a small-boat party led by E. J. Webber The party started near the head of the Meade River and traversed the full length of that stream. From the mouth of the Meade the party followed the west coast of Admiralty Bay and the south shore of Elson Lagoon to Point Barrow. The party continued along the coast southwest of Barrow, up the Kugrua River for about 10 miles, along the coast to Wainwright, and 25 miles up the Kuk River. Aerial reconnaissance flights were made along the Usuktuk, Nigisaktuvik, and the headward part of the Topagoruk Rivers, but the bedrock exposures are so few that only a few landings were made.

Three eastward-trending anticlinal axes about 10 miles apart were recognized in the headward part of the Meade River. For about 18 miles northward from the axis of the northernmost anticline recognized, which is at about 69°42′ N., the structural data suggest the presence of similar, though gentler, open folds but fewer and poor outcrops did not permit close definition of the fold axes. Northward from that point the strata are nearly horizontal, and broad regional trends are more significant than local folds. About 20 miles south of the Meade River coal mine was found sandstone float containing material that may be petroleum residue.

At Skull Cliff, about 25 miles southwest of Barrow along the coast, a very light petroleum drips slowly from an 8-foot sandstone. The bed was traceable for nearly 25 miles, but petroleum was not found in it elsewhere although a seepage has been reported near the head of a gully about 1½ miles northeast of the Sina shelter cabin. The seepage is said to be readily visible in the winter.

Gas bubbling from beneath a lake near the head of the Meade River appeared on analysis to be methane or coal gas. The seepage is on the south limb of an anticline.

PARTY 4

Robert M. Chapman was chief of party 4. Robert F. Thurrell, geologist, was a member of the party. The party worked in an area of about 1,200 square miles between the Killik and the Kurupa Rivers.

A gas seepage on the south side of the Colville River about a mile above the mouth of Aupuk Creek was sampled. The gas was bubbling rapidly at about 18 places in a small lake near the river. A National Bureau of Standards' analysis later showed the gas to be methane. A major anticlinal axis (the Aupuk anticline, see fig. 12) coincides with the course of the Colville River between the Kurupa River and Aupuk Creek, and there appear to be two domes on the anticline although more work would be needed to estimate the closure. The gas seepage near Aupuk Creek is on the crest of the fold.

PARTY 5

George Gryc, chief, and E. H. Lathram, geologist, and party were assigned a stratigraphic and structural investigation along the Sagavanirktok River east of the Reserve (see fig. 24) as well as shorter studies along two small tributaries of the Colville between Ninuluk Creek and the Kutchik River.

The structure of the Upper Cretaceous rocks in the Sagavanirktok area is similar to that in the Colville area. Complex structure near the mountain front gives way to progressively less intense folding farther north, and near the Arctic coast the dips are less than 5°. No structures could be studied in detail in the time available although closed anticlines in the strata of Late Cretaceous age are believed to be present.

One of the two creeks south of the Colville between Ninuluk Creek and the Kutchik River was traversed by Gryc and the other by Lathram. The purpose of that work was to obtain information on the anticline south of the Prince Creek syncline. That anticline has since been named the Fossil Creek anticline (see fig. 12), and the easternmost of the two creeks is now called Fossil Creek. In general, the stratigraphic section appeared much the same as in the Prince Creek and Umiat areas. There appears to be a "saddle" in the anticline at the mouth of the more westerly creek and

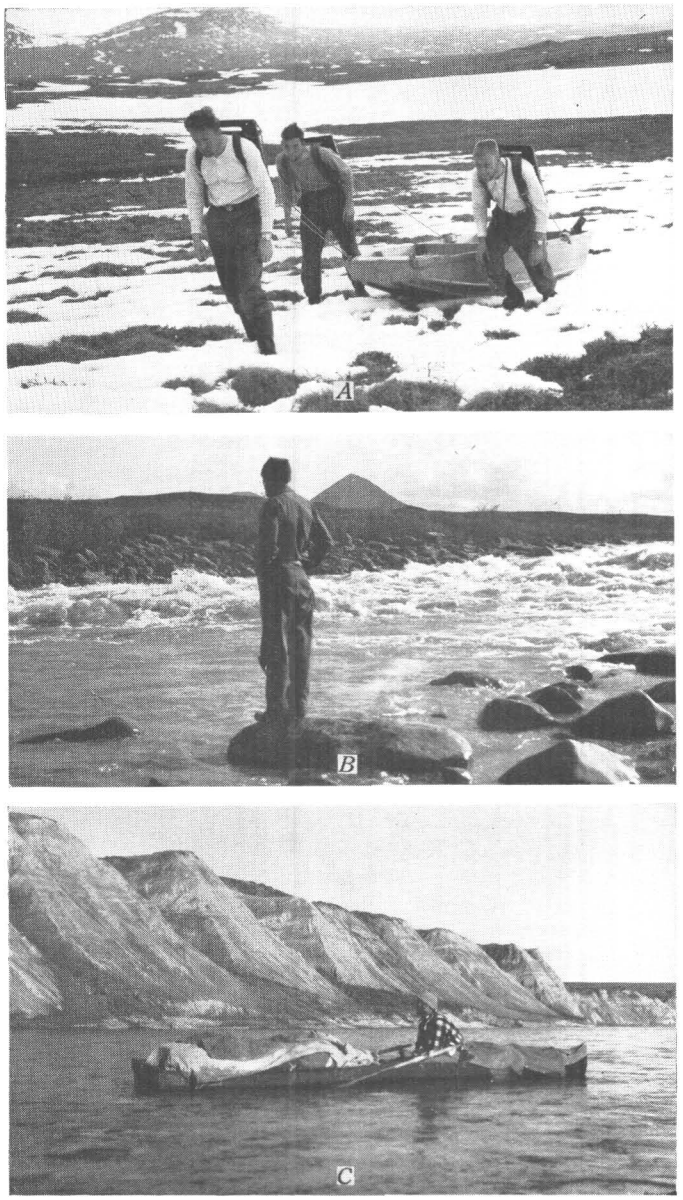

FIGURE 24.—Geologic party 5. *A*. Party dragging boat over tundra from landing strip on a lake to the headwaters of the Sagavanirktok River. *B*. Rapids where the Sagavanirktok River flows over the moraine of a former glacier. *C*. Tertiary sedimentary rocks exposed in Franklin Bluffs along lower course of the Sagavanirktok River. Photographs by Geological Survey.

a nose at the mouth of Fossil Creek, but whether or not there is a closure east of the nose where the trend of the axis bends southward is not known.

AERIAL GEOLOGICAL RECONNAISSANCE

In the summer of 1946 several reconnaissance flights were made in the southern part of the Reserve and adjacent areas by George O. Gates, Stewart H. Folk, and George Gryc to obtain information on areas most favorable for study by geological field parties in 1947 and to determine areas where structural and stratigraphic information is most abundant and especially where closures on anticlines may be present.

About 15,000 square miles was covered, and the experience proved beyond doubt the value of such aerial reconnaissance before sending parties into the field. Much was learned about the distribution of the rocks and the positions of structural axes. One result of the reconnaissance was the prediction that the area of the Kukpowruk, Kokolik, and Utokok Rivers could not be considered as a possible source of oil from Upper Cretaceous rocks. The flights showed also that, in the Cretaceous rocks in the Reserve, closures on anticlines are very difficult to detect from the air largely because the rocks near the crests of the anticlines are generally weak and do not crop out well.

The reconnaissance resulted in the following recommendations for areas within the Reserve to be studied by field parties in 1947: (1) The Kigalik anticline (see fig. 12), (2) the anticline between the Kigalik and the Awuna Rivers, (3) the Utokok River and, (4) the Ipnavik and the Colville Rivers between the Ipnavik and Kurupa Rivers.

HEAVY-MINERAL STUDIES

Robert E. Fellows and Ernest H. Lathram carried on studies of the varietal characteristics of detrital garnet grains contained in samples from some of the rocks. Their work indicated that garnet can be used to differentiate rock units of Late Cretaceous age. Further investigations were planned for investigating the possibilities of the use of heavy minerals in correlation.

PALEONTOLOGIC STUDIES

After the 1946 field season a comprehensive taxonomic and stratigraphic study was begun of the macrofossils from all collections from northern Alaska. The material at hand indicated four major faunal zones in the Upper Cretaceous rocks. The long range objectives of the macropaleontological work as defined were to (1) describe the fossils collected and establish their taxonomic positions as a tool for future stratigraphic work; (2) establish faunal zones for use in stratigraphic correlations; (3) determine the environmental conditions indicated by the faunal assemblages as an aid in the reconstruction of the geologic history; and (4) correlate the Upper Cretaceous rocks of northern Alaska with other successions as a basis for comparison with oil-bearing regions.

A good start was made toward the preliminary accomplishment of the objectives.

Microfossil studies also were begun in 1946; and although the results that year were too preliminary for

much application, a good start was made, and the future possibilities of the use of microfossils were clearly indicated.

UMIAT TEST WELLS 1 AND 3

After completion of Umiat test well 1 in October and after consideration of all available data, it was indicated that the test was 800 feet south of the axis of the Umiat anticline, about 5 miles west of the highest point on the axis, and 700 feet below the crest of the anticline. The rocks dip between 5° and 9°. The upper half of the hole is in a sandier zone than the lower 3,000 feet that penetrated clay shale and siltstone.

Traces of oil and gas were slight but consistent. The best showings were between 2,295 and 2,350 feet where samples gave strong oil and gas odors with good saturation.

The rocks were found to contain about 2 percent of montmorillonite-type clay which would be ample to swell by hydration and further reduce porosity and permeability. In general, the rocks are not good reservoir rocks, but the consistent indications of petroleum were encouraging.

It was concluded also that Umiat test well 3 (first called Umiat core test 1) was started about 1,000 lower stratigraphically than Umiat test well 1.

GEOPHYSICS

Geophysical work in 1946 consisted of seismic and gravity-meter surveys by the United Geophysical Co., the completion of the airborne magnetometer survey by the Geological Survey and the Naval Ordnance Laboratory, and the gathering and interpretation of geophysical data, such as temperature and electrical information, from holes drilled (See pl. 3).

J. A. Legge was in charge in the field of the work performed by the United Geophysical Co.

GRAVITY-METER SURVEYS

MEADE RIVER

The Meade River gravity-meter project was designed to investigate further a large magnetic anomaly indicated by the airborne magnetometer in 1945. An area of about 900 square miles was investigated.

Between 13 April and 10 May a gravity meter was moved by air over the area in a Piper Cub cruiser on skis. Landings were approximately 5 miles apart. When the snow became too thin, the airborne party was replaced by a ground crew.

The ground crew was moved into the area over ice between 3 and 7 April. Mobile equipment consisted of 10 wanigans, 10 weasels, 3 tractors, and 3 Athey wagons. The work was done from 5 campsites.

A control line was run in from stations established on Admiralty Bay by the Coast and Geodetic Survey in 1945. Two gravity meters were used. Engineering and contour computing were done in the field; second derivative maps were made in the Barrow office.

The gravity observations were unlike the magnetic results of 1945. The lack of correlation between them could not be explained with the data available. A distinct gravity-high zone lay along the western part of the area covered. In the northern part of the area, there was a strong gravity gradient to the south. The magnetic high between the Meade and Topagoruk Rivers appeared as a gravity low. Also in the southern part of the area, a gravity high corresponded approximately to a magnetic low.

CAPE SIMPSON

In the Cape Simpson area a gravity-meter reconnaissance survey of approximately 466 square miles was carried out between 9 and 26 July. The objective was the further investigation of the area preliminary to covering it with a seismic survey. The gravity meter was transported by a Piper Cub trainer on floats, and stations were at intervals of 2 or 3 miles. There was no need of determining elevations as the whole area has a relief of less than 10 feet. It was calculated that the limit of error of such an airborne operation is about 20 times that of a ground operation.

The project confirmed the presence of a northeast-trending gravity high. That high roughly corresponded to a magnetic high.

IKPIKPUK RIVER

An air-transported gravity-meter reconnaissance was made between 7 August and 4 September of an area of about 1,000 square miles near the Ikpikpuk River. The project was designed to check magnetic anomalies revealed by the airborne magnetometer in the same area. Supplies were flown in to a camp by a Bellanca, which landed on a sandbar on the east fork of the river. Vertical control was obtained by using a surveying altimeter.

Three gravity highs superimposed on a regional gradient to the south corresponded to the three intense magnetic highs that prompted the project.

SEISMIC SURVEYS

CAPE SIMPSON

The primary purpose of the seismic survey in the Cape Simpson area was to complete the coverage of the gravity high revealed by the gravity-meter work in 1945.

Party 43 was assigned the task and departed Barrow by tractor train on 24 April. The camp consisted of 10

wanigans in addition to water and instrument wanigans, 4 tractors, and 8 weasels. The 2 Failing drills left from the year before were used by the party. Shotholes had an average depth of 75 feet. Two drilling crews and two recording crews were used on different shifts. One lake deep enough to contain water below the ice was used for water for drilling before the thaw. After that, surface water, available almost everywhere, was used. Geophones were placed in contact with the frozen ground which in the summer required digging holes to place them.

The work proceeded from east to west from a total of four campsites. Surveys were tied to the triangulation net established in 1945 by the gravity party. One computer was with the party to do enough preliminary work for a rough check on current data. The interpretation office at Barrow made all maps, sections, and reports. On 2 September the project was terminated because of icing conditions, and the men and equipment were moved to Barrow by boat.

The area is one of generally steep northwest dips which continue only to depths of about 5,000 feet. It was believed that the block of steep dips was cut off below by a thrust fault from the northwest. A small closure of about 150 feet was indicated off Wright Point. The possible fault on the northwest side of this little closure and the syncline to the southeast suggested by the gravity-meter work were interpreted as favorable indications of a possible oil trap.

Lines shot in the vicinity of the oil seepages showed the seepages to lie almost parallel to the strike of the shallow beds, and this was interpreted as indicating that the seepages issued from the outcrop of an oil-bearing sand. Oil appeared in shotholes in two locations several miles from the seepages and from each other.

All horizons showed an elongate syncline under Lake Minga, the large lake with enough depth to prevent its freezing to the bottom in winter. This apparent syncline, after considerable study, was believed to be the result of decreased velocities in unfrozen material under the lake and not a structural feature at all.

UMIAT

W. R. Fillipone directed party 46 of the United Geophysical Co. in the Umiat area between 14 August and 9 November. The objective was to obtain additional subsurface information on the Umiat anticline.

A sled-mounted Failing rotary drill hauled by a tractor was used for drilling most holes, the average depth of which was 79 feet. Holes in the flood plain of the Colville River were drilled with cable tools after the ground froze. The flood-plain gravel, which hindered rotary drilling, is 23–38 feet thick, and the average depth of the holes was 50 feet.

The recording unit was in a small wanigan mounted on tracks in summer and skis after freezeup. An office was maintained at the Umiat camp.

Movement on the steeper slopes of the Umiat area was difficult in August but became easier after the ground froze. Profile lines were surveyed by plane-table and tied into the Geological Survey triangulation net. Permafrost proved a disturbing feature in interpreting seismic results. Because of its high velocity, only a bed that would transmit seismic waves at a greater velocity would furnish good subsurface information.

The seismic results indicated that the anticline plunges slightly eastward. Absence of reflections along the crest indicated strong anticlinal folding with fracturing rather than faulting.

SPECIAL ALASKA MAGNETIC SURVEY

The Special Alaska Magnetic Survey (SPAMS) by the Geological Survey and the NOL (Naval Ordnance Laboratory) was continued in 1946 between 11 June and 4 August. The 1946 coverage aggregated about 22,600 square miles including the western part of Naval Petroleum Reserve No. 4 and areas east, west, and south of the Reserve. The combined results of the work of the two seasons yielded a map of total magnetic intensity with a contour interval of 10 gammas over an area of 36,000 square miles.

The 1946 project went on during an interval of major sun-spot activity with which magnetic disturbances are directly related. One of these magnetic storms continued for most of July, and few good readings could be taken during this time. Final magnetic measurements were correct within 10 gammas, but lack of detail and precision in the base maps (compiled from 1943 aerial photographs because the 1945 photography was incomplete) resulted in the plotting of some anomalies as much perhaps as 2 to 3 miles from their true positions.

The map compiled from both seasons' work showed a regional magnetic gradient to the northeast. Eleven closed positive anomalies extending from the vicinity of the Meade River to and beyond Umiat are flanked to the northeast by a line of closed negative anomalies. Conclusions based on the magnetic and scant geologic information were that—

1. Most of the positive anomalies are caused by variations in the surface and susceptibility in pre-Devonian rocks.

2. No consistent correlation could be found between magnetic anomalies and observed geologic structures.

3. The line of positive anomalies probably indicates a stable axis present during Late Cretaceous and Tertiary times.

4. An anomaly of large areal extent south of Tigvariak Island appeared worthy of further investigation.

UMIAT TEST WELL 1

Before drilling began in Umiat 1 in 1946, a second temperature survey was made on 27 to 29 May after the hole had stood undisturbed for 8 months. The temperature ranged from −11°C at 12 feet below the ground to −0.5° C—the temperature of the oil standing in the hole. The bottom of the ice plug at about 900 feet was taken to indicate the bottom of permafrost.

Electrical surveys were continued as the hole went down and confirmed the indications from 1945 that such surveys would be of great value in indicating the presence and position of any porous and permeable rocks and for correlation purposes.

UMIAT TEST WELL 3

An electric log was made of Umiat test well 3 (first called Umiat core test 1) on the completion of drilling on 21 December. The normal resistivity log corresponded very closely to the geological log, and the high resistivities of the sandstones indicated the absence of ice. Two zones, 247–267 feet and 346–361 feet, possessed both favorable potential and resistivity values. Inspection of the cores indicated that these intervals also were the most promising. The electrical logs revealed no conclusive correlation between Umiat test well 1 and Umiat test well 3.

DRILLING

DEEPENING OF UMIAT TEST WELL 1

Visits to Umiat test well 1 (see pl. 3 for location of drilling in 1946) in April indicated that the hole and the equipment were in good shape for starting operations again after the thaw. Supplies and equipment were checked by Don Meek, drilling supervisor. Drilling crews arrived at Umiat on 21 May and prepared camp and equipment for starting as soon as warmer weather made water available. Water began flowing in Seabee Creek on 3 June. The hole, which had been left the year before at 1,816 feet, was opened and was found to be full of ice from 775 to 920 feet. Thirty gallons of oil was bailed from above the ice.

Direction of the work was by Don Meek; Ralph Coleman, petroleum engineer; Don Jopling, geologist; and Stewart Folk, technical assistant in charge of Schlumberger and temperature surveys.

The hole was found to have a deviation of 4½° at 1,816 feet. At 2,080 feet the deviation had been reduced to 2°, and at 2,180 feet, to only 1°. A 10⅝-inch hole was carried to 4,085 feet where it was reduced to 9⅞ inches.

The well was started with an aquagel and water mixture. Small amounts of Fibrotex and Micatex were used to reduce water loss into the formations. The hole made more mud than it used, and the mud constantly gained in weight. No treatment with any chemical was necessary. Mud viscosity averaged 37½ seconds, weight 81½ pounds per cubic foot, and temperature 55°–60°F.

To insure an adequate water supply, an earth dam was constructed across Seabee Creek in July to form a pond of about 15,000 barrels capacity. The dam was cut through because of heavy rain and melting snow in August; and because the ground was so soft in the vicinity, it could not be repaired by tractors. Instead, a smaller dam was built about 200 yards below the first. Seabee Creek froze solid in September, and thenceforth water was hauled in a 30-barrel tank mounted on a sled.

Because of the freezing temperatures in early August, the winterization of the rig was hastened. A welded steel frame covered with canvas was placed over the front of the derrick. By the middle of September, the hole was drilling at 5,000 feet, and the winterization was 65 percent complete. By the end of September the hole was down to 5,700 feet, and the winterization was 90 percent complete.

The plan for Umiat test well 1 drilling in 1946 called for a minimum of coring. Intermittent coring was carried to a depth of 4,204 feet. The next coring was from 5,990 to 6,005 feet—total depth of the hole. In all, 70 cores were taken in 1946 for a total footage of 514 feet with an 83 percent recovery. Careful ditch sampling provided samples at 5-foot intervals throughout.

Total depth was reached on 5 October. Deviation of the hole at 5,990 feet was 1¼°. Drilling mud was bailed down to 950 feet to get below probable freezing, and the rig was secured except for repair of equipment. All equipment was inventoried, and plans were made to overhaul the drilling machinery in preparation for the 1947 season.

Total drilling time was 5,042 hours—2,090 hours in 1945 and 2,952 in 1946.

UMIAT TEST WELL 3

Umiat test well 3 (first called Umiat core test 1) was spotted on the northeast edge of a tiny lake, Lake Umiat, near the north edge of the flood plain of the Colville River and not far from the main Umiat camp and airstrip. Based on surface geology and from the information from Umiat test well 1 several miles farther west, the test was south of the axis of the Umiat anticline and at a surface position about 1,000 feet lower

in the section than the cellar of Umiat test well 1. About 450 feet of the 1,000 feet was because of topography and the remainder because of structural position. The purposes of the core test were to check the geology, determine the stratigraphy, test the oil-bearing zones encountered in Umiat test well 1, and serve as a check on the proposed location of Umiat test well 2.

The core test was spudded in on 15 November with a Starr Well Drilling Machine (Model 71-SK). The spudder was used because no bits large enough for 7-inch casing were available for use on the Failing rig and because of the possibility of there being gravel at the surface which could not be drilled easily with a rotary drill.

On 19 November 7-inch casing was run in for 62 feet and cemented. After the cement had set, the mud in the casing was kept at 150°F by using steam until 23 November. By that time the Failing drill, mounted on a pipesled and enclosed in a wanigan, had been rigged up over the hole. An additional mud pump was operated independently of the rotary table and used for circulation, with the regular pump acting as a standby. That provided better circulation and insured against the pipe becoming stuck in the hole if the rotary engine should stop. Pontoon sections were cut to make mud pits, and a prospecting boiler was used to heat the mud. Water could be pumped directly from the lake to the storage tanks even at temperatures as low as −50°F.

A 5⅞-inch hole was drilled to 236 feet where coring began. An oil sand was cored from 248 feet to 286 feet, where a bailing test produced an estimated 5 barrels per day. Coring continued, but no major oil shows were found after bottoming the first sand at 390 feet. A 3-inch hole reached the total depth of 572 feet on 21 December. The hole had been reamed to 5⅞ inches to 538 feet.

After a Schlumberger run the hole was bailed down to 400 feet, and a 24-hour bailing test produced 49 barrels of oil, with an estimated capacity of 45–50 barrels per day.

Although the rig housing of Umiat test well 3 was satisfactory, an excessive amount of disagreeable, time-consuming, outside construction work was necessary. This work was eliminated on future core tests by mounting the auxiliary equipment on housed sleds. Three heating stoves, the prospecting boiler, and the three engines supplied adequate heat in the rig except on very windy days, when the inside temperature dropped to 15°F and caused freezing of the mud and control apparatus in the cellar. A heater was recommended for future operations.

Drilling of the core test, the first cold-weather drilling carried on in Arctic Alaska, was completed by the end of the year.

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ANALYSIS OF THE OIL

UMIAT TEST WELL 1

A sample of the oil which had been bailed from Umiat test well 1 at the start of the 1946 drilling was submitted to Esso Laboratories (Standard Oil Company of New Jersey) for analysis. The report indicated that the crude was paraffinic, of a clear red color with a greenish cast, of medium gravity, and low in sulfur content. Because of the contact with frozen ground, it was suggested that the sample may have been subjected to natural dewaxing.

Gasoline yield, volatility, and octane numbers were very low. The sample contained virtually no aviation gasoline. The crude oil was an excellent source of sweet, low-sulfur kerosene. A cut of more than 70 percent would meet diesel-fuel specifications with a pour point of 20°F. Lubricating oils and cylinder stocks of good viscosity index and low sulfur were obtainable.

Reports by the Bureau of Mines Petroleum Experiment Station at Bartlesville, Okla., suggested the similarity of the crude oil to the better grades from the mid-continent, differing only in a deficiency of the lower-boiling products. The gasoline cut was not good, but relatively large quantities of kerosene, jet-propulsion fuel, and diesel fuels of good quality could be made. A fair quantity of good quality lubricating oil also was available.

UMIAT TEST WELL 3

Two samples of crude oil from Umiat test well 3 (first called Umiat core test 1) were sent to the Bureau of Mines Petroleum Experiment Station at Bartlesville. The samples were unlike the sample from Umiat test well 1 and from other known crudes. They were unusual in having a very high content of naphthenes and aromatics. It was suggested that the samples represented a naphthenic condensate combined with material similar to the Umiat test well 1 sample to form a composite.

The two core test samples were virtually identical. They had 16 percent of aviation gasoline base stock, 40 percent of motor gasoline, 32 percent cetene diesel fuel with −10°F pour point, 65 percent of jet-propulsion fuel, and 20 percent of lubricating oil with a −10°F pour point. Pour points of the samples were −15° and −25°F.

SUMMARY OF 1946

During 1946 the operation of Pet 4 was taken over by Arctic Contractors from the Navy. This was done with a minimum of confusion and with the project meanwhile continuing without interruption. By the end of the year, Arctic Contractors had demon-

strated its ability to handle all the difficult and unusual aspects of this unique arctic effort.

By the spring of 1946, the contractor had completed more than twice the amount of winter freighting that had been estimated. Additions and improvements were made in the Barrow camp; new construction at Umiat included the rebuilding of the airstrip and the construction of a permanent quonset-hut camp. The Seattle office did an outstanding job in procuring materials for Barex '46 in the period of postwar shortages. Barex '46 was favored by good weather and was the smoothest, most effective expedition to that date. Through careful planning and preparation, all field parties operated effectively without unusual delays or difficulties.

During that first year of contractor's operation, the aerial magnetic survey of the Reserve and adjoining areas was completed. Air photography and base-map compilation progressed. The work of five geological field parties was supplemented by office and laboratory studies.

Two seismic and two gravity-meter parties were in the field and accomplished their assigned tasks as planned. The practicability was demonstrated of covering areas on the coastal plain by the gravity meter using a bush plane on skis or floats for transportation.

Umiat test well 1 was completed to a total depth of 6,005 feet before the onset of cold weather. The contractor then completed Umiat test well 3 just before the end of the year.

Accomplishments for the year were encouraging. Large areas had been explored in a preliminary fashion. Magnetic and gravity anomalies justifying seismic surveys had been found. An anticline delineated near Cape Simpson appeared worthy of testing, and hopes were still high for production possibilities from the Umiat anticline.

FOURTH YEAR—1947

GENERAL PLANNING AND ADMINISTRATION

Preparation of equipment for winter freighting, core-hole drilling, and geophysical prospecting was the big job at Barrow and Umiat as Pet 4 moved into its fourth year. In March Lieutenant Commander Wolfstein was relieved at Barrow by LCDR James B. Urquhart, Jr., CEC, USN. Also in March, Navy photographers arrived in Pet 4 to make a color motion picture of the various operations as a training and indoctrination film.

It had been determined that payment for the services of Walter A. English as chief technical advisor to the DNPR was not reimbursable under the contract with Arctic Contractors, and in March a personal-services contract was entered into with Mr. English.

On 28 March in Los Angeles, Mr. English met with Herbert Hoover, Jr., A. A. Curtice, and Glen M. Ruby, all representing the contractor, and George O. Gates, of the Geological Survey, to discuss the whole program preliminary to the operating committee meeting scheduled for April. The group felt that a shallow-core-drilling program should be fitted in with the seismic shothole drilling. As the stratigraphic column became better known, the holes would need to be drilled only deep enough to recover fossils for a stratigraphic tie. The group also recommended that gravity and seismic investigations should be made of the areas of magnetic anomalies in an attempt to determine the significance of the anomalies. Finally, the group urged that the Fish Creek seepage be drilled.

Mr. English, in reporting to Commodore Greenman, pointed out that interest was focussing more and more on the northern and northeastern parts of the Reserve as being the most hopeful. He also expressed his opinion that the funds allotted were not sufficient to attain fully the major objective of Pet 4—to determine the oil possibilities of the Reserve.

In replying to and agreeing with the last statement, the DNPR indicated that every effort should be made to have some oil wells by the spring of 1949 as that was the best way to justify to the Congress the need for additional funds to attain the program objectives. He felt that basic investigations should emphasize at the moment geologic structural features that could be drilled before the spring of 1949.

On 28 March change order G authorized the drilling of Umiat test well 2 for an estimated cost of $260,000. The hole was planned to reach a depth of approximately 3,000 feet.

Commodore Greenman called the sixth meeting of the operating committee in Washington, D. C., on 15–17 April. At that time the official members of the committee were Commodore Greenman, DNPR; COL O. F. Kotick, Army-Navy Petroleum Board; W. E. Wrather, Director, Geological Survey; LCDR Frederick Cooke, BuDocks; L. W. MacNaughton, of DeGolyer and MacNaughton; A. A. Curtice, of Hoover, Curtice, and Ruby; and Walter A. English, chief technical advisor.

Five principal items were on the agenda:

1. To study the results since the fifth meeting and to receive final reports presented in preliminary form at the fifth meeting.

2. To receive reports on progress of paleontologic studies and on thin-section analyses of cores from Umiat test well 1 and Umiat test well 3 (first called Umiat core test 1).

3. To review the program for 1947 as outlined at the fifth meeting and to suggest such modifications as funds or developments might indicate as being desirable.

4. To receive the report and recommendations of the chief technical advisor.

5. To receive a report of the Bureau of Mines on analyses of oils from Umiat test well 1 and Umiat test well 3.

George O. Gates, of the Geological Survey, stated that the reports of the various geologists on their 1946 studies were complete and would be presented. He pointed out that logistics limitations apparently would require the dropping of one of the geologic field parties as planned at the fifth meeting and that therefore one party would be assigned both the Kigalik and the Awuna anticlines. Mr. Gates indicated that the Army, according to its plans, would have completed by the end of June the required trimetrogon and vertical photography.

The following geologists reported on their 1946 fieldwork: Richard G. Ray on the Maybe Creek-Wolf Creek area; R. M. Chapman on the area of the Kurupa, Oolamanagavik, Killik, and Colville Rivers; E. J. Webber on the Meade River area and a part of the Arctic coast; and Karl Stefansson on the detailing of the Umiat anticline. Paul D. Krynine discussed reservoir characteristics as indicated by thin-section analyses of cores from Umiat test well 1, and E. H. Lathram reported on the progress of heavy-mineral studies which by that time included a number of minerals in addition to garnet. George Gryc summarized the status of the macropaleontology of northern Alaska, and A. Loeblich (for Helen Tappan Loeblich) presented a comparable summary of the micropaleontology.

Thomas G. Payne reviewed the status of the knowledge of the geology of northern Alaska and made a number of pertinent inferences therefrom. He predicted, for example, that relatively clean sands in the northern part of the foothills province would be found to be of the shoestring type and not blanket strata of wide extent. Payne felt that, on the whole, the sands would likely be cleaner, and hence would have greater porosity and permeability, in the coastal plain province than sands farther south.

Harold Smith, of the Bureau of Mines, discussed the analyses of oils from both Umiat test well 1 and Umiat test well 3. He believed the oil from the two wells came from different sources. The crude oil from Umiat test well 1 yielded large cuts of diesel and jet fuel.

Fred Keller, Geological Survey, outlined the results of the SPAMS projects in 1945 and 1946. It was concluded by SPAMS that—

1. Most of the positive magnetic anomalies are caused by variations in the topography and magnetic susceptibility of metamorphic rocks. Exceptions might be the Umiat and Ikpikpuk areas.

2. Only at Umiat is there good correlation between magnetic anomalies and an observed geologic structure.

3. The trend of positive anomalies from the Meade River to the Anaktuvuk River may indicate a stable axis present during Late Cretaceous and Tertiary time.

The chief technical advisor, Walter A. English, discussed the gravity and seismic work in Pet 4 in the light of his recent visit to the Reserve. After discussion, Mr. English recommended an air-transported gravity survey of the northern part of the Reserve with at least 250 stations spaced not more than 10 miles apart. He also recommended that the seismic party near Smith Bay continue southward with a single line to connect with the work of the party in the Ikpikpuk area before the thaw. Then, as previously planned, the two parties would combine to explore the anomalies in the latter area.

Bart Gillespie, project manager, reported that winter freighting was progressing satisfactorily in spite of the unusually severe winter—in one interval of about 40 days the temperature never rose above −40°F. He announced that Umiat test well 3, Sentinel Hill, and Skull Cliff core tests were satisfactorily completed. He emphasized the feasibility, but high cost, of such winter drilling.

CDR P. W. Roberts, OICC, summarized the fiscal situation to the effect that of the original $9,600,000 appropriation approximately $4,565,000 would still be available as of 1 January 1948. Commander Roberts pointed out the critical housing needs and stated his opinion that dormitory and family housing must be provided in Fairbanks and family housing in Barrow and Umiat.

After full discussion, the operating committee proposed, as recorded in the minutes of the sixth meeting, that "* * * modifications be made in the program as approved at the fifth meeting and that the future program * * * contained in these conclusions be used as the basis for planning and for the procurement of personnel, material, and equipment necessary to continue * * * after 1 January 1947."

In essence, the modified program provided for the elimination of one geologic field party, the study of an anticline on the lower Anaktuvuk River by an air-transported geologic party, further geologic work in the Maybe Creek-Wolf Creek area, the running of a single seismograph line southward from Smith Bay to connect with the work in the Ikpikpuk valley, an air-transported gravity-meter survey of the northern part

of Naval Petroleum Reserve No. 4, the drilling of Simpson test well 1 and Umiat test well 2, and the provision by Arctic Contractors of a resident geologist and a petroleum engineer for each well. It was believed that the geologic reconnaissance of the region would be essentially completed by the close of the 1947 season.

More details on the program as summarized will be given at appropriate later places in this review of the fourth year of Pet 4.

In June, Glen Ruby, of Hoover, Curtice, and Ruby, Inc., and George O. Gates, of the Geological Survey, made an air reconnaissance of parts of the Reserve and surrounding areas and a river traverse down the Colville to Umiat from a point about 120 miles upstream from Umiat. As a result they recommended some modification of the geologic program for the 1947 season.

An interim meeting of the operating committee was held in Umiat on 5 July to consider Messrs. Ruby's and Gates' recommendations and to prepare a guide for the use of Mr. English in preparing a proposed program for consideration at the anticipated November meeting of the operating committee. The interim meeting was attended by the following members and alternates of the committee: Commodore Greenman, Glen Ruby, Walter English, Commander Roberts, and George Gates. Bart Gillespie, the project manager, was also present.

The committee approved the recommendations of Messrs. Ruby and Gates which in outline principally involved the deferment of the plans for one geologic party in order to free that party to make additional investigations of three anticlines—one along the Colville west of the Kurupa River, a second at the mouth of the Oolamnagavik River, and the third, the first anticline, (now called the Fossil Creek anticline) south of the Prince Creek syncline.

The committee recommended that Walter English and others as indicated prepare both a long-range plan and a short-range plan, as follows, for consideration at the November meeting of the committee. The short-range plan would provide either for—

1. Closing out the exploration contract by 30 June 1950.

2. Or utilizing the remaining funds to continue the exploration after 30 June 1950.

Item 1 above was to be prepared by the OICC. Item 2 was to be prepared by Mr. English and would include the selection of locations for two more wells with cost estimates and other areas to be explored by the seismograph also with costs.

The long range plan would involve—

1. A proposal to exclude from the Reserve a large part of the western part of the Reserve and to add a somewhat larger area southeast and east of the Reserve.

2. Suggestions with estimated costs of exploration west of the Meade River but within the Reserve as contemplated by the revised boundaries.

3. Suggestions with cost estimates of additional geologic and geophysical work in the vicinities of the Kigalik and the Awuna Rivers and including estimated costs of drilling.

4. Suggestions for detailed geophysical work with estimated costs to determine well locations in the southeast part of the Reserve including the Sentinel Hill area.

5. All required work in the northeast part of the Reserve with costs.

6. Additional work with costs in the proposed extended area of the Reserve.

In September Pet 4 was visited by members of the Senate Interstate and Foreign Commerce Committee and by the House and the Senate Public Lands Committees. The overall scale of the operation in the fall of 1947 is indicated by the facts that in September approximately a contractor personnel of 475 was in the Reserve and more than 11,000 meals were being served weekly with about 8 percent being supplied to the Navy and the Army personnels.

The second interim meeting of the operating committee was held in Fairbanks on 7 and 8 September to review a report by the chief technical advisor on the short-range plan as requested at the first interim meeting in order that impracticable parts could be eliminated and the various operating groups could prepare cost estimates on the elements remaining for consideration at the regular November meeting of the committee. Mr. English submitted a report that earned the approbation of the whole committee. In brief, the following decisions were made:

The Geological Survey was requested to make cost estimates or take such other action as is indicated by the following:

1. A geological study of the White Mountain area east of the Reserve.

2. Any additional investigations that might be necessary to round out the geological information on all areas in which the operating committee is interested.

3. The preparation for the November meeting of all surface and subsurface data that might affect the program of deep well drilling.

4. The bringing up to date of all micropaleontology by 1 April 1948.

5. The supplying of a well geologist for the proposed Simpson core holes.

6. The keeping current of the micropaleontology of Simpson test well 1 and Umiat test well 2.

7. The presentation at the November meeting of the main features only of the 1947 season's field parties.

The United Geophysical Co. should—

1. Place two seismograph parties in the field as early as possible in 1948, and they should work until about 1 September.

2. Employ a geophysical operations manager to serve as a liaison between the field parties and Arctic Contractors and as a planner for the support of field parties.

3. Provide a geophysical supervisor to serve for 12 months.

The Contractor was requested to—

1. Prepare cost estimates for placing two parties in the Fish Creek area to detail any structural features that might be found or to work westward and southward respectively, if no structural feature is found.

2. Prepare cost estimates for a profile across the Gubik anticline.

3. Estimate the cost of a seismic survey of the Barrow area.

4. Estimate the cost of, and make velocity surveys at Umiat test well 2 and Simpson 1 after completion of drilling.

5. Furnish estimates for 5 core holes near the Simpson seepages to depths of 250 feet or less.

6. Furnish alternative estimates for drilling on the Oumalik anticline (a) a 3,000-foot hole with the Cardwell rig (b) a 3,000-foot hole with the National-50 rig, and (c) a 6,000-foot hole with the National-50 rig.

7. Estimate the cost of a cable-tool hole on the Umiat anticline to a depth equivalent to 1,050 feet in Umiat test well 2.

8. Make a test of the production capacity of Umiat test well 3 by the November meeting.

It was the opinion of the Committee that—

1. No further gravity work should be done until a comparison is made of gravity and seismic results at Fish Creek.

2. Umiat test well 2 should penetrate beyond 3,000 feet to a final depth to be determined at the November meeting.

3. No change is needed in the drilling program for Simpson test well 1.

4. No change be made in drilling specifications and that indications of any substantial sand body merited coring.

Mr. English was requested to prepare a program of aerial photography and mapping for the 1948 season for consideration at the November meeting.

The seventh regular meeting of the operating committee convened in Washington, D. C., on 12 November and continued until 14 November. All members of the committee were present and included: Commodore Greenman, DNPR; W. E. Wrather, Director, Geological Survey; Mr. MacNaughton; Mr. Curtice; Colonel Kotick, Army-Navy Petroleum Board; and LCDR Fred Cooke, BuDocks. Among the substantial number of others present were Mr. English, chief technical adviser to the DNPR; Commander Roberts, OICC; and Mr. Gillespie, project manager. It had been determined since the 6th meeting that, as a consultant to the DNPR, the chief technical advisor should not be an actual member of the operating committee. Commander Roberts was finishing his duty as OICC and at the meeting he introduced CDR George E. Fischer, his replacement, who relieved him on 1 December. On 1 November LTJG C. F. Krickenberger, Jr., assumed the duties of assistant OICC in Fairbanks.

After reports on various aspects of Pet 4 had been presented and after discussion by committee members and others, the committee reached a series of conclusions and made a number of recommendations. These were so influential on the subsequent course of Pet 4 that they are quoted here in full (minutes of seventh meeting of operating committee). The conclusions were—

1. That the information and results obtained to date from the exploratory program indicate that the prospects of finding oil in this Reserve are as good if not better now than when the work started; therefore, the exploration should continue until all the possible oil-bearing areas are investigated as below outlined:

A. While the character of the sands of the Upper Cretaceous sediments which have been explored to date in the southeastern sector of the Reserve have been disappointing, indications of oil deposits are still sufficiently good to warrant the drilling of two or three more wells on closed anticlinal structures in the southeast sector.

B. There is evidence of a considerable basin of deltaic type Tertiary deposits underlying the flat Arctic plain in the northeasterly sector of the Reserve. Source beds are indicated by the oil seeps at Fish Creek and Cape Simpson. This area should be explored by geophysical means to determine structures for drilling locations. At least two wells should be drilled in this area.

C. The Lisburne limestone which has been studied along the front of the Brooks Range south of the Reserve, and to the east in the Sagavanirktok-Canning River areas, has zones of probable good porosity and is of a petroliferous nature. The deep seismograph reflections at Simpson and refraction work at Barrow indicate that the Lisburne may be present at drillable depths over a considerable area in the Barrow-Simpson-Meade River area. This area should be further explored by geophysical methods and the drilling of 2 or 3 wells.

2. From the experience gained in conducting the exploration, it is obvious that the work necessary to prove or disprove the presence of commercial oil in the above areas cannot be accomplished within the time and funds now available. It is estimated that four additional operating seasons after 1948 will be required to fully explore the Reserve. Therefore, the period of

exploration should be continued at least through the season of 1952 and additional funds should be made available. It is estimated that between $12,000,000 and $15,000,000 will be required.

3. The last operating season under the present availability of funds is the spring, summer, and fall of 1949. Until some expression can be obtained from the committees of Congress having cognizance of this exploration that the program should be continued, it is not considered advisable to project the work beyond the season of 1948 even though funds will still be available. The reason for this is that considerable funds are required to purchase materials and equipment a year in advance of the active field season and the committee does not feel that such expenditure is warranted for continuing work which will not be completed unless additional funds are made available. Therefore, it is desirable that the interested committees of the Congress be advised as soon as practicable that the Navy is now half-way through the program for which present funds are available; advise them of the progress to date and future prospects; and describe to them the plans for continuing the operation for their approval or disapproval.

4. There has been considerable discussion in the committee as to whether the boundaries of the Reserve should be extended to include additional public lands to the eastward which give indication of being oil-bearing. Assuming that oil will be discovered in the Reserve and that the Government must initiate some sort of development program to make this oil readily available, it is believed that private enterprise should be encouraged to prospect for oil in the areas outside the Reserve and to develop such of these areas as may be oil-bearing in order that the costs of installation and maintenance of transportation facilities may not be borne entirely by the Government. However, it is believed that the boundaries of the Reserve should be redefined on a latitude-longitude basis to facilitate accurate surveying.

With the above in view, it is suggested that a letter be addressed by the Secretary of the Navy to the Secretary of the Interior requesting his opinion concerning:

A. A revision of the boundaries of the Reserve on a latitude-longitude basis within the limits lying between 150° and 160° W. longitude and on the south by 68°30′ N. latitude with the Arctic Ocean as the northern boundary, provided the area of the Reserve is not materially changed. In this connection the village of Wainwright should lie outside the western boundary.

B. The matter of opening up the lands lying outside the Reserve to private exploration on the basis of making sufficient land available to interested companies large enough to undertake proper programs of exploration to insure rapid development.

5. In planning the work for next season, the committee found it necessary to consider the alternatives that the work may or may not continue when present funds are exhausted. Therefore, the work for the 1948 season must fit into a long range program, without unwarranted expenditures for projects that cannot be concluded, and at the same time insure a sufficient reserve of funds to close out the enterprise in the summer of 1949. Therefore, it was concluded that the program to be recommended for the 1948 field season should include:

A. Two geological field parties to fill in geological data in areas where information is not complete.

B. Three geophysical field parties; two of which will operate in the Tertiary basin in the northeast sector of the Reserve to further define the basin and locate structures, and the third will explore for indications of the Lisburne limestone in the northwest sector. The actual assignment of this party will depend on results from Simpson No. 1 which will be available in January.

C. The drilling of a well at the Fish Creek seep in the Tertiary basin if structure is defined; if not, at one of two other locations now available.

D. The possible drilling of a well on the Maybe Creek anticline in the southeast sector using cable tools. This type of drill will be tested at Umiat in the early winter.

E. In carrying out the above program, the contractors will cut all operating costs to a minimum.

If it appears that the Committees of the Congress are favorable to the continuation of the program, the committee plans to eliminate item "C" above and use the funds for the purchasing of heavy drilling equipment for deep tests. This equipment would be shipped in the 1948 resupply expedition.

6. It was the consensus of the committee that properly to evaluate the geological information available at the committee's annual meeting, it is necessary that a Subcommittee of the operating committee meet in Washington, D. C., at least 1 week prior to the scheduled date of the meeting to study the information.

The recommendations were—

In the light of the above conclusions, it is recommended that the following program be approved for the calendar year 1948.

1. U. S. Geological Survey; Geological Field and Laboratory Work, Mineral Studies, and Mapping.

A. The Geological Survey should place two geological field parties in the general area of the Reserve, one of which will be airborne. The airborne party should fill in missing geological data in the areas already covered and search for additional porosity and microfossil samples. The other party should define stratigraphy and structure in the western part of the Reserve in the areas of the Avalik-Ketik-Kaolak Rivers. Upon completion of this work, the party should make further study of the Lisburne limestone outcrops to the south. The Survey should submit details of the program for these parties for the approval of the operating committee at the meeting scheduled for 31 March 1948.

B. The Geological Survey should maintain in Fairbanks and in Washington, D. C., the necessary laboratory and office personnel and facilities commensurate with the anticipated workload.

C. Heavy-mineral studies should be undertaken as outlined by the Survey at this meeting.

D. The Survey, in collaboration with the coordinator (Mr. English), should prepare and submit to the Director, Naval Petroleum Reserves, prior to 1 January 1948, a plan for the continuation of aerial photography in the Reserve during the summer of 1948. It is understood that the Navy will take the photographs and the Survey will construct the planimetric maps.

E. Items of expense incurred by the Geological Survey in carrying out the above program will be met by transfer of funds by the Director, Naval Petroleum Reserves, from the naval appropriation available for this purpose.

2. Arctic Contractors Program

A. Geophysical Work

a. Three seismograph parties will be placed in the field. Two of the parties will start the season in the vicinity of the Fish Creek oil seep in the northeast sector and detail this area in an effort to find structure in the vicinity of the gravity high located last season. If no structure is found worthy of de-

tailing or if detailing is completed in time, one party will continue working in a general southerly direction and the other in a general westerly direction. The third seismograph party is to do general reconnaissance refraction and reflection shooting in the general area to the south and southwest of the Barrow-Simpson area and will do some work in the Barrow vicinity at a convenient time. The details of this work will be prepared by the Coordinator after the final stratigraphic results are obtained from Simpson test well 1 in January.

b. Whenever it will not interfere with the normal seismograph operations, each party will drill an occasional shothole to a depth of approximately 200 feet for stratigraphic information. If, in any particular hole, the drill at 200 feet is in Gubik sand, it would be desirable to drill deeper if such would not jeopardize seismograph operations. From each shothole drilled a composite ditch sample of cuttings will be taken from the bottom 20 feet of the hole to be shipped to the Geological Survey laboratory at Fairbanks to be tested for microfossils.

B. Drilling

a. The National 50 rig now at Umiat will be moved to the Fish Creek seep area this winter and the contractor will purchase the necessary equipment to recondition it.

b. If it is determined that the committees of the Congress having supervision will not approve of continuing the work, a well to the capacity of the rehabilitated rig will be drilled at Fish Creek if structure is found. If no structure is found, this rig will be moved to another location to be determined by the operating committee at its meeting on 31 March, 1948.

c. If it is determined that the work will continue, no wells will be drilled in 1948 with the rotary rigs and the money saved will be used to purchase a heavy rig for deep drilling.

d. The purchase of the rehabilitation equipment this year will be accomplished under either situation.

3. The cable tool equipment now at Barrow will be freighted to Umiat as soon as possible and a well will be drilled to approximately 1,000 feet to test the use of that type of drill in the permafrost and for other data.

If the test is satisfactory, this rig may be moved to Maybe Creek to drill a well in that area this summer provided funds are found to be available. This will be determined at the March meeting of the operating committee.

The chairman will appoint a subcommittee of the operating committee to meet in Washington, D. C., at least 1 week before its annual meeting to study, evaluate, and report on the results of the season's geological and geophysical work.

4. The committee took note of the fact that CDR P. W. Roberts, CEC, U. S. Navy, will be detached in December as the officer-in-charge of supervising the work of the contractor conducting the exploratory field work in the Reserve. His work has been of a superlative nature in every phase of the program, and the committee suggests that the Secretary of the Navy address a letter to this officer commending him on his splendid performance of duty.

Of general interest in regard to administration of Pet 4 was Commander Roberts' report at the seventh meeting of the operating committee that overhead costs were running about 17½ percent of the total cost. This figure was based on a running inventory system and a system of charging equipment costs against each project.

On 17 December change order J was issued to provide for the anticipated 1948 activities. The order covered 7 projects as follows:

Project	Object	Estimated cost
22	Seismic surveys	$1,500,000
23	Camp construction and maintenance, operation	1,566,400
24	Support for noncontract activities	95,000
25	Logistic plans, shipping preparation, unloading of ships, and transportation to storage	215,000
26	Purchase of materials, supplies, and equipment	800,000
27	Service to Loran station at Skull Cliff, including painting	66,420
28	Logistic support to Air Sea Rescue and Direction Finder units	30,000
	Total	[1] $4,272,820

[1] Includes the contractor's fee of $190,000.

In 1947 there was a sharp increase in the amount and complexity of services performed for other activities, mostly military, that for various reasons were interested in the Arctic. Projects supported included such diverse ones as the "Beetle" (Loran) projects and the Arctic Research Laboratory of the Office of Naval Research. Such extracurricular support became a very substantial item in 1947 and has required a separate section in this report for proper detailing. Thus, there began to come into the picture a sort of byproduct return on the investment in Pet 4 whereby many things that the Nation needed to know about the Arctic and that it needed to know how to do in the Arctic were possible for the first time because of Pet 4.

OPERATIONS

LAND TRANSPORTATION

In the first few days of 1947, there was intense activity at both Barrow and Umiat in building wanigans and sleds, and in overhauling and winterizing tractors. In mid-January, a tractor train of drilling equipment started from Umiat for Sentinel Hill. A similar train left Barrow about the same time for Skull Cliff. That was the start of the most varied freighting program that had yet been carried on in Pet 4. In all, the total freight moved was 5,975 tons, and the total distance was 3,711 miles. The total ton-miles was 749,000. Fortunately, the 1947 spring was late, and freighting was able to be done until June although that after April was largely for supported activities and not for Pet 4 itself.

The freighting season began in earnest about the middle of February (see figs. 25, 26, 27) when freshwater ice was 54 inches thick and salt-water ice 41 inches. Thereafter, trains to or from Cape Simpson, Skull Cliff, Umiat, and the Ikpikpuk were arriving or departing Barrow almost daily.

The increased freighting requirements in 1947 warranted 3 tractor trains instead of 2, additional tractors, and better equipment. Tractor cabs were redesigned for greater visibility and greater strength to withstand the severe vibration. The somewhat modified Micheler

FIGURE 25.—Hoisting jamesway huts onto Micheler sleds at Point Barrow for winter freighting, 7 May 1947. Photograph by U. S. Navy.

No. 9 extra-heavy-duty sleds performed remarkably well. Wanigans were held more firmly in place by cinching them to the sled decks with cables looped over the roofs. Between the first of the year and early March, 25 portable wanigans were built in Barrow for seismic-crew housing.

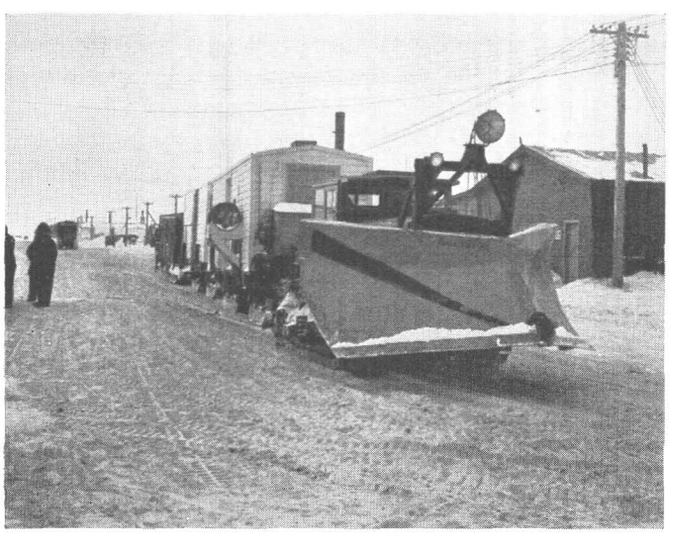

FIGURE 26.—Tractor train at Point Barrow, winter freighting, March 1947. Photograph by U. S. Navy.

Communication between camps and trains was maintained with improved radio facilities. A Bellanca aircraft visited the trains every few days with mail and passengers. The Bellanca was used also to drop weighted stakes ahead of the scouting parties which then made only local changes in route because of topography and ice conditions. This saved much time as it prevented most of the backtracking and restaking.

A new phase of freighting in 1947 was the redistribution of considerable tonnages located at old caches and drill sites. This involved uncovering the materials from snow drifts, breaking down, and loading for the trip to the new locations.

In general, the trail conditions in the 1947 freighting season were considered average. On 19 January be-

FIGURE 27.—Tractor train on open tundra during winter freighting, March 1947. Photograph by U. S. Navy.

tween the Meade River and Skull Cliff, the temperature dropped to −65°F with a 40-mile-per hour wind. Again in mid-February, the freighting was slowed by a blizzard with 50-mile winds and −45° temperatures. The high winds caused large snow drifts that for removal required snow-plow attachments on the leading tractors of each train. It was found that net tonnage ran about 20 percent below gross tonnage because of food and fuel consumed enroute.

In the late fall of 1947 all boats and barges were winterized. The repair and the overhauling were started of sleds, wanigans, and tractors. In late November, which was marked by a 12-inch snowfall, overland freighting was begun to Skull Cliff. An LVT (landing vehicle, tracked) was tested on this haul as a

personnel and cargo carrier and was found to be very satisfactory. Twenty more were ordered to come on Barex '48. Winter freighting for the 1947–48 season began in December to seismograph parties and to Umiat.

BARROW EXPEDITION, 1947

The assigned task of Barex '47 was to provide the necessary resupply for Pet 4 and to develop a personnel nucleus of those experienced in cold-weather operations. Subsequently, the CNO (Chief of Naval Operations) assigned additional tasks including the transporting of Army Loran equipment to Skull Cliff, monitor station equipment to Barter Island, general cargo for the Coast and Geodetic Survey and the Presbyterian mission to Wainwright, and small amounts of cargo to Barrow for the Coast and Geodetic Survey, the Bureau of Indian Affairs, the CAA, and the Army.

Planning was well underway by the end of April. On 23 April, a conference was held at the USN Amphibious Base, Coronado, Calif., and was attended by the Commander, Transport Division 12 and staff, in charge of the expedition; staff officers of the Amphibious Force, Pacific Fleet; the Marine Terminal Superintendent at Port Hueneme, loading officer; the project manager, Mr. Gillespie; and the OICC, Commander Roberts.

It was reported that labor was difficult to obtain and shipping was deficient, but that an ample personnel had been assigned and additional ships were being considered. One month's training of the personnel using dummy cargo was possible, and the lighterage assigned could probably handle cargo in excess of that which could be handled by the beach equipment. An ice breaker was assigned, and radar screens were to be built at key points along the Arctic coast.

Reconditioning of barges and landing craft was completed at Barrow by mid-July, and radar screens were established at key points from Icy Cape to Barter Island. The ice was well offshore during July and supplies were barged from Barrow to Skull Cliff. Members of the supply expedition made the usual advance inspection of Barrow facilities and the coast to the southwest. A final Barex conference was held in Seattle to insure that all was in readiness at the end of July.

Ships assigned were the U. S. S. *Seminole* (AKA–104), the U. S. S. *Union* (AKA–106), the U. S. S. *Diphda* (AKA–59), the U. S. S. *Muliphen* (AKA–61), the icebreaker, U. S. S. *Burton Island*, and LST *642*, which was to be beached and left at Barter Island. The commanding officer was CAPT B. S. Anderson, USN. CAPT Leonard Frisco, USNR, who had commanded Barex '46 was ordered to the staff as senior technical advisor. CDRS John Backlund, USNR, and Richard E. Morell, USCG, were assigned as ice pilots. Others included an expedition beachmaster, assistant beachmasters, an aerologist, beach communication officer, and a task-group communication officer. Additional specialists were added as the scope of the operation increased—9 Marine officers and 9 Marine sergeants were assigned as observers and student transport quartermasters; 6 aerographer mates were to assist in weather coverage; 1 photographer's mate, and 1 enlisted correspondent were included. Special observers represented the Army Transportation Service, the Seattle Star, BuDocks, and the Coast and Geodetic Survey.

An ice pilot was assigned to LST *642* at Barrow for piloting the craft to Barter Island, and to the *Burton Island* were attached 2 officers and 11 men from under-

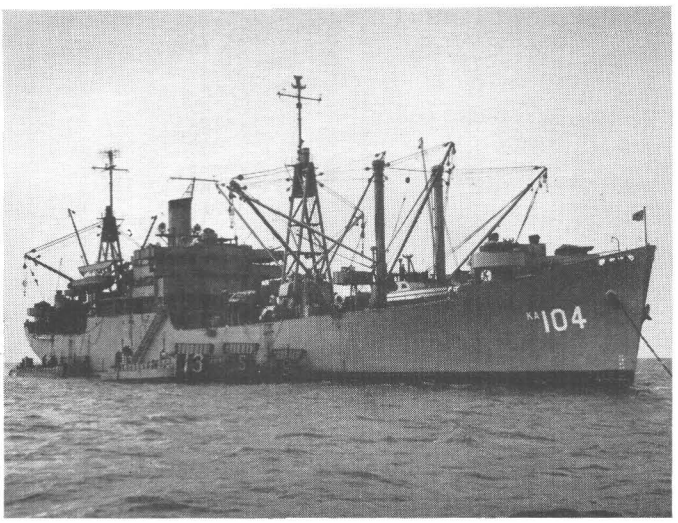

FIGURE 28.—Unloading of the U. S. S. *Seminole* at anchor off Point Barrow during Barex '47. Photograph by U. S. Navy.

water demolition teams to assist in beaching the LST at Barter Island.

Loading went on at Point Molate, Port Hueneme, and Seattle from 23 June to 30 July, when the expedition departed Seattle. The radar screens along the Arctic coast proved to be useful, and the helicopter carried by the *Burton Island* was helpful in navigation. The *Muliphen* left the group at Wainwright to discharge cargo, and the remaining ships arrived off Barrow at 1800 on 7 August.

The weather was excellent, the ice was far out, and unloading operations proceeded smoothly (see figs. 28, 29, 30). The rate of discharge was the highest yet attained by a Barex. By 10 August the *Seminole* had discharged her complete cargo of 4,178 long tons; and the *Union*, 2,912 tons with 95 tons remaining for Wainwright. On 13 August the *Diphda* completed the offloading of her 4,600 long tons.

Meanwhile, the *Muliphen* had gone from Wainwright to Skull Cliff and had offloaded at the rate of 29 long tons per hour. After unloading only 1,400 tons of the Skull Cliff cargo, the *Muliphen* was ordered to Barrow, because of increasingly adverse sea conditions, for the unloading of the remaining 480 tons of Army Loran cargo. On 12 August she returned to Skull Cliff, but after 100 tons had been taken off, she again had to return to Barrow where the remaining 600 tons of Skull Cliff cargo was discharged. Two swamped LCM's at Skull Cliff were transferred to the ROICC for eventual salvage and use.

After the departure of Barex '47, the Skull Cliff cargo left at Barrow was moved to its destination by barge and LCM, and supplies at Skull Cliff were moved to

FIGURE 29.—Beaching barge with palletized cargo during Barex '47. Photograph by U. S. Navy.

higher ground as high seas and strong winds continued. Another barge movement was made from Barrow to the Simpson rig site.

While the rest of the expedition was unloading at Barrow, the *Burton Island* with LST *642* in tow (see fig. 31) proceeded according to plan to Barter Island. Some difficulty with ice was encountered, but with the use of PBY flying cover, radar, and helicopter, the destination was reached on 9 August. At Barter Island two possible landing beaches had been selected. Ice made landing difficult, but in a few hours the LST moved into the alternate beach and grounded in 9 feet of water about 40 feet from shore. Preparations were made with difficulty for unloading from this position, but on 10 August an abnormally high tide and wind moved the ship in toward the beach where she stopped with the forward ramp in only 3 feet of water. A bulldozer was put ashore which built a dry ramp to the

FIGURE 30.—Miscellaneous cargo on beach during Barex '47, 8 August. Photograph by U. S. Navy.

ship and water-filled pontoons were placed as a dam to keep floating ice from the forward ramp. By midnight on 10 August 310 long tons had been unloaded.

By that time the ice had piled so high on the starboard side that the UDT (underwater demolition team) was used in breaking up the jam with explosives. This was entirely successful. Early in the morning on 11 August, a shift in the wind moved all the ice away from the ship and the beach, and it was decided to move the ship to the other and more desirable beach. This was

FIGURE 31.—LST *642* being towed by icebreaker U. S. S. *Burton Island* between Point Barrow and Barter Island, 9 August 1947, Barex '47. Photograph by U. S. Navy.

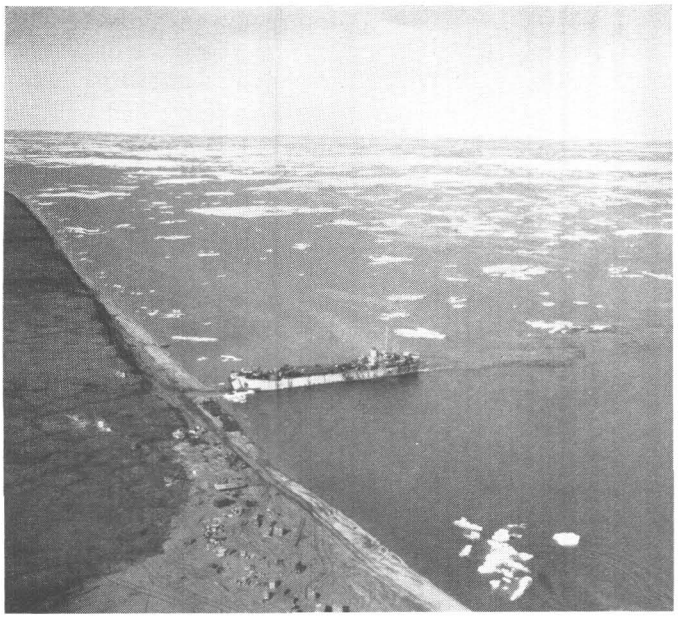

FIGURE 32.—LST *642* beached at Barter Island during Barex '47. Photograph by U. S. Navy.

accomplished after much difficulty with grounding and in attempting to maneuver the ship in strong shore currents and wind. After 40 total hours of actual unloading, 490 long tons of cargo had been discharged. The ship and unmovable equipment were transferred to the OICC, Fairbanks. The beaching of LST *642* at Barter Island had been successfully accomplished (see figs. 32, 33) in the face of adverse weather, unknown waters, and poor mechanical condition of heavy equipment.

On 13 August the *Burton Island* returned to Barrow. On 12 August the *Union* went to Wainwright, unloaded 95 tons of petroleum products, and was released from the expedition on 13 August. The *Seminole* departed Barrow on 12 August and awaited the *Diphda* at Icy Cape. On 13 August the *Muliphen* was released. The *Burton Island* joined the *Diphda* at Barrow, and they departed for Icy Cape. Barex '47 had been completed.

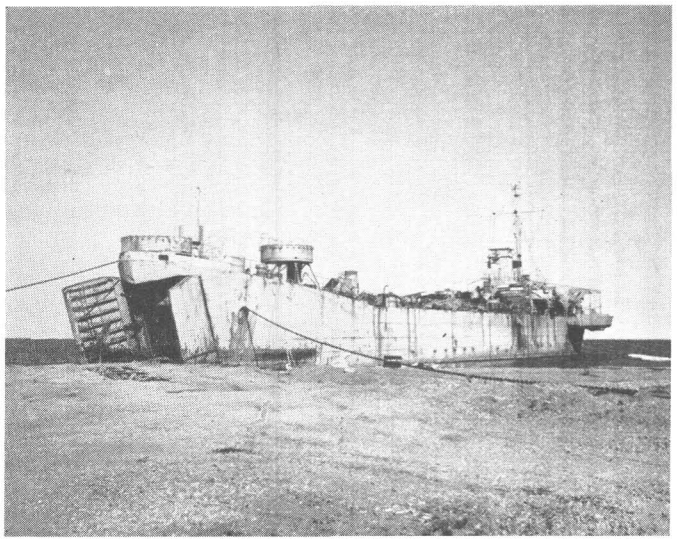

FIGURE 33.—LST *642* beached at Barter Island during Barex '47. Photograph by U. S. Navy.

AIR SUPPORT

Air support, both linehaul from Fairbanks to the Reserve and bush-plane service in the Reserve (see fig. 34), proceeded in a fashion similar to that of previous years. Some of the details of that critically important aspect of Pet 4 are discussed in the sections of the record for 1947 that deal with various activities.

FIGURE 34.—Bush-plane support of Pet 4—a small plane on skis is used for setting out cache in an isolated part of Pet 4 for later use by a geologic party. Photograph by U. S. Navy, 3 May 1947.

In the summer the linehaul northward into the Reserve carried an average of about 25,000 pounds of freight weekly. The maximum weekly total southbound was 125,000 pounds of cargo from Barrow for use at Umiat.

GENERAL CONSTRUCTION AND MAINTENANCE

A large amount of varied construction was planned and executed in 1947. A large part of such work was for supported activities and is discussed along with those activities in a later section. An attempt has been made to include here only work that had some direct connection with Pet 4 itself. In addition to construc-

tion of new or improved facilities, the general repair and maintenance of camp facilities in the Arctic are always substantial items.

In February the contractor force in the Reserve was about 210 men. About 4,500 meals were served weekly, about 5 percent of which were to the Army and the Navy personnels. In March an influenza epidemic swept Barrow village, and nine deaths were reported, but exploration operations were not noticeably affected. A resident physician and surgeon, Dr. Condon, was employed by Arctic Contractors. On 9 March in spite of a continuous fire watch and with extinguishers and pumps that were tested periodically, a fire broke out in the hangar at the airport, and the hangar and all equipment and planes in the vicinity were completely destroyed.

By October the number of contractors' employees in the Reserve had climbed to 450. Subsequently, the number decreased to 300 with the completion of some projects and the coming of winter in December.

Early in 1947 portable camp wanigans and two Failing drill rigs were winterized at Barrow in preparation for the Sentinel Hill and the Skull Cliff core tests. By May an extensive building program was underway at Barrow, including, in addition to construction for some supported activities, an addition to the administration building and improvements in contractor's barracks, such as a water system, partitions, and cabinets. In July, warehouses and shops were under construction as were also several family housing units. In September a new carpenter shop was completed at Barrow as well as additions to the general warehouse, machine shop, and generator building. Also in early September all Barex supplies and equipment were moved from the beach to warehouses or stockpiles. By the end of the year, certain contract repairs had been made to the Alaska Communication System (ACS) station in Barrow village; additions had been made to the airfield warehouse; overhead cranes had been installed in the heavy-duty-equipment and machine shops; family housing was nearly complete; and a new hangar started to replace the one burned.

Airways communication was an important matter throughout Pet 4 as air transportation to, from, and within the Reserve was virtually the only means of transportation, except, of course, for Barex each year, the over-ice freighting, and some local ground and boat transportation. In the latter part of 1946 and early 1947, a transmitter building was constructed at Barrow for operation of the airport by the CAA. An additional installation of low-angle approach equipment was planned at the airstrip.

In March the AACS (Airways and Air Communication Service) installed and operated a homing beacon at the Barrow airstrip. During June and July, work was done on a new CAA operations tower and receiver station at the airstrip and on a radio range, a new antenna, and transmission lines for the CAA installation.

Umiat also had a busy year, because it supported the Sentinel Hill core test. Camp and airways communication systems were greatly improved (see fig. 35), including a standard CAA weather and receiver station and a radio range. These were completed by late summer.

In March a welding shop was constructed at Umiat. By fall, additional quarters had been built and a 40- by 100-foot quonset warehouse. Also a road had been built

FIGURE 35.—Tower and radio building at Umiat on 18 March 1947. Photography by U. S. Navy.

to a proposed drill site near the camp, a 50-kilowatt generator installed at the camp, and a light-duty-equipment shop built.

The urgent need for housing in Fairbanks to take care of the needs of key employees had long been recognized. Such housing was planned and designed early in 1947. Construction of apartments in quonset huts in a compound adjacent to the offices on Garden Island was started in May, along with warehousing and office additions. That construction was nearing completion by the end of the year.

AERIAL PHOTOGRAPHY AND MAPPING

The Geological Survey had received by the end of 1947 all the trimetrogon aerial photographs that would be required. However, the vertical aerial photography of some of the more important areas was still incomplete. The Survey's compilation of planimetric maps on a scale of 1:48,000 from the photographs was about 75 percent complete at the end of 1947. The Survey

had pointed out that new and better maps could be made as the new photography became available.

By the end of the year also, three sheets—Barrow, Wainwright, and Umiat—covering the Reserve on a 1:250,000 scale were nearing completion, as follows: Barrow, 95 percent complete; Wainwright, 60 percent; and Umiat, 80 percent.

GEOLOGY

The Geological Survey in the season of 1947 sent five field parties to northern Alaska to perform the work recommended by the operating committee (see pl. 3). Four of those parties were supported by Navy funds, and one, by Survey funds. Logistic support for all five was supplied by the contractor. Laboratory and office investigations were carried on both in Washington and in Fairbanks as required. George O. Gates remained as the chief of the Survey's Navy Oil Unit.

FIELD SURVEYS

PARTY 1

Party 1 was led by Karl Stefansson; other geologists were R. F. Thurrell, Jr., and J. H. Zumberge. The party used two weasels for moving camp and traveling between outcrops. The party left Umiat on 31 May and between then and 19 July covered an area north of Umiat and in the vicinity of the Colville River. A 10-foot canvas boat was used for river work, mostly on the Kikiakrorak, Kogosukruk, and Colville Rivers. No instrumental control was carried, but all outcrops were plotted on the aerial photographs and on the new 1:48,000-scale planimetric base maps.

Regional dips are low to the north, but some reversals were seen, and several anticlines recognized. The largest anticline was named the Gubik (see fig. 12), and it was mapped by planetable methods.

Two of the geologists of party 1 (Stefansson and Thurrell) attempted to establish west closure on the Wolf Creek anticline by planetable methods between 31 July and 5 August. East plunge had been established in 1946. Because of incomplete exposures, the results were inconclusive.

On 8 August, Thurrell and Zumberge were flown by bush plane to the mouth of the Ipnavik River and from there traversed the Colville River down to the mouth of the Kurupa River. On 14 August, Stefansson and one assistant were flown to the Ipnavik River about 30 miles above its mouth. They completed a river traverse to the Colville on 2 September and returned to Umiat on 6 September. Several structural features were seen, but the Lower Cretaceous black shales are tightly folded and much faulted.

PARTY 2

Party 2 was under the leadership of Charles Whittington, who was assisted by M. L. Troyer. The party was flown late in May to a lake west of the Ikpikpuk River, where weasels and supplies had previously been cached. From there the party made its way into the area of the Kigalik and Awuna Rivers. On 10 September the party returned to Umiat in weasels. The Kigalik, Awuna, and Knifeblade anticlines (see fig. 12) were studied. The Kigalik anticline showed no closure. The large Awuna anticline is closed, but no closure could be proved on the Knifeblade.

PARTY 3

R. M. Thompson, assisted by W. L. Barksdale, geologist, led geological party 3 by boat down the Utokok River from its head in the Brooks Range to its mouth. The party was in the field from 12 May to 31 August, but the last week was spent in a reconnaissance in the Corwin–Cape Beaufort area west of the Reserve. Major emphasis was placed on the petroleum possibilities of the Upper Cretaceous rocks. The geology was plotted on aerial photographs where they were available. Elsewhere, mapping was controlled by carrying a triangulation net. Some of the Upper Cretaceous rocks are fairly porous. Large gravel-covered areas were noted, especially near Driftwood Creek, and it was pointed out that some of them might be potential sites for airfields.

The thick section of rocks between Corwin and Cape Beaufort along the Arctic Ocean is well exposed and was recommended for additional study.

PARTY 4

E. J. Webber was chief of party 4, which investigated the Nanushuk River area, an area along the Colville River between Ninuluk and Prince Creeks, and in the vicinity of the Titaluk and the upper Ikpikpuk Rivers.

Webber and R. L. Detterman traversed the Nanushuk River by boat from mid-May to early July. R. L. Detterman and D. E. Mathewson between 19 July and 1 September traversed the Colville River in canvas boats from Ninuluk Creek to Prince Creek, and traveling in a weasel from 6 to 15 September they studied the lower part of Prince Creek. In the latter half of August, Webber traversed the Ikpikpuk River by boat from the junction of Maybe Creek and the Kigalik River to near the mouth of the East Fork of the Ikpikpuk. Five days were spent studying the Titaluk River, using a small plane for transportation; and the lower Ikpikpuk and the East Fork were examined from the air.

PARTY 5

Geological party 5, George Gryc, chief, and including M. D. Mangus, geologist, was financed with Geological Survey funds. It operated far east of the Reserve in the Shaviovik-Canning Rivers area to obtain information of the eastern part of the Arctic depositional basin. The party was flown in to the Shaviovik on 17 May and traversed that stream by boat with difficulty for 30 miles. On 10 July the group moved to the Canning and traversed that river for 70 miles to its mouth. On 1 September a chartered boat picked the party up and took it to Barter Island, whence it returned to Umiat by air on 5 September. The lack of good aerial photographs or base maps required that party 5 carry its own instrumental control over the entire area covered.

Oil-bearing sands were discovered in the rocks of the area. The great bend in the north front of the Brooks Range appears to be the result of older rocks to the east pitching under the flatter terrain to the west rather than to any change in direction of fold axes in the mountains.

All geological field parties left the Reserve in September. The results of the work on the Wolf Creek and Gubik anticlines had been disappointing; the Oumalik anticline was believed to be too far north to contain favorable sands.

OFFICE AND LABORATORY STUDIES

At the seventh meeting of the operating committee in November, R. M. Chapman, head of the Geological Survey's Fairbanks Laboratory reported that the laboratory staff consisted of 2 geoligists, 4 subprofessional employees, and 1 full-time clerk-typist. Two geology students from the University of Alaska were employed part time. Representative microfossil samples had been prepared from all field party collections and from all drill holes although samples from some intervals remained to be worked. Porosity and permeability tests were completed on samples from all drill holes and on about 75 percent of the field samples. Strip logs were completed for all drill holes except Umiat 2 and Simpson 1 then drilling.

Heavy-mineral studies were continued in 1947 by E. H. Lathram. The possibility of correlations by means of the heavy minerals thus far studied appeared limited, but studies were to continue in the hope of finding more useful criteria. Helen Tappan Loeblich continued her studies of the microfossils from Pet 4 and, in spite of the difficulty of making precise correlations in a new area with limited and unfamiliar material, made good progress in correlating the work of the field parties and the sections penetrated by drilling. A sound base was being developed for later greater use of micropaleontology in Pet 4.

T. G. Payne made extensive studies in 1947 of sedimentation of northern Alaska in Cretaceous and Tertiary time. His results indicated that oil-bearing sands are likely to be largely limited to shoreline belts within a regional deltaic pattern of sedimentation. This hypothesis was found to be essentially correct. It was modified and expanded as Pet 4 went on and became an increasingly influential guiding principal in the program. Payne also had studied the correlation of the three holes at Umiat and had found Umiat test well 3 to be 150 feet stratigraphically above Umiat test well 2 and 1,100 feet above Umiat test well 1.

GEOPHYSICS

Geophysical investigations in Pet 4 in 1947 included seismic surveys, an air-transported gravity survey, and temperature and other measurements at test wells.

SEISMIC SURVEYS

The seismic program for 1947 was largely outlined at the fifth meeting of the operating committee in November, 1946. It was somewhat modified at the sixth meeting in April, 1947, although a substantial part of the work was accomplished by that time. (See pl. 3.) Except as otherwise noted, all geophysical work was by the United Geophysical Co.

PARTY 43

Party 43 was charged with the responsibility of connecting across the coastal plain the seismic work in the Cape Simpson area with an area near the head of the Ikpikpuk River and with the work of party 46. The party was in the field from 17 March to 1 September. The seismic data were studied and reinterpreted a little more than a year later.

The route of the party was southeast from the Cape Simpson area to the west shore of Teshekpuk Lake, thence southward for 50 miles to a point about 15 miles east of the junction of the Ikpikpuk and Titaluk Rivers. A detailed survey was then made with reconnaissance lines extending eastward about 20 miles toward Sentinel Hill. Both vertical control and horizontal control were carried by the party, and shotholes ranged from 20 to 200 feet in depth.

Three phantom horizons gave good reflections in the northern part of the area, but the reflections became progressively poorer southward, and only the shallowest horizon could be carried southward all the way.

PARTY 46

Party 46 was led by Samuel O. Patterson. The fieldwork went on from 28 March to 7 September. The

following data on the equipment and the personnel are included as illustrative of a typical, full-scale seismic operation in Pet. 4. Heavy equipment for the party included 8 weasels, 4 tractors, 3 sleds, 1 Micheler sled, 14 wanigans, and a drill. The personnel for the party included:

Drilling operations	4
Recording operations	4
Shooting operations	1
Survey operations	4
Shop operation	3
Camp operation	6
Total	22

Party 46 was to investigate two areas in the vicinity of the confluence of the Titaluk and the Ikpikpuk Rivers. One of these had been indicated as an area of magnetic anomaly and low gravity; the other one was both a magnetic high and a gravity high. The latter actually was studied by party 43. The shooting revealed the presence of a large anticline, since named the Oumalik anticline. Approximately 21 miles along the axis was surveyed. The work indicated an unconformity in the subsurface. Above the unconformity the plotting showed 400 feet of closure and a closure of 800 feet below the unconformity.

GRAVITY SURVEY

On the basis of experience gained in 1945 and 1946, it was decided to carry on an air-transported gravity survey to obtain quickly a regional gravity picture of the previously unsurveyed parts of the area between the Meade and the Colville Rivers and north of latitude 69°45′. The area includes about 13,500 square miles. Stanley W. Spannare was placed in charge, and he was assisted by a gravity-meter operator and a Wien Alaska Airlines pilot. A lucid and detailed report on this operation was prepared by Mr. Spannare under date of September 1947 and is the source of the extremely condensed record set forth here.

The operation was entirely practicable. It went on from 11 April to 5 September. In all, 491 stations were observed in 69 operating days; the average station spacing was 5 miles. Part of the operation was out of Umiat, part out of the camp of party 46 in the Oumalik area, and part out of Barrow. At first the plane was on skis and later was converted to pontoons.

It was concluded that—

1. Provided planimetric maps or vertical photos are available and terrain is suited to numerous landings, an airplane can be used to obtain speedily and at low cost a good regional gravity picture over a large area.

2. If possible, base camps should be centrally located, and fuel caches should be provided, at least in those areas distant from the base.

3. Operations can be carried on in Naval Petroleum Reserve No. 4 through April and May though at a lower production rate than in July and August.

4. Reasonably accurate results can be obtained with surveying altimeters, but at a high cost because of reruns and the added need for base observations.

5. A sensitive automatic recording base altimeter used in conjunction with a similarly sensitive field instrument would greatly expedite such a survey.

TEMPERATURE AND OTHER MEASUREMENTS AT TEST WELLS

In the discussion of the drilling of the Sentinel Hill core test, it was pointed out that, at the completion of the hole, tubing was run in to 1,172 feet and was filled with diesel oil in preparation for future temperature surveys. When visited in August 1948 by J. H. Swartz and G. R. MacCarthy, of the Geological Survey, for the purpose of making temperature measurements, it was found that mud slides from the adjacent bluff had completely covered the cellar and the pipe, and no readings could be taken. In the same month, however, MacCarthy and Swartz were able to make a careful temperature survey of the Skull Cliff core test to a depth of 500 feet.

A temperature survey by Arcon (Arctic Contractors) of Simpson test well 1 on 19 August indicated the bottom of permafrost at 890 feet. On 22 December another temperature survey yielded the following temperatures at the depths shown:

4,800 feet	102°F
5,378 feet	100°F
5,478 feet	108°F

Near the end of the year a seismic velocity survey was made at Umiat test well 2. Schlumberger resistivity measurements were made in the hole at regular intervals, and 6 logs covering the hole to 6,203 feet were made. The bottom of permafrost was estimated at 750 feet. At the close of the drilling, an electric log, a seismic survey, and a temperature survey were made of Umiat test well 2. The temperature at 6,198 feet was 104°F.

DRILLING

The Pet 4 drilling program in 1947 was by far the most extensive attempted to that time. It included the starting of two fairly deep tests, Umiat test well 2 and Simpson test well 1, and the completion of another; and the drilling of several shallower core tests at widely scattered localities. The bulk of the drilling program was authorized by the operating committee at its fifth meeting in November 1946, but substantial modifications were subsequently made, especially at the sixth meeting in April 1947. The drilling was plagued with perhaps more than its share of bad luck, and in retrospect, much

of the difficulty could be charged to learning how to operate in the Arctic, especially how to deal with permafrost. Nevertheless, most of the objectives of the program as laid out were accomplished successfully.

The following discussion covers first the core-drilling program and then the drilling of the two deeper tests.

CORE DRILLING

SENTINEL HILL CORE TEST

The Sentinel Hill core test was supported almost entirely from Umiat. The site was about 20 miles northward from Umiat at the foot of the bluff on the west side of the Colville River. Assembly of equipment, supplies, and materials began late in 1946, and the first tractor train went from Umiat to Sentinel Hill on 16–19 January. The drill rig, a model 1500 Fail-

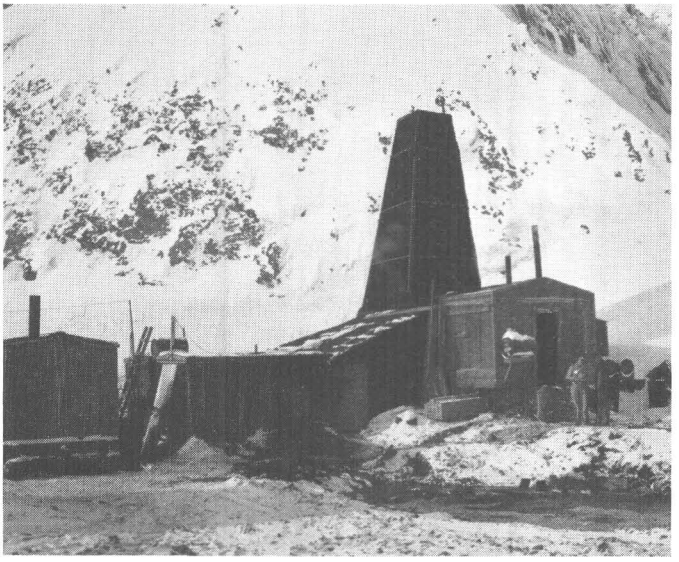

FIGURE 36.—Camp and rig at Sentinel Hill core test 1 a few days before completion of the drilling. Photograph by U. S. Navy, 17 March 1947.

ing, and wanigans left Umiat on 21 January. The wanigans, of course, provided quarters, galley, heating, and water supply. One weasel was also assigned to the project. Personnel comprised 10 men, including the cook and the tractor driver. Two 12-hour shifts were worked 7 days a week. There was a little delay in plane transportation of crews and supplies from Fairbanks because of the extremely cold weather there at the time with attendant ice fog.

Light and power was supplied by a 15-kilowatt generator driven by a gasoline engine. A 20-kilowatt diesel-powered generator was recommended for future operations of the Sentinel Hill type.

The drilling equipment arrived at the site of the core test on the same day it left Umiat, the trip had required a total of about 18 hours. Included in the load were 300 barrels of gasoline, diesel oil, and lubricants that were required to complete the project, and drilling supplies, largely tubing and cement.

By 26 January the cellar was dug and the rig set up, and the hole was spudded in. In spite of darkness, cold weather, and one successful fishing job, the hole was cored from 109 feet to its total depth of 1,180 feet in 53 days. (See fig. 36.) Coal or lignite and bentonitic shale and sandstone were penetrated. After completion of the hole, 1,172 feet of 2½-inch tubing, plugged at top and bottom and filled with diesel oil, was run in for use in later temperature surveys. On 25 March the rig and equipment were hauled back to Umiat.

The Sentinel Hill core test was a valuable experiment in cold-weather operations. Much was learned that was directly applicable to later operations. About one-fifth of the cost was the cost of winterization of the equipment.

SKULL CLIFF CORE TEST

The drilling of the Skull Cliff core test was similar to but less successful than the Sentinel Hill operation. The location was about 1¼ miles inland from the oil seepage at Skull Cliff. The objective was to obtain cores of the rocks to a depth of 1,500 feet. A tractor train, similar to the Sentinel Hill train, was made up at Barrow and left for the location on 20 January. It reached the site on 26 January. Water for drilling was difficult to find—all lakes in the vicinity, on testing with a steam point, appeared frozen to the bottom. Finally, a passing Eskimo told the crew of a lake with water under 4 feet of ice 2 miles northeast of the camp. Further trouble was found setting the surface pipe. On 4 February coring was started at 150 feet and continued to 779 feet. While drilling at that depth, the drill pipe broke, and all fishing attempts were unsuccessful. While awaiting more fishing tools from Barrow, the drilling mud was not circulated because it was thought that the cuttings might jam the lost tools. As a result, the mud froze solidly to a depth of 250 feet, and the hole was abandoned. To provide for later temperature measurements, the hole was bailed to 527 feet, filled with diesel oil, and capped with a wooden plug. On 17 March the equipment was sledded back to Barrow.

Like the Sentinel Hill core test, the Skull Cliff test yielded much valuable information and experience in cold-weather activity. During coring in February, the temperature dropped to as low as −54° F, and wind velocities ranged from 10 to 50 miles per hour. As at Sentinel Hill, the cost of winterization was about one-fifth of the total cost.

SEABEE CORE TEST 1

Seabee core test 1 was near the Barrow camp and was planned to reach a depth of 1,500 feet. Objectives were to experiment further with drilling methods and

to obtain stratigraphic information. The equipment that had been returned from Skull Cliff was used, and the hole was spudded in on 29 March. As before, difficulty was experienced in properly cementing the surface casing, and it was recommended that in the future the hole be steamed for a few hours to heat up the formation before cementing.

Logistics were no problem at the hole because the operation was supported by the main camp. Reverse mud circulation was tried and was found to be less successful than normal circulation. From 3 to 28 April, the hole was cored from 100 feet to 1,442 feet, where the test was stopped because the capacity of the rig had been nearly reached. The hole was prepared for a temperature survey by the running in of 708 feet of tubing.

IKPIKPUK CORE TEST 1

The Ikpikpuk core test 1 was designed to penetrate, to a depth of 400 feet or more, the rocks on an anticline now called the Oumalik anticline that had been revealed in the area of the Ikpikpuk and Oumalik Rivers by seismograph party 46. The purpose was to obtain stratigraphic and structural data. The location was near the campsite of party 46 in order to use the camp for support. A drilling foreman, 2 other drillers, and 4 floormen were employed in addition to the supporting crew from party 46. The drill used was a Failing Model 1500 core drill and auxiliary pumps formerly used for shotholes by party 46. Supplies were flown in by a DC 3 on floats in April.

On 6 July rigging-up was started. Ice and sand caused the hole to cave and allowed circulation to break out around the surface pipe. By the time the hole was 179 feet deep, 20 feet had been cored. At that point the drilling string twisted off at 90 feet below the surface, and all fishing attempts ended in failure. The hole was abandoned, and seven stands of drill pipe and the bit were left in the hole. Several attempts were made to find a better location.

OUMALIK CORE TEST 1

Finally a new location was selected on a hill about a quarter of a mile away where it was believed that ice and sand would not present such problems. This was called Oumalik core test 1. Two days were required to rig-up for the test. Cores were pulled at intervals, and the last 10 feet, to a total depth of 392 feet, were cored. There the drill pipe twisted off, and eight stands of drill pipe and core barrel were abandoned in the hole.

OUMALIK CORE TEST 2

In September a third attempt was made to drill a core test in the same general area. The drilling was by the shothole crews of parties 43 and 46 and was supervised by S. O. Patterson and Perry Wilder. Regular shothole equipment was used, including a Model 1000 Mayhew drill. No core barrel was available, and ditch samples were taken for stratigraphic information. When the hole was at a depth of 180 feet, a weld holding the surface pipe to a bell nipple with a mud outlet broke, and the surface pipe fell into the hole. It was fished up, split, and half of it removed; the other half was dropped and pushed aside in the wall. At 190 feet the drill pipe plugged. Pressure, possibly the pump pressure, forced the drill pipe out jamming the kelly into the crown block and breaking cables and generally fouling the rigging. After clearing things up it was found that the bit and a drill collar were stuck in the bottom of the hole, and the test was abandoned.

These three unsuccessful attempts pointed up some of the difficulties of drilling in permafrost, especially the importance and difficulty of a good cement job on the surface casing and the danger of freezing the mud if circulation stopped for any considerable period. Also, the futility was demonstrated of attempting a job in isolated areas in the Arctic under difficult conditions without adequate equipment and supplies in first class condition. These matters were carefully studied by the contractor in order to use the experience in obviating further difficulties as Pet 4 progressed.

TESTING OF UMIAT CORE TEST 1

Umiat core test 1 had been drilled in 1946 to 572 feet. It penetrated oil sands from 248 to 390 feet. In 1947 the productive capacity was partly tested. (See fig. 37.) The testing was started in September in order to

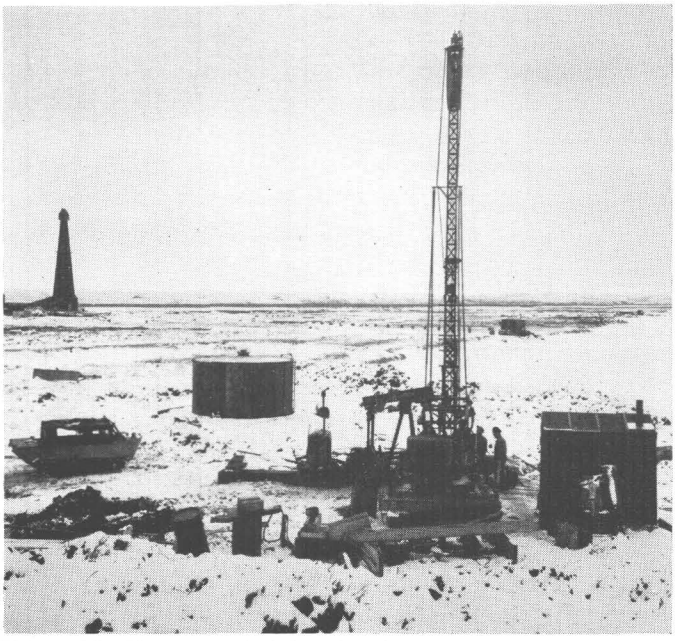

FIGURE 37.—Umiat core test 1 undergoing pumping test; Umiat test well 2 in background. Photograph by U. S. Navy, 10 October 1947.

have the information available for the November meeting of the operating committee. When reopened the fluid level was at 145 feet, and the hole was bridged at 240 feet. The hole was cleaned out to 457 feet with a Keystone spudder. A string of 2½-inch tubing was run in. On 6 November pumping started, and between then and 18 November the average yield was 14 barrels of oil a day. There was no water.

The hole was shot with dynamite and then tested again between 2 November and 15 November. An average of 24 barrels a day was recovered. Air temperatures ranged from −20°F to 20°F. At 22°F the average gravity of the oil was 34.0° API.

DEEP DRILLING

SIMPSON TEST WELL 1

At the fifth meeting of the operating committee in November 1946, a deep test was recommended in the Cape Simpson area on a closed structure mapped by seismic methods in 1946. The purpose was to test the Upper Cretaceous section in that area. The committee felt that the objective of Pet 4 would not be reached until a carefully located test in the general area of the Cape Simpson seepages was drilled. The location was approximately 70°57′ N., 155°22′ W. The rig used was a National 50 which was designed to drill to about 5,000 feet using 4½-inch drill pipe. The permanent personnel was 26, and in addition, 20 temporary employees were used as required. Housing included a 20- by 48-foot quonset hut for warehouse, office, store, and sick bay; 10 jamesway huts for living quarters; a jamesway hut for galley; and several wanigans. The camp was on open tundra, and mud was a serious problem in warm seasons.

The hole was spudded in on 14 June, and by 16 June 18 feet of 24-inch conductor pipe was set. On 20 June 115 feet of 16-inch casing had been set. Oil sand was cored from 218 to 221 feet, and a little trouble was caused by gas. Another oil sand was cored from 383 to 403 feet, and a small sample was collected. A temperature survey indicated the bottom of permafrost at 890 feet. On 18 July 11¾-inch casing was set to 1,028 feet. Drilling and coring 10-foot intervals approximately every 200 feet was continued to 3,003 feet, which was reached on 29 July. At that time the hole was yielding substantial gas, which was piped to the boiler for fuel. The gas died out in a few weeks. With increasing depth the hole caved badly. By the time of the November meeting of the operating committee, Simpson test well 1 was drilling at about 6,000 feet, and at the meeting Project Manager Gillespie pointed out that the rig was overtaxed at that depth. On November 30 attempts were being made to recover metal dropped in the hole, which had reached 6,094 feet. By the end of the year the metal had been cased off, and drilling continued.

UMIAT TEST WELL 2

On 3 February the drilling of Umiat test well 2 to 3,000 feet was authorized. The hole was justified by the production of 24 barrels a day from Umiat core test 1 and by the fact that the area of closure had not been determined. The proposed location would have had a poor foundation for both camp and rig, and after a study a revised location with better foundation possibilities and nearer the Umiat camp was recommended and was authorized on 17 March.

In dismantling the derrick at Umiat core test 1 in May, the derrick was twisted beyond repair, and the use of another derrick had to be authorized. Camp and derrick were set on an area 100 by 200 feet which was first stripped and then raised by a gravel pad. On 25 June the well was spudded in. Water came from a nearby lake. The waterline was supported on halves of oil drums in which oil was burned in cold weather to keep the line from freezing.

Conductor pipe was cemented in to a depth of 103 feet on 28 June. To 1,006 feet, seven sandstones with oil shows were penetrated and tested, and it was determined that the oil-bearing zone was from 315 to 745 feet. At the end of July a packer and 50 feet of tubing were lost in the well but were recovered without difficulty after only 3 hours. The bottom of permafrost was found to be at about 750 feet.

Again on 3 September, at a depth of 2,791 feet, a tool joint failed, and 1,607 feet of drill pipe, collars, and bit were left in the hole. As before, the damage was repaired with only a few hours delay. Early in October the melting of permafrost from heat from the mud pits caused the derrick to tilt a little out of plumb, and it was straightened with jacks and shims.

The total depth of 6,212 feet was reached on 6 December, and an electric log, a seismic survey, and a temperature survey were run. At 6,198 feet the temperature was 104°F. Dismantling began on 12 December. Before final capping the hole was bailed to 1,030 feet for later temperature measurements. After bailing the hole began to yield gas which was tested at 15,520 cubic feet per day.

At the November meeting of the operating committee, Mr. Gillespie warned against the practice of extending holes to depths far beyond the rated capacity of the rigs. Umiat test well 2 was planned originally to go to 3,000 feet, was drilled with a rig rated at 5,000 feet, and eventually actually reached 6,212 feet.

OTHER ACTIVITIES IN NAVAL PETROLEUM RESERVE NO. 4

As Pet 4 continued and expanded, other activities appeared and were incorporated in some degree into the overall effort. Some of these other activities, like the basic control work of the U. S. Coast and Geodetic Survey, were of major importance to Pet 4 itself. Much of the closely related work such as this was financed in whole or in part by Pet 4 and became essentially a part of the oil exploration program. Others of these activities were partially to very remotely related to Pet 4 but were supported and assisted, generally on a repay basis, in a spirit of genuinely wishing to help other interests do their jobs in the Arctic in so far as possible.

In 1947 the support of such additional projects became a major item and remained so until the close of Pet 4. Thus, the justification for the existence of Pet 4 had added to it to some degree the justifications for all of the additional activities.

In March, employees of the Coast and Geodetic Survey arrived in Barrow to start geodetic control work along the Arctic coast southwest from Skull Cliff. In February representatives of search and rescue units of the Alaska Scouts under the direction of the Commanding General, Alaska, departed Barrow by dog team for Beechey Point. The expedition returned successfully in March. The party was supported by supplies dropped from an Army B17, which was based at Barrow. Near the end of May a detachment from the Naval Medical Research Institute entered Naval Petroleum Reserve No. 4 to study mosquito control, an ever-present problem in the Arctic summer.

Change order F issued on 8 January assigned to Arcon (Arctic Contractors) support for the establishment and operation of a field test station for Arctic research by BuDocks. The estimate of cost was $50,000 including a $2,000 fee. Navy Seabees for this Arctic Test Station began to arrive in Barrow in April. By the latter part of the year, a 40- by 100-foot quonset hut had been completed for use as the Laboratory of the Seabee detachment.

In May an extensive building program was underway at Barrow to provide housing and laboratory facilities for the Arctic Research Laboratory of the Office of Naval Research. It was not until 1 August, however, that change order H was issued in the estimated amount of $50,000, including a $1,500 fee, to provide for the support and maintenance of the ARL (Arctic Research Laboratory). In August the ONR (Office of Naval Research) party arrived to occupy the space provided.

At first the ARL was assigned two 40- by 100-foot warehouses and a 20- by 56-foot quonset hut. Assigned also were family quarters. Later the quonset hut was converted to an animal house, and one of the warehouses, to a laboratory.

BEETLE PROJECTS

But by far the largest and most complex extracurricular activity supported by Pet 4 in 1947 was the so-called Beetle projects. At that time, long-range radio navigation (Loran) was being developed by the Radiation Laboratory of the Massachusetts Institute of Technology. Support and execution of developments were largely carried out by the Army. As part of this work, a chain of stations was to be built across the Arctic coast of North America, and a subsidiary station (Beetle A) and a monitor station (Beetle B) were to form the western end of this chain. The Corps of Engineers was responsible for all construction on the Alaskan projects. Equipment was to be installed by the Watson Laboratory of Red Bank, N. J., and the Army Air Material Command. The Army Airways and Air Communications Service (AACS) was to occupy the completed installation.

On 18 April the Air Material Command called a conference in Washington at which the Beetle requirements were supplied to the contractor. The Navy agreed to transport supplies for the projects to Barrow and to perform the construction under contract NOy–13360, the Pet 4 basic contract. The additional load required the adding of another ship to Barex '47 and the flying of large quantities of supplies needed early so that foundations could be completed before the arrival of Barex. This advance preparation would be a prerequisite to completing the projects in 1947.

Work got underway immediately. A committee entered Pet 4 in April to choose a site for Beetle A, which involved the erection of 625-foot tower, which had to be far enough from Barrow so as not to constitute a hazard to airplanes. A location near Skull Cliff was chosen. In May a temporary camp of jamesway huts on skids was built in Barrow and freighted to Skull Cliff, and on 31 May actual construction started.

Although change order I, which provided for the Beetle activity, was not issued until 6 October, the work went on meanwhile. In brief, the change order in the amount of $1,998,759, including a $60,000 fee, provided for project 19 (Beetle A), consisting of a 625-foot tower, an antenna system, operations buildings, housing, messhall, and storage facilities, and installation of equipment; project 20 (Beetle B), consisting of construction of a monitor station at Barter Island, including an antenna system, operations building, housing, messhall, and storage facilities, a landing strip, and installation of equipment; and project 21 (Beetle C), consisting of construction of a temporary direction-finder

station near Point Barrow, including an antenna system, operations and housing facilities, and installation of equipment, the construction of air-sea rescue facilities at Barrow and Barter Island, including parking areas for gliders, supply and storage buildings, extension of the Barter Island runway to 5,500 feet, and the handling and stockpiling of materials and equipment for future use.

BEETLE A

Skull Cliff is a difficult place at which to erect a 625-foot steel tower. There is no bedrock foundation close to the surface. The material underground to tens of feet is frozen unconsolidated material and ice.

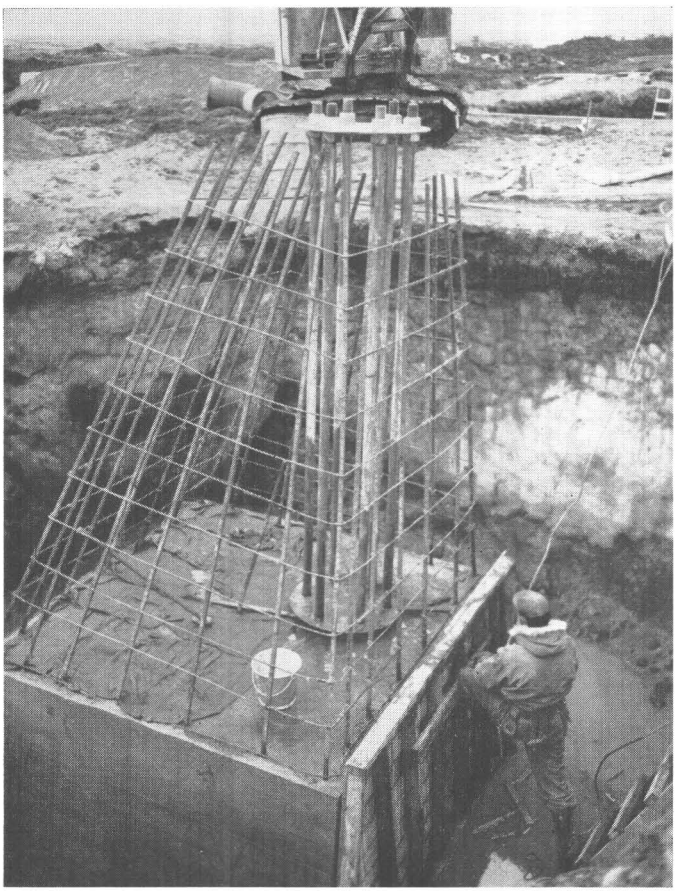

FIGURE 38.—Foundation pier for one of the legs of the Skull Cliff tower (Beetle A), 2 July 1947. Photograph by U. S. Navy.

Fred Endresen, of Arctic Contractors, was placed in charge and excavation work started on 1 June. Special care was taken in handling the permafrost, and after the ingenious solving of unpredictable difficulties, the foundations were complete and ready for the steel by August. Supplies and materials that had not already come in by air reached the Reserve on Barex. It will be recalled that some of this material was unloaded at Skull Cliff, but because of bad weather, some had to be offloaded at Barrow and freighted to the site.

FIGURE 39.—Installing base plate for one of the legs of the Skull Cliff tower, 17 July 1947. Photograph by U. S. Navy.

While the foundations were still in preparation, (see figs. 38, 39) the steel crews assembled the lower parts of the tower. By mid-August the tower stood at 200 feet; by the end of the month it was topped off. (See fig. 40.)

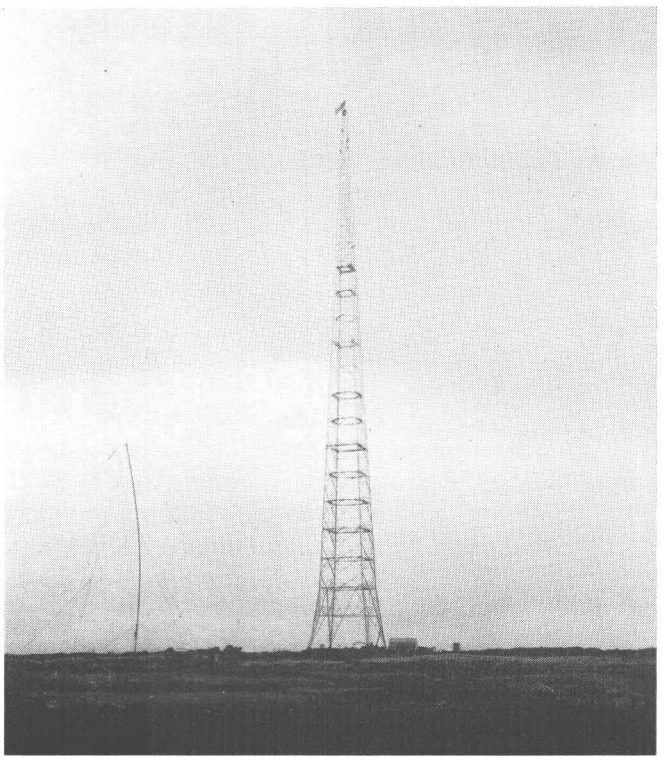

FIGURE 40.—Completed Skull Cliff tower, 625 feet high, 26 August 1947. Photograph by U. S. Navy.

The total weight of the tower steel was 300,000 pounds. Work then proceeded on the completion of other facilities. This later work was greatly complicated by the thawing of the surface in the vicinity of the job and the aggravation of the difficulty by the continual churning up of the mud with heavy equipment. The later concrete work was further complicated by the advent of cold weather, necessitating the use of heated water in the aggregate, heating of the mixers, and curing under tarpaulins with heat applied.

Cold windy weather also hindered the construction of the camp which would accomodate 40 men, including warehouse, laundry, barracks, and other buildings. Lumber, equipment, and stores temporarily stowed on the thawed tundra a few months before were tightly frozen and hard to remove.

Because of anticipated turn over, especially among the steel workers, small weekly quotas of replacements were sent to Fairbanks from Seattle and Minneapolis. There were no delays because of labor shortages. Ray Bills, the rigger foreman, finished the job with his original crew.

In spite of all the troubles encountered, the station was turned over to the Army in November, although the tower was watched for settling until March 1948 as unequal settling of as much as one-half inch would have caused failure of the tower.

In all, good fortune favored an unusually hazardous undertaking that had to be done in a hurry. There were no serious accidents and no fatalities on the job. Much credit is due the contractor's superintendent and the steel foreman for skill and good judgment.

Both the Army and Navy authorities sent written commendations to the contractor. The Navy representative reported that "The efficiency of the contractor was at all times outstanding and commendable in successfully accomplishing a unique and difficult task in record time * * *."

BEETLE B

The Beetle B installation at Barter Island was to monitor the pulses transmitted by the master station in northern Canada and the subsidiary station at Skull Cliff. Jim Dalton, construction foreman, made a reconnaissance of Barter Island on 18–20 June and determined that a sand and gravel spit projecting eastward from the island would be the best place for the airstrip. It also was proposed to build the camp on the spit, but the Army preferred the higher tundra near the base of the spit. A later reconnaissance between 28 July and 3 August resulted in the erection of a radar screen and landing guides for the anticipated beaching of the LST (landing ship, tank). The landing has already been described in the discussion of Barex '47. The LST served as an excellent construction camp during Beetle B.

The western end of the spit was first cleared and dragged to make a temporary strip. Next the overburden was removed from the western 3,000 feet of the spit, and the area was backfilled with gravel, leveled, rolled, smoothed, and put in operation with a DC3 landing on 26 August. The complete runway, 150 by 5,500 feet was finished on 5 October. By that time the ground was freezing and difficult to work. A lighting system was later installed. In all, about 15,000 yards of overburden was removed, and 40,000 yards of gravel, backfilled.

Next, the camp construction was started. Buildings were placed on gravel pads laid directly on the tundra. About 16,000 yards of gravel was moved into the camp area. Concrete slabs were poured for laundry, kitchen, powerhouse, and shop buildings. The radio operations and remote transmitter buildings away from camp were on piling instead of gravel mats. The masts for transmitter and antenna systems were on pile foundations. Construction was completed in mid-November, and LST *642* was secured.

As early as December the concrete slabs began to crack and sink unequally. Heat had been transmitted through the slabs, and melting of the permafrost followed. When it was thought that equilibrium had been reached, the machinery was raised, and the floors repoured to level. Settlement continued, however, and more elaborate measures had to be taken in 1948.

BEETLE C

Much of Beetle C was carried out at Barrow although there was some work both at Skull Cliff and at Barter Island. Because a larger program was contemplated soon for the Beetle C plant at Barrow, only the barest essential equipment was installed to provide for the Army's needs. The contractor's camp facilities and CAA radio facilities were utilized to the maximum extent.

By August construction was well along on the Army Sea-Air Rescue installation, consisting of housing and a parking area for gliders and small planes. Most construction materials, however, came in on Barex '47. Much of the electronic equipment came by plane from Anchorage and was installed by Army men under the direction of MAJ William Geyser. Work on the AAF Polar Direction Finder Net was begun at Barrow in September. This included an operations building and powerhouse, a remote transmitter building, an underground control cable, a 9,000-foot antenna, and a receiver antenna system. Laying of the underground cables and outside construction was done as soon after the expedition as possible.

The Sea-Air Rescue group at Barrow was to consist of 8 officers and 25 men with 4 gliders. A smaller detachment was to be at Barter Island.

Beetle C was nearly completed before the end of 1947.

SUMMARY OF 1947

Much progress was made in Pet 4 in 1947. One deep test was completed, and another was almost finished. A total of more than 15,000 feet of drilling was done. Winter freighting totaled 749,000 ton-miles. Barex brought in 20,000 tons, which was unloaded in 6 days.

The picture of the regional geology developed satisfactorily. Especially valuable was the development by T. G. Payne of a theory of facies changes that subsequently was very useful in planning the program. Good progress was made in geophysical exploration and the air-transported method of gravity-meter exploration was further tested and improved.

The Beetle projects imposed a heavy burden, but all three of them were successfully accomplished. In total, the effort expended for interests other than Pet 4 almost equaled that for Pet 4 itself. The year 1947 could appropriately be designated as the principal year of services to other activities.

On analyzing the situation at its last meeting of 1947, the operating committee found that the prospects of finding oil in the Reserve were as good if not better than when Pet 4 started. It recommended continuation to at least 1952 and indicated that the original objectives could not be reached with the funds thus far appropriated.

A number of important changes in the personnel took place in 1947—Walter A. English appeared as chief technical advisor to the DNPR; and, henceforth, Pet 4 had the advantage of his broad experience, keen intelligence, and extraordinary power of analysis and summarization. Ted Mathews was promoted to project superintendent for Arcon. Drex Spaulding became chief engineer; and Ed Rusing, chief accountant. CDR P. W. Roberts was replaced as OICC late in 1947 by CDR G. E. Fischer. Lieutenant Commander Wolfstein, ROICC at Barrow, was relieved by Lieutenant Commander Urquhart.

FIFTH YEAR—1948

GENERAL PLANNING AND ADMINISTRATION

Pet 4 swung smoothly into its fifth year in accordance with the plans laid at the seventh meeting of the operating committee the previous November. As the year began it was not yet known whether or not the long-range plan recommended by the committee would finally be approved and followed.

Several important changes in the personnel took place in the early part of the year. On 22 January, Lieutenant Commander Urquhart was relieved by LCDR Lawrence P. Frate, CEC, USN, as ROICC in Barrow. Lieutenant Commander Frate was destined to play a key roll in Pet 4 for several years. Ted Mathews was promoted to assistant project manager for Arctic Contractors in Fairbanks, and Drex Spaulding moved up to project superintendent at Barrow. Jack Adams, who had been personnel manager, went to Barrow as assistant project superintendent. William Fackler was designated chief petroleum geologist for Arctic Contractors. In 1948 the ROICC at Seattle was LCDR E. C. Bamberg, and J. H. McCormick was the purchasing agent for Arcon.

The winter complement of the contractor in the Reserve was about 280, but this number increased to 350 with the start of geophysical operations. During the winter about 9,000 meals were served each week; about 6 percent of these were to the Army (AACS) and the Navy personnels. The linehaul traveled from Fairbanks to the Reserve nearly every day and made many shuttle flights within the Reserve. During January Navy photographers returned to Pet 4 for additional material to fill out the film of exploration operations.

The eighth meeting of the operating committee convened in Washington, D. C., on 20 April. Voting members present included Commodore Greenman, chairman; J. C. Reed, Geological Survey (alternate for Director W. E. Wrather); L. W. MacNaughton, DeGolyer and MacNaughton; A. A. Curtice, Hoover, Curtice, and Ruby, Inc.; COL O. F. Kotick, who had by this time been designated Deputy Director of Naval Petroleum Reserves; and LCDR F. A. F. Cooke, BuDocks. Walter A. English, advisor to the DNPR, and Commander Fischer, OICC, were present as were additional representatives of Arctic Contractors; United Geophysical Co.; Hoover, Curtice, and Ruby, Inc.; and the Geological Survey.

The agenda of the meeting included consideration of the final reports on the 1947 field and laboratory geological investigations, on drilling operations, and on the geophysical work. Also to be considered were detailed plans for 1948 and preliminary plans for 1949, tentative long-range plans, and the financial situation of Pet 4.

Commodore Greenman advised the committee of the approval of the long-range plan by the Secretary of the Navy, the Joint Chiefs of Staff, the Munitions Board, the Bureau of the Budget, and the Armed Services Committee of the House of Representatives. The plan called for five more operating seasons after 1948 at an estimated cost of $28 million with an initial

appropriation of $15 million. The DNPR suggested that BuDocks proceed with the purchase of supplies for 1949 in view of the likelihood that Pet 4 would go on. Sufficient funds were not available, but $950,000 had been advanced from the Naval Procurement Fund, and $800,000 worth of expendable supplies would later be purchased with the anticipated appropriation and would be shipped on Barex '48 or by boat, rail, and air if required sooner.

Some modifications of the 1948 program had previously been approved separately by the committee members at the DNPR's request and were well underway at the time of the meeting. These included the rehabilitation of the National 50 rig at Simpson and the drilling of Simpson test well 1 to 7,200 feet in an effort to penetrate to the Lisburne group, if present, or to basement rocks. The modifications also included the shooting of a seismograph line eastward from the existing Simpson-Ikpikpuk line to pass north of Teshekpuk Lake and another line from Fish Creek southwestward to tie with the Simpson-Ikpikpuk line about 50 miles south of Teshekpuk Lake.

The financial status of Pet 4 was summarized at the eighth meeting of the operating committee by Commander Fischer. It was apparent from the summary that, if new funds were not forthcoming, it would be necessary to cut back immediately in order to assure an orderly close out.

Project Manager Gillespie reported that procurement was proceeding according to plan. A heavy-duty rig, a Wilson Super Titan of 15,000-foot capacity, had been purchased. Construction equipment and spare parts were supplied to the contractor at no cost from surplus stocks at Pearl Harbor at a saving of more than $500,000.

George O. Gates, chief of the Navy Oil Unit, Geological Survey, summarized the status of geological work. Plans were complete for two field parties in 1948 as previously decided. The details of planning had been slightly modified because of local field conditions. One party, financed by the Geological Survey, would be working east of the Reserve.

The committee, after discussion, recommended an experimental test of color aerial photography for use in geologic interpretation.

John Legge, geophysical supervisor for the United Geophysical Co., who shortly was to be relieved by Howard Myers, reported that refraction profiling on a loop from Barrow to Simpson to the Meade River indicated, on the basis of about 60 percent completion, a basin southwest of Barrow. Reflection profiles had been shot so as to form a cross over the Fish Creek gravity anomaly, and current work was tying the Fish Creek to the Simpson area.

The committee recommended for future study the use of oil-base mud for drilling to eliminate any expansion of montmorillonite clay by water. The contractor was requested to estimate the cost of a small refinery at Umiat to use Umiat oil in Pet 4 operations. BuDocks was to investigate the use of windmills for electric-power generation.

The committee recommended that Arctic Contractors have (1) party 47, the refraction seismograph party, try to locate the high-velocity beds in the Barrow area with a view to picking a location for a test by the National 50 rig in the fall while the rig would be enroute from Barrow to Umiat; (2) a party shoot a refraction profile lengthwise along the Oumalik anticline; (3) party 43 run reconnaissance lines north and northeast of Teshekpuk Lake; (4) a study made of the advisability of seismic work from boats on the Arctic Ocean or large lakes; (5) consideration given to a widely spaced refraction survey of all the coastal plain part of the Reserve; and (6) additional core holes drilled when convenient in the Simpson seepage area.

In order to obtain information on permafrost as it affected seismic and other activity, a program was initiated to place temperature cables in all core holes and shotholes deeper than 125 feet. The thermal gradient beneath deep lakes also was to be studied.

Commodore Greenman emphasized the paucity of drilling sites, which hampered acceleration of the drilling program to the most efficient use of the facilities available. This, of course, was a reflection of the fact that throughout Pet 4, exploration drilling had been very close on the heels of the collection and interpretation of basic information. Preliminary investigations were to be speeded up to correct this situation.

In May Commodore Greenman, supported by Mr. Curtice and by statements from Wallace E. Pratt, special assistant on petroleum matters to the National Security Resources Board, and W. E. Wrather, Director of the Geological Survey, appeared before the House Appropriations Committee to defend the Navy's request for an appropriation of $14.6 million to purchase supplies and materials for 1949, 1950, and 1951 and to cover operations through calendar year 1950. The Secretary of the Navy, the Secretary of Defense, and the House Armed Services Committee also favored continuation of the program as a security measure in the face of a possible oil shortage. After the hearings, the DNPR reported to the operating committee that the funds were expected to be appropriated by 1 July.

On 8 June appeared change order L, modifying article 27 of the original contract and providing for total

payment to the contractor at the end of each year instead of at the end of the contract.

In August there were about 400 contractor employees on the Reserve, 45 in Fairbanks, and 20 in Seattle. On the Reserve the contractor was supporting, in addition, between 85 and 100 persons from ONR, Navy Arctic Test Station, AACS, CAA, Alaska Airlines, Weather Bureau, and Coast and Geodetic Survey. By the end of the year, that number was reduced slightly to 350 contract employees on the Reserve, 40 in Fairbanks, and 15 in Seattle. Other employees by then numbered about 70.

Change order M, of 20 September, provided for the support of several of activities not connected with Pet 4 that will be mentioned later and for the purchase in the amount of $600,000 of supplies needed to expand the program as planned.

A third interim meeting of the operating committee was held in Fairbanks on 3 and 4 September. At that meeting the preliminary results of the year's activities to date were reviewed, and the first consideration was given to plans for 1949.

Because of the urgency of completing South Barrow test well 1 as soon as possible even at the expense of some stratigraphic information, the committee approved Mr. English's suggestion that coring and drilling procedures be left to the discretion of the contractor except that cores should be taken at least every 400 feet.

The work of Geological Survey parties 1 and 2 was reported to the committee. The Survey-supported party 3 was still in the field east of the Reserve. The summer's geologic work apparently had filled in local details but revealed no unexpected conditions. It was reported that the Navy's photographic squadron had made excellent progress and the committee recommended that the DNPR "address a letter to the Chief of Naval Operations setting forth the accomplishments of this photographic squadron and commending it for the splendid manner in which the work had been carried out."

The geophysical supervisor reported that experience had shown the advisability of combining reflection and refraction seismic work. The waterborne party was iced in and needed 2 weeks of good weather to get 50 percent coverage from Barrow to Icy Cape. Mr. English pointed out some inconsistencies in the geophysical maps and recommended some checks on the micropaleontologic work.

Mr. English anticipated that eventually several wells would be drilled in the Barrow area. Refraction work at Oumalik had indicated that the Lisburne group, if present, probably was below drill depth, and it was recommended that the well be rigged for 15,000 feet but with supplies to drill to 6,000 feet only, pending further authorization. Mr. English was designated to select sites for core holes in the Simpson seepage area. A 2,500-foot cable-tool hole at Maybe Creek was authorized.

Four seismograph parties were planned for 1949. This was the maximum number that could be supported. Four to six geologic parties a year were visualized, including an airborne party, as well as laboratories in Fairbanks and Washington. The contractor was requested to plan for a new department under a chief of exploration. The lack of a chief of exploration had been noted by visiting experts from the oil industry.

The ninth meeting of the operating committee was held in Washington on 15–17 November. Items for consideration included review of the status of the program, plans for maximum acceleration of the program, ways and means of improving organization and operating procedures, and methods of securing greatest possible results for the funds to be expended.

Geological and geophysical reports were presented. The geologic presentations were directed by Ralph L. Miller, who in October had relieved George O. Gates as Chief of the Navy Oil Unit of the Geological Survey. No good correlations could be made either in the Tertiary or in the Cretaceous rocks between Barrow and Simpson, possibly because of the near-shore character of the sediments with their restricted faunas. It was reported that South Barrow test well 1 had penetrated Tertiary and Cretaceous rocks before reaching the argillite basement. Microfossil work had been checked by Mrs. Helen J. Plummer, of the Texas State Bureau of Economic Geology. Thomas G. Payne presented an "Areal evalution of petroleum possibilities of major stratigraphic units of northern Alaska" in which he interpreted the available geologic information on the Reserve.

Mr. English analyzed the geologic and geophysical results in relation to future plans. He believed that oil possibilities in the foothill country were limited to the Upper Cretaceous and that lithologic conditions in rocks of that age are better to the west. The Lower Cretaceous rocks of the foothills are lithologically unfavorable, and the Lisburne group probably is too deep to reach with the drill. He felt that the Meade River anticline, the Wolf Creek anticline, and the Maybe Creek dome should be drilled if closure could be determined. He indicated that the seismic program for 1949 should be carried through as earlier planned, that 4 or 5 wells should be drilled in the Barrow area, and that the prospect of finding good sands was fair. He felt that to drill the Oumalik test below 6,000 feet would be useless.

Authority to start South Barrow test well 2 immediately was dispatched to Fairbanks. Edward W. Beltz was appointed to fill the newly created position of chief of exploration, and he was to assume his responsibilities on 1 January 1949.

The preliminary program worked out for 1949 included two or three 1,500-foot core holes in the Simpson area, a 4,000- to 6,000-foot test in the Fish Creek area, a deep test (estimated at 6,000 feet but with rig and foundations capable of permitting drilling to 15,000 feet if that should later be determined to be desirable) on the Oumalik anticline and one or more additional wells in the Barrow area based on information to come from South Barrow test well 2. There would be 6 geologic field parties—3 using weasels, 2 using river boats, and 1 using a bush plane. Four seismic parties were authorized as earlier planned as well as an air-transported gravity-meter party to cover the northeast part of the Reserve with stations to be spaced about 5 miles apart. The project manager, Mr. Gillespie, reported that the program as outlined could be supported although it would require the maximum use of available facilities.

The change of name of Hoover, Curtice, and Ruby, Inc., to Exploration Contractors, Inc., was announced.

On 27 December appeared change order O that listed the projects for 1949 which are given in the following table.

Projects for 1949

Project	Title	Approximate estimated cost
30	Erect drill rig, including establishment of a camp, in the Fish Creek area and drill to between 4,000 and 6,000 ft by 31 Dec 1949	$533,500
31	Erect drill rig, including establishment of a camp, in the Oumalik area and drill to approximately 6,000 ft by 31 Dec 1949	717,000
32	Explore the vicinity of the seepages at Cape Simpson with the expectation of drilling 3 core holes to an approximate depth of 1,500 ft each	161,000
33	Erect a rig and drill a test well about 6 miles south of the Barrow camp to approximately 3,000 ft	259,500
34	Make geophysical surveys with 4 seismograph parties, 1 of which may be a waterborne party during part of the season, and 1 airborne gravity-meter party, all between 15 Feb and 15 Sep; and provide personnel for supervision, computing and analysis during the full year	1,615,000
35	Maintenance and operation of camps and airstrips in NPR No. 4, contract office at Fairbanks, construction of 6 housing units at Fairbanks and at Pt. Barrow, and construction of a recreation hall, power plant, and two 10,000-bbl fuel tanks	1,000,000
36	Planning for, and support of, a resupply expedition, exclusive of procurement	215,000
37	Support of other designated activities	152,000
38	Purchase of materials, supplies, and equipment for a similar program for 1950, and procurement of additional material, supplies, and equipment for 1949	1,100,000

OPERATIONS

BARROW EXPEDITION, 1948

Barex '48 was accomplished by the Amphibious Force, Pacific Fleet. Both planning and execution of the operation drew heavily on the experience of the four earlier expeditions. It was a well-planned and successfully executed operation.

The preliminary planning conference was held on 4 March at the Base of the Amphibious Force, Pacific Fleet, Coronado, Calif. Preliminary loading data were submitted by Arcon, and it was agreed that the job could be done with 5 AKA's (attack cargo ship), 2 LST's, and an icebreaker. Cargo would be onloaded at Port Hueneme and San Francisco, Calif., and Seattle, Wash., and the expedition would depart about 23 July.

Toward the end of May, with the close of the winter freighting season, barges and boats that would be needed in unloading at Barrow were dug out of the snow and ice and overhauling and servicing began. During June and July, LCM's and barges were serviced; a canal into the lagoon behind the landing beach was dredged; cranes and unloading equipment were repaired; radar screens and beach markers were painted; and the beaches were cleared and prepared for the landings.

Captain Lademan, commander of Barex '48, and Captain Scruggs, commander of a detachment for Barter Island, inspected the beaches and unloading preparations at Barrow, Skull Cliff, and Barter Island on 12 July. The party also made a reconnaissance of ice conditions and then returned to Seattle where a final conference was held on 17 July. It was decided to delay the departure date from 23 to 26 July because of the late breakup of the ice that year.

On 17 July the loading was 50 percent complete, and it appeared that some materials would have to be left behind because of lack of space. The Army agreed to withdraw 1,000 drums of fuel oil to make room for Arcon cargo, such as pontoons, weasels, and LVT's. For earlier expeditions the materials had been packaged at their sources by the concerns from whom they were obtained. This had led to a wide range in packing methods, unit sizes, and costs. For Barex '48, the consigning agencies were required to ship their products to the Naval Supply Depots at Port Hueneme, San Pedro, Point Molate, and Seattle where they could be inspected, specially packed, and palletized before loading.

At Barrow all preparations were complete by 1 August. In addition to all usual unloading preparations, a physical inventory had been made in all warehouses and stock record cards were brought up to date. Empty oil drums, 10,000 of them, were checked for return on the expedition. The beach had been divided into six areas, each designated by large, distinctive signs, and each marker symbolizing the type of cargo to be landed there.

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Overall, the cargo consisted of 40,727 tons for Arcon, the CAA, the Army, the Office of Naval Research, the Coast and Geodetic Survey, the Weather Bureau, the Bureau of Indian Affairs, and the Alaska Communications System of the Signal Corps, U. S. Army.

During loading, difficulty was had with drums of gasoline which, in spite of special inspection, developed occasional leaks. These resulted in dangerously explosive conditions in some of the holds of the ships.

The voyage from the ports of embarkation was marked with much fog and many overcast days. From Unimak Pass northward through the Bering Sea, Bering Strait, and the Arctic Ocean as far as Franklin Point, the main navigation data were from bottom soundings and radar plots of the shore. The low and little-marked shores greatly reduced the effectiveness of the radar equipment.

As the ships neared Barrow, ice reconnaissance flown by 9 PB4Y's and 2 PBY's notified the expedition of inshore ice at Barrow. The ships therefore anchored temporarily at Point Belcher while awaiting the seaward movement of the ice pack. The icebreaker *Burton Island* with its two helicopters proceeded to the edge of the pack for further reconnaissance.

Again the ships delayed at Wainwright, a small Eskimo village southwest of Barrow, and did not arrive at Barrow until midnight on 4 August. The air reconnaissance had made it possible for the ships to reach their destination as soon as the ice went out. Unfortunately, when the ice did move seaward, the heavy pressure ridge remained grounded and intact except for some passages through it to the beach.

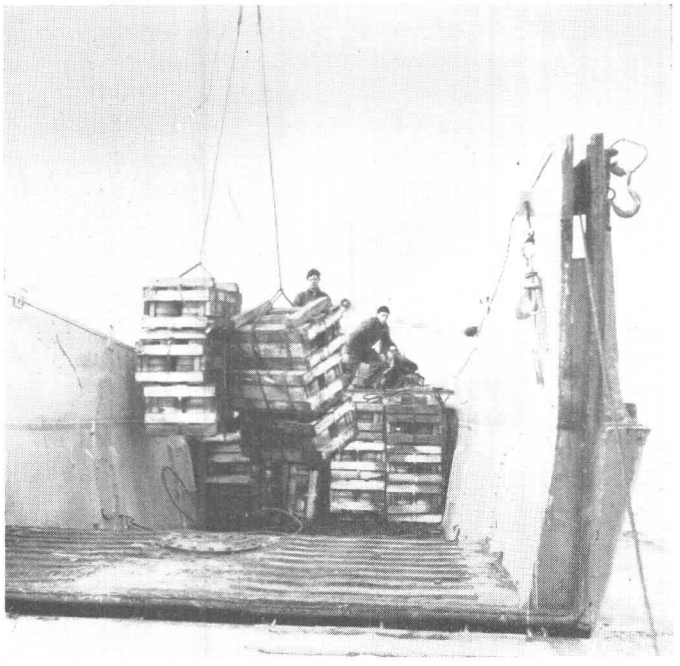

FIGURE 41.—Unloading LCM at Barrow beach, during Barex '48. Photograph by U. S. Navy.

FIGURE 42.—Unloading bulldozer at Barrow beach, 5 August 1948. Photograph by U. S. Navy.

On the 5 August the *Burton Island* led the two LST's eastward for Barter Island, but progress was very slow through much ice. An average speed of only about 2 knots was maintained to Barter Island in order to avoid ice damage to the LST's. The two LST's had additional fir planking over the forward 85 feet of their hulls; but, nevertheless, there were several bow punctures. For test purposes each LST was equipped with 1 bronze and 1 steel propeller. The bronze propellers were badly bent, but the steel ones came through intact. The LST's were unloaded on Barter Island and returned without further incident.

Meanwhile on 5 August unloading began at Barrow. First the U. S. S. *Washburn* unloaded freight for the Army's Loran station at Skull Cliff southwest of Barrow. Some supplies also were offloaded at Point Lay. At Barrow the unloading of the AKA's *Union*, *Titania*, *Skagit*, *Leo*, and *Washburn* was completed by midnight on 9 August. Altogether, 32,285 tons was unloaded in 4 days and 15 hours on an around-the-clock basis. (See figs. 41, 42.) The 10,000 empty oil drums were loaded, and the ships departed.

According to the commander of the Amphibious Forces, Pacific, Barex '48 was the largest naval operation ever accomplished in the Arctic Ocean. The bad weather and large amount of floating ice had provided a most valuable training operation.

WINTER FREIGHTING

By late 1947 it had become apparent that facilities would be strained to the limit to accomplish all the

winter freighting necessary to carry out the 1948 program as planned. In fact, as early as December 1947 it was imperative to send one train to the Oumalik area to return to Barrow with vitally needed equipment to be overhauled for the later freighting season. That train returned to Barrow in January. Also in January, fuel oil was hauled to Skull Cliff, and the temporary construction camp there was returned to Barrow. Three complete, overice trains were to be commissioned. To do this about 18 sleds that were top heavy with high bunks had to be revamped to a model similar to the highly satisfactory Micheler No. 9 sled. This required the full use of the welding shop for about 30 days. New trail wanigans were constructed; all tractors were overhauled, and snow plows fitted to the lead tractors for each train. These snow plows proved to be exceedingly valuable additions.

All of the difficulties previously experienced were expected—bad weather, broken plows, broken transmissions, and ice break-throughs—and fortunately, preparations had been made for all.

Overice freighting began on 1 February. Tractor trains hauled seismograph material to Fish Creek, drilling supplies to Simpson test well 1, and camp supplies to Umiat. Sled trains broke through the ice four times in the 1948 season. Immediate recoveries were made except when 2 tractors and 3 sleds missed an obscured trail in a storm and broke through the ice on the Chandler River. Assistance was procured from Umiat, 15 miles away. A 25-ton crane recovered the sleds with the loss only of a load of pipe and 50 sacks of cement.

While trains were enroute communication with them was maintained by radio although reception was only poor to fair. Contact was maintained by bush planes on skis for medical, repair, and emergency purposes. Sometimes materials in brightly colored bundles were dropped to the trains.

Freighting continued until 29 May. Freight went to Simpson, Skull Cliff, and the geophysical parties. The National 50 rig at Umiat was hauled back to the Barrow shops for overhaul. In early May equipment, including an LVT, and supplies were taken to Oumalik for a short refraction job.

In summary, the 3 trains traveled 6,726 miles to 6 locations and to 3 geophysical parties. The trains made 19 trips carrying 4,580 tons for a payload total of 840,808 ton-miles. Materials hauled included 10,000 barrels of petroleum products, 22,000 board feet of lumber, 2,100 cases of blasting powder, 300 pieces of drill pipe and casing, 1 rig and derrick, 2 cranes, 5 launches, and 28 weasels. The OICC reported to the CO of Ladd Air Force Base that the average cost was 35 cents per ton-mile.

On the basis of total experience gained in Pet 4, a report was compiled by the ROICC (resident officer in charge of construction), Barrow, for the Marine Corps School at Quantico, Va. The following is extracted from that report:

> Winter freighting starts about 1 February and concludes about 15 May. Ordinarily the ice is about 4½ feet thick, and 3 feet is a minimum for safety.
>
> An average crew consists of a foreman, 5 tractor operators, 1 mechanic, 1 oiler, and 1 cook. The foreman leads in a trail weasel followed by a tractor pulling the sleeper, galley, and shop wanigans. The 4 tractors that follow pull the load. Each tractor has a draw-bar pull of about 80 tons. The load is on 2 Micheler sleds (18 net tons each) and 2 sleds (14 net tons), or 3 Micheler sleds.
>
> Food consumed averages about 5 pounds per man per day. The train operates from 0630 to 2130 with half-hour breaks for lunch and supper. Trains average about 35 miles per day.

By November 1948 preparations were 95 percent complete for the 1949 freighting, and sled and wanigan construction was started. The first train of the new season started from Barrow on 1 December 1948 with a load of lumber and fuel for Oumalik. Soon four trains were running to Oumalik on schedule in order to get overland freight out while the sea ice, that would be used for hauling later, was yet unsafe.

AIR SUPPORT

In 1948 air support continued in the Reserve and to and from the Reserve as usual. LCDR Norman W. McLeod reported for duty on 18 June as aviation technical advisor to the OICC. Lieutenant Commander McLeod was stationed at Barrow. The air-support contract was readvertised, and as a result, on 1 July, Alaska Airlines replaced Wien Alaska Airlines as the contractor. Air traffic to the Barrow strip was continuously heavy because of the additional Army freight for Skull Cliff.

CAMPS

Camp construction and maintenance and miscellaneous operations continued in 1948 to constitute a large part of the overall operation of Pet 4. Such operations inherently are of critical importance in any large operation in the Arctic and because of low temperatures, high winds, darkness, and blowing and drifting snow are especially difficult in the winter.

Umiat test well 2 was abandoned, and the equipment was boxed for shipment to Barrow later in the freighting season. By early spring an overhead crane had been installed in the machine shop at Barrow, and at the airport a nose hanger had been constructed for working on the bush planes. Seismic shotholes near the Barrow camp had been redrilled and shot in an unsuccessful attempt to obtain a fresh-water supply. Three 20- by 48-foot quonset huts were added to the Barrow

camp. By April an additional 50-horsepower boiler was installed in the boiler house.

The main construction season started in the latter part of May and continued through the summer. In the early spring a site near the Barrow camp was surveyed and cored for foundation information for the construction of 3 bulk-fuel storage tanks of 10,000-barrels capacity each. In May a gravel fill was made for the tanks, and thermocouples and bench marks were placed for testing the stability of the gravel mat. The installation was supervised by the Permafrost Section of the Corps of Engineers, U. S. Army, at Ladd Field.

In June a new receiver antenna for the CAA was started at Barrow. A sand mat 500 by 1,000 feet was placed northwest of the camp for equipment storage,

FIGURE 43.—View northward over Barrow camp toward airfield showing camp as it appeared during Barex '48. Photograph by U. S. Navy, 8 August 1948.

and in July the construction of a 40- by 100-foot welding shop attached to the machine shop was started. This was completed before the arrival of Barex '48 in August. Additional quarters were constructed for the ARL (Arctic Research Laboratory) of the ONR. Construction was started on a 1,100-foot extension to the runway by mixing tundra with gravel and covering with pierced plank. Only 800 feet of the runway extension was completed before freezeup. A crown was built into the new section, and a crown was added to the old section by lifting the mat and sifting gravel through. All this had to be done while the strip was in constant use by C–46's, C–47's, C–82's, and an occasional B–29.

In August the new receiver antenna was completed, and a start was made on a 40- by 100-foot sled shop, a general warehouse of the same size, and an addition to the administration building.

A 50-foot section was added to the light-duty-equipment shop and a similar one to the heavy-duty-equipment shop. A special-equipment building was constructed for heavy-duty equipment that had to be repaired or overhauled more rapidly than could be accomplished in the regular heavy-duty-equipment shop. Sled repairs, exterior tractor repairs, such modifications as insulation and new cabs, skid blocks, and track changes were made in this building.

Two additional warehouses were built, and a new power house was partly constructed for 2 diesel-electric generators. This building was not completed because some of the power-plant equipment did not arrive on Barex '48. The hangar which had burned in March 1947 was rebuilt in September 1948 for the use of bush planes stationed at Barrow. At Umiat the load of drill pipe that was lost through the ice on the Chandler River during the previous freighting season was recovered.

By October most of the summer's construction projects were completed (see fig. 43), including the addition to the administration building and large additions to the galley and messhall, including a new bakery. The piling foundations for the new 1400-kilowatt diesel-electric generator house were placed. Final construction of the new general warehouse and powerhouse was postponed until after Barex '49 because of materials shortages.

During the fall weeks the Barrow shops were busy rebuilding tractors obtained from Pearl Harbor that had arrived on Barex '48.

Emphasis was given in the engineering office during the summer and fall to the foundation design for the proposed Oumalik test well. Concern was felt over the possibility of a foundation failure owing to the thawing of permafrost because it was estimated that it would required 2 years to drill the test and that mud temperatures might be as high as 200°F. COL G. W. Rathjens was retained as a consultant to study and advise on the problem. A test laboratory was constructed at Barrow to investigate the physical properties of the foundation materials.

AERIAL PHOTOGRAPHY AND PLANIMETRIC MAPPING

At the third interim meeting of the operating committee in Fairbanks in September, Commander Van Dusen, CO of Photo Squadron 1, reported on the results of his squadron's activity to that date. The area

assigned for photography was about 50,000 square miles. The squadron was based at Big Delta southeast of Fairbanks, and the aircraft consisted of 4 Liberators and 2 Beechcraft. About 46 percent of the vertical photography was finished, 47 percent of the trimetrogon photography, 82 percent of the proposed pipeline route between Umiat and Fairbanks, and more than 90 percent of the color and black and white, low-angle, oblique photography. The committee commended Commander Van Dusen on the excellent work of the photo squadron.

Low-angle oblique photographs, both black and white and color proved to be very useful in making geologic interpretations.

At the ninth meeting of the operating committee, William A. Fischer described the increasingly important role of aerial photographs in geologic work connected with Pet 4. He traced the course of the geologic use of aerial photographs in Pet 4 and made some recommendations as to their future use. He said:

> They (aerial photographs) serve many purposes, starting with the planning of the field program, through its operational stages, to the field data and preparation of reports. Partly they supplement field studies and permit interpolation or extrapolation of geologic information from known into unknown areas. They may also be used as an independent research tool, but in this capacity they must be used with extreme caution. Interpretations based on study of aerial photographs should be checked whenever and wherever possible by ground observations * * *.

The status of planimetric mapping was reviewed late in 1948 by Francis L. Witkege, of the Topographic Division of the Geological Survey. He described the earlier mapping on a 1:48,000 scale based on old trimetrogon photography, on newer, lower-altitude trimetrogon photography, and on a small amount of vertical photography. He pointed out that better horizontal control was becoming available as the map compilation went on and that some maps therefore would have to be recompiled to make the map detail of adjacent sheets join.

GEOLOGY

In the field season of 1948 the Geological Survey maintained 3 parties in the field. The laboratory at Fairbanks also continued throughout the year to process field samples and cores. In addition, a large amount of effort went into the office preparation of reports, the development of plans for future geologic work, the planning and activation of an expanded and improved organizational pattern, and into making special office and laboratory geologic studies and interpretations.

At the ninth meeting of the operating committee, Ralph L. Miller outlined the somewhat modified organizational pattern of the Navy Oil Unit within the Geologic Division of the Geological Survey.

By the end of the field season of 1948, the accumulated information from all the geologic investigations made possible an increasing amount of geologic interpretation. Such interpretation was useful not only in appraising the oil possibilities of Pet 4 but in making possible rather specific plans for geologic investigations still required for additional information. Both long- and short-range plans for additional geologic work were presented by the Geological Survey in some detail at the ninth meeting of the operating committee.

FIELD SURVEYS

PARTY 1

Party 1 was under the general supervision of E. J. Webber, who was assisted by two geologists, R. L. Detterman and W. W. Patton. The party was subdivided into various working units as occasion required.

Detterman and Patton restudied the Chandler River from Tuktu (Paneak) Bluff to the mouth. Samples were taken for possible microfossils, and more than 35 percent of them were later found to contain microfossils that would assist greatly in microfossil control in Pet 4. The structural observations along the river corroborated the 1945 observations.

On the completion of the Chandler River traverse, Patton and Detterman were assigned to Karl Stefansson for work in the Chandler and Kurupa Lake areas. Patton was assigned to the geologic interpretation of the vicinity of the oil seepages which were being excavated near Cape Simpson.

In the Cape Simpson area, 10 pits from 9 to 13 feet deep were dug—7 of the pits were on seepages, and 3 were on neighboring mounds. Some of the rock fragments found may have been brought to the surface by frost action. Microfossils were determined by Helen Tappan Loeblich. At the seepages fresh green oil with some gas welled up through steep fissures. The rate of flow at one pit was estimated to be a little more than 2 barrels a day. A sample contained no volatile fractions of gasoline or kerosene.

Meanwhile, Webber, with a small float plane also used to service other parties, inspected several places in the very extensive area south of the Colville River and between the Nanushuk and the Etivluk Rivers in order to obtain direct evidence at key places and to attempt to answer certain specific questions that had arisen as to geologic interpretation.

PARTY 2

Karl Stefansson was the head of party 2. Stefansson and Marvin Mangus traversed the Ketik, Avalik, and Nigiaktuvik Rivers. Exposures are generally very poor in those areas, but some lithologic and some struc-

tural information was obtained. No fossils were found except a few plant fragments.

Party 2, then augmented by the addition of Determan and Patton, mapped structural features and measured some stratigraphic sections in the Lisburne group near Chandler Lake. No zones of high porosity were recognized in the limestone, which has a strong organic odor. Structural interpretations were limited by the lack of base maps.

The work of party 2 near Kurupa Lake had scarcely started when it was terminated by heavy snow. The Lisburne group there is similar to that at Chandler Lake. Triassic rocks are also exposed, and the structure is complex.

PARTY 3

Charles L. Whittington was the leader of party 3. He was assisted by E. G. Sable, and the party was financed by the Geological Survey although it received logistic support from Pet 4. The party operated far east of the Reserve along the Okpilak, Hulahula, and Sadlerochit Rivers and started at the Okpilak River and worked westward on foot across the Hulahula and finally to Lakes Peters and Schrader. The information gained proved to be useful in interpreting conditions in and near the Reserve.

FAIRBANKS LABORATORY

During 1948 the laboratory at Fairbanks, under Robert M. Chapman, continued to perform its services to the overall Pet 4 effort. In the latter part of 1948, the laboratory staff was being increased toward the total of 8 that were considered necessary for the anticipated increased program. Mr. Chapman reported in September that the laboratory then was manned by 6 persons—himself, 1 micropaleontologist, 2 fossil pickers, 1 laboratory technician, and 1 clerk.

OTHER INVESTIGATIONS AND REPORTS

George O. Gates, of the Geological Survey, reported on his systematic appraisal of the petroleum possibilities of many of the anticlines known in northern Alaska. He related each of the structural features to the part of the stratigraphic section that might be tested there.

Helen Tappan Loeblich continued to examine and report on microfossil samples received from the Fairbanks laboratory. By the November meeting of the operating committee, Mrs. Loeblich had prepared a report on progress in microfossil investigations that included a range chart for Simpson test well 1, a Cretaceous outcrop range chart, and a chart showing top occurrences of all species common to the two Umiat deep tests. Mrs. Loeblich's report also interpreted her studies of the fossils from the drilling near Barrow.

Helen J. Plummer, of the Texas State Bureau of Economic Geology, was requested by the Geological Survey to make a special study of the micropaleontology of the Cape Simpson area. Mrs. Plummer's report proved valuable in interpreting the Simpson area and was much appreciated by the operating committee and the Geological Survey, especially since her work was done without compensation as she was a full-time employee of the Texas Bureau.

During 1948, heavy-mineral studies, as an aid in geologic correlation, were continued by E. H. Lathram, and he summarized the progress made in those studies. Four heavy-mineral zones were recognizable in the section.

Paul D. Krynine, of the Pennsylvania State College, made studies of the petrography and reservoir characteristics of samples from Pet 4. The work was done by arrangement with the Geological Survey.

Stephen W. Dana, of the Geological Survey, reviewed all of the geophysical data accumulated to 1948 and attempted to interpret them in terms of the geologic picture of Naval Petroleum Reserve No. 4 and surrounding areas as it was then known.

Thomas G. Payne was continuously engaged in interpretation of the overall geologic features of Pet 4. By 1948 there were enough data for him to prepare a progress report on the evaluation of the oil possibilities of the major stratigraphic units. That report, which stated Payne's facies interpretation, was a milestone in the development of the understanding of the geology of the Reserve.

GEOPHYSICS

During January and February there was additional activity at the Barrow camp occasioned by the complete reconstruction of the seismograph camps. Approximately 35 wanigans were built for the 3 land seismograph parties that were planned. Throughout, the wanigans were designed to last about 3 years. The sleds were made of pipe. On these were constructed 16- by 24-foot jamesway huts to make wanigans for sleeping, galleys, and messing. Storage and shop wanigans were of frame construction also built on pipe sleds. Each seismograph party of about 25 men was to have 9 wanigans as follows—1 galley, 1 mess and recreation, 1 utility, 1 storage, 1 shop, 1 office, and 3 sleeper wanigans. In addition there would be water wanigans and wanigans used in connection with drilling and shooting operations. All preliminary preparation was completed, and the parties were ready to enter the field by the first of March. They operated until the latter part of August.

The three parties of the United Geophysical Co. in 1948 were designated parties 43, 46, and 47.

PARTY 43

Party 43 begans its work in the Fish Creek area southeast of Teshekpuk Lake. It ran a long continuous line near the Fish Creek seepage. Next it moved to the northwest of Teshekpuk Lake and extended a continuous line northward from a point on a seismic line of the previous season. The line was carried around the lake and eventually tied into the work of party 46 east of the lake.

Party 43 then moved to the Oumalik area to make refraction shots over the seismic high there. The results indicated the absence of any high-velocity bed, such as limestone, down to a depth of at least 15,000 feet.

PARTY 46

Party 46 also began southeast of Teshekpuk Lake in the Fish Creek area. After completing some detail around an indicated structural feature there, it moved southward to tie with 1947 work south of the lake. The work of parties 43 and 46, plus earlier work completely encircled the lake. No large structural features were indicated in the whole area. Generally the dips are gentle toward the east. Data from shallow horizons were much more continuous than from deeper ones. There appears to be an unconformable zone at depths of 4,000 to 6,000 feet, but the interpretations were difficult and problematical. The basement was estimated to be at about 10,000 feet.

PARTY 47

A refraction survey was started near Point Barrow by party 47. It consisted of a loop of 13 refraction profiles including one over the Simpson 1 location. The cost was about $10,000 for each of the 13 profiles. Following that work it was recommended that reflection and refraction seismic work be combined in the future.

A high-velocity horizon was indicated at a depth of about 2,400 feet just south of Point Barrow. At location 13 the depth was about 4,700 feet, and at Simpson test well 1, 6,700 feet. The greatest distance to a high-velocity horizon is about 12,000 feet near refraction profiles 9 and 10.

Later, more detailed work in the Barrow area indicated complex stratigraphy and structure just south of Point Barrow. Faulting and irregularities in the permafrost were indicated near Barrow village. The basement appeared to be highest about 5½ miles south of the Barrow camp. At the north end of the sand spit at Point Barrow there is about 4,500 feet of conformable section.

About the middle of the summer of 1948, it was decided to attempt some waterborne seismic operations, and the task was assigned to party 47. Wanigans and equipment were placed on barges following the unloading of Barex '48. (See fig. 44.) The work started late in August but was ineffective because the ice pack had blown in southwest of Barrow. Only a few days shooting was accomplished because of ice, wind, and extreme cold. Shots were made along short lines northwestward from the camp and in Elson Lagoon. The party moved to Peard Bay but accomplished only two experimental shots. Results in the water were good, and the work was rapid when weather permitted. The line in Elson Lagoon indicated a northwest regional dip.

About the middle of September, party 47 was equipped as a winter party to work in the Barrow area. The main problem was the poor light that made surveying difficult. Drilling was also difficult, and progress was slow. By the middle of December, however, the area was covered seismically.

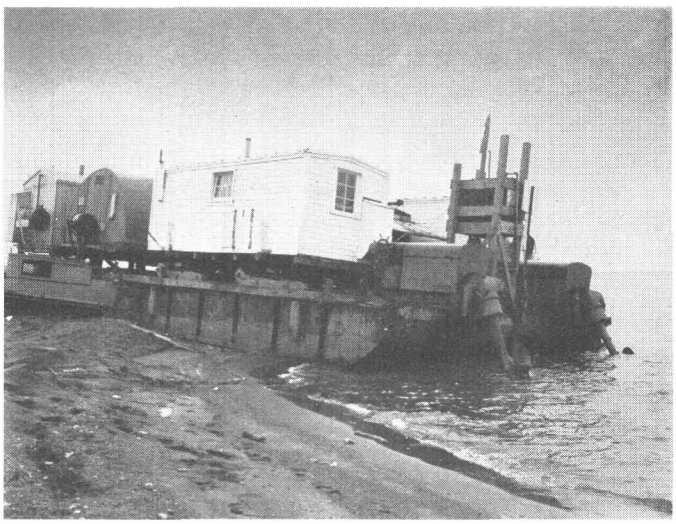

FIGURE 44.—Camp set up on barge for waterborne seismic operations. Photograph by U. S. Navy, September 1948.

It was suspected from a velocity survey of the hole that at South Barrow test well 1 the permafrost is less than 300 feet thick.

DRILLING

At the end of 1947 a fishing operation was underway at the Simpson 1 test hole. This hole was drilled to its full depth by May. No new drilling projects were started until the fall of 1948; and, therefore, the activity at Barrow during the summer months was less than normal.

SIMPSON TEST WELL 1

November 1947 had been spent in attempting to recover the materials dropped in Simpson test well 1 which were lodged at 2,561 feet. Finally the hole alongside the lost materials was reamed and special tools used to cut the waste into several lengths. Some

of the metal, but not all, was recovered, and it was necessary to run 7-inch casing alongside to a depth of 5,954 feet where it was cemented in. At aproximately 6,100 feet the drill pipe was changed from 4½-inch to 3½-inch. At about that time the local water supply froze, and it was necessary thereafter to haul water for nearly 4 miles.

At 6,170 feet the drill pipe stuck again. The bit would not come free; so it was necessary to back off, leaving about 100 feet of drill pipe in the hole. After considerable difficulty the lost materials were recovered; and, to prevent further difficulty, 118 lengths of drill pipe were replaced. Difficulty was still had with the mud, and it was reconditioned. At 6,314 feet samples from the bottom were highly cut with gas. At that point the equipment was serviced, and some of it was replaced in preparation for drilling to 7,200 feet with the 5,000-foot rig. The rig engines were overhauled and the pumps torn down and worn parts replaced.

Three shotholes were drilled for a seismic velocity survey to prospect for ground water as an aid to the deeper drilling. Also a larger mud pump was installed. After the above preparations the hole was drilled to 7,002 feet, which was reached about the middle of May. A series of formation tests was run, and the hole was plugged to 6,387 feet. No oil was recovered, and there was little gas. About 20 barrels of salt water came up per hour while swabbing with the fluid level at 1,200 feet. Core samples studied by the Geological Survey in Washington indicated that the rocks below 6,535 feet were a brick-red and greenish-gray argillite comparable to basement rocks farther east in the Canning River area. The material in the lower part of the Simpson hole was therefore interpreted as being older than the Lisburne group, and the hole was stopped in June. The rig was torn down and prepared for winter storage.

SOUTH BARROW TEST WELL 1

South Barrow test well 1 is about a half mile southwest of the Barrow camp. Testing equipment came from Simpson 1. The rig used was an Ideco 122-foot standard API derrick with a shorter substructure than had been used at Simpson 1 and a National 50 drawworks. The ground at the well was coarse beach sand, and it was considered unnecessary to drive a piling foundation. Instead, a timber mat was laid, and rigging-up started in July.

A 15½-inch hole was spudded in about 15 August (see fig. 45), and 16-inch casing was driven with the aid of steam and cemented. Within 10 days a smaller casing was set at 400 feet, and preparations were made

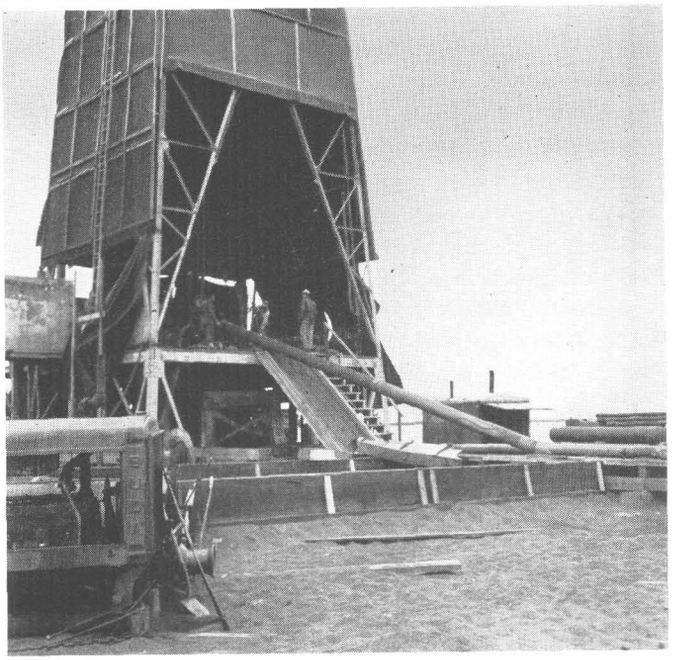

FIGURE 45.—Front view of rig at South Barrow test well 1, 14 August 1948. Photograph by U. S. Navy.

for deeper drilling. (See figs. 46, 47.) By the end of August the hole was drilling at 750 feet, and rig housing and winterizing was complete. After drilling out below the casing, an electric log was taken, but there were no indications of oil or gas. Tubing was run and a packer set to test the formation, but the packer did not hold. With continuous swabbing through the tubing from 1,750 feet, it was impossible to lower the

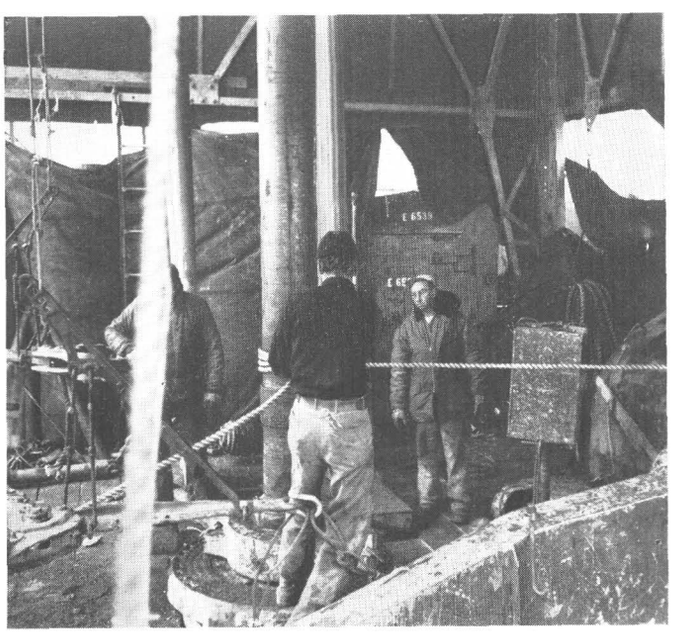

FIGURE 46.—Spinning-in joint of 11¾-inch casing at South Barrow test well 1, 25 August. Photograph by U. S. Navy.

fluid level below 600 feet. Salt water began to show in the mud, and it was believed to be coming from a sandstone bed at 1,900 feet.

Basement rocks of black slate and phyllite were encountered at 3,385 feet. These were believed to be pre-Cretaceous and possibly to correlate with the argillite found in Simpson test well 1. Drilling stopped at the end of October at 3,553 feet, and the hole was abandoned on 11 November.

Thin sand streaks in the interval 3,040–3,200 feet showed stains of light oil, and it was felt that the chances for a well somewhere in the Barrow vicinity were good.

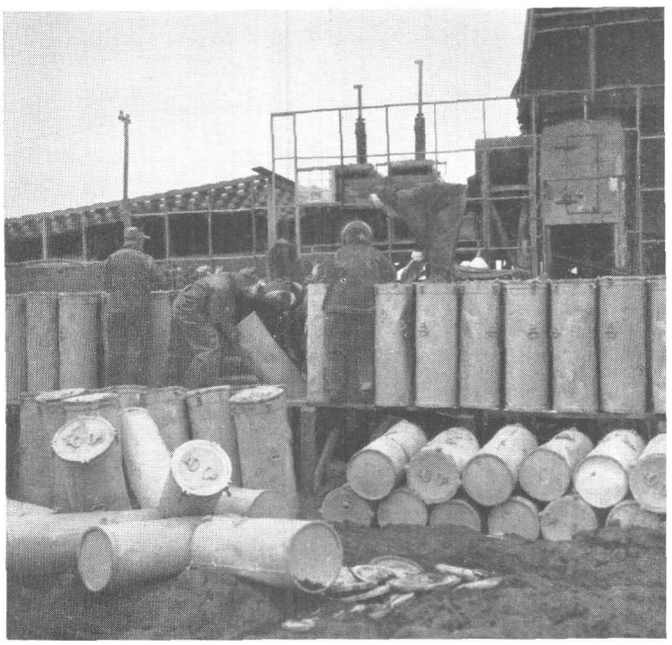

FIGURE 47.—Cementing 11¾-inch casing at South Barrow test well 1, 25 August. Photograph by U. S. Navy.

SOUTH BARROW TEST WELL 2

A location about 5 miles southeast of the Barrow camp was selected for South Barrow test well 2; this was the high point on the "structure" as located seismically. Piling foundations were set, rigging up was accomplished, and the hole was spudded in December. The Cardwell rig and the International Cementing Unit were overhauled and reconditioned for South Barrow test well 2.

SUPPORTED ACTIVITIES

During 1948 the use of the facilities in the Reserve for activities other than the oil exploration program was even more diverse than in 1947. The value of Pet 4 to a wide variety of such other activities was becoming even more evident.

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INSPECTION AND INDOCTRINATION

Following out the general policy of disseminating information to the oil industry, so far as practicable, and of obtaining and using as much informed advice as possible, several well-known men from the oil industry toured the Reserve and inspected the operations. Their advice and reactions were invaluable.

A pattern of inspection by Army and Marine Corps officers of field grade was initiated as part of their indoctrination into the Arctic. Through that pattern many high-ranking officers interested in various phases of Arctic activity were able to observe Pet 4 operations on the ground. Thus, a degree of Arctic background began to be disseminated through military circles.

BEETLE PROJECTS

All three Beetle projects, which it will be remembered required substantial work in 1947, were continued in 1948 but on a much smaller scale because much of the work had already been accomplished. Beetles A and C required only minor maintenance, but Beetle B was continued with considerably more work.

BEETLE A

During the early part of 1948, a small maintenance crew at Bettle A, at Skull Cliff, pumped water from the footings of the 625-foot tower and took elevation and temperature readings on the foundations. Through the winter and summer months, workers and supplies were moved regularly to Skull Cliff by LVT and bush plane. The plan called for the painting of the tower in the late summer of 1948. The paint was suitable for applying to a damp surface; but, when the painters were ready on 9 August, the tower was coated with ice, and the only way to prepare it for painting was to scrape it. It was slow work, and the weather continued bad, so that only the top 160 feet of the tower had been given the prime coat when the project was canceled on 6 September.

BEETLE B

In January new concrete floors were poured over the old cracked and sinking slab foundations at Barter Island. The old floors had first been covered by 1½ inches of Celotex. When the job was completed, the contractor personnel was returned to Barrow. The situation was not yet satisfactory. In May, probing of the gravel fills under the floors indicated that they were saturated, and pumps were installed in the galley and laundry. Subsidence still continued, but slower, and a new solution had to be found. It was decided that a piling foundation would be required, and piles were driven in July for four buildings. By September, after Barex '48, it was found that the power-plant foun-

dation apparently had stabilized, and further work was deferred on it although materials were left at hand to complete the job if that were found to be necessary. Steel-beam supports were laid on the piling for the galley, shop, and laundry, and an air space was left between the buildings and the ground to minimize heat flow. This additional work at Beetle B was provided for by project 27 of change order M of 20 September 1948 by the addition of $13,580.

BEETLE C

In February it was discovered that the 26-pair control cable for Beetle C at Barrow did not function. It was deduced that moisture had entered, probably through a small break, and had grounded the cable. A Wilcox Control Unit was substituted to operate the various channels until the cable could be inspected after the spring thaw. Early in the spring the Air Rescue detachment towed gliders to Barrow and made practice pickups.

The concrete floor slab at the transmitter standby power plant began to sink a few weeks after it was completed. It had been laid on sand that was thought to provide a base much like that at the Barrow camp. There proved to be silt and ice lenses below that allowed settling. Water was pumped from the sand, and the engines placed on large timbers laid across the building. The whole was insulated to reduce the heat flow, and it was felt that the situation was corrected.

COAST AND GEODETIC SURVEY

The geodetic control work of the U. S. Coast and Geodetic Survey was continued eastward from Barrow in 1948. The work was under the general direction of Commander Woodworth but was supervised locally from Barrow by LCDR Hubert A. Paton.

About February, when the shopwork for the seismograph crews had been completed, the contractor concentrated on preparing equipment, sleds, and wanigans for the Coast and Geodetic Survey. This additional work resulted in a somewhat unusual load for the Barrow shops. About the middle of March the Coast Survey's sled train departed Barrow along a trail that already had been staked by weasel. Good progress was made all the way to Barter Island, 350 miles away, and caches were established along the route.

In addition to the geodetic control work of the Coast and Geodetic Survey, that bureau decided upon the establishment of a magnetic station at Barrow. In July two buildings were approved for construction by the contractor for the magnetic observations. One of these was for the observation of magnetic variation, and the other for magnetic absolute. The construction was begun by Arcon in November and required special methods, as nonmagnetic materials had to be used throughout. By the end of the year, the buildings were 90 percent complete.

ARCTIC RESEARCH LABORATORY

The Arctic Research Laboratory of the Office of Naval Research began field activity from the camp at Barrow in August 1947. Plans were made almost immediately for expansion of the laboratory facilities in 1948. The construction of two large 2-deck quonset huts was visualized. The first was started by Arcon for the ARL early in the year. In April, work was suspended temporarily, but by July the building was ready for occupancy. The other large quonset hut was started in 1948 also but was not completed that year.

ARCTIC TEST STATION

An Arctic test station was established at Point Barrow by the Bureau of Yards and Docks in June of 1947, and the establishment was authenticated in a memorandum of Acting Secretary of the Navy W. John Kenney on 12 January 1948. The station was used for the testing of materials, techniques, and equipment under arctic conditions. Administrative control and logistic support were provided by the OICC of Pet 4, and technical control was under the cognizance of the proving ground officer, Port Hueneme, Calif.

Fiscal support was provided through 30 June 1948 by change order K of 10 March 1948 and through December 1948 by change order M of 20 September 1948.

In 1948 the complement consisted of 1 officer and 14 enlisted men. They were designated NCBD (Naval Construction Battalion Detachment) 1801, and they carried out in the winter of 1947–48 tests on various types of cargo sleds, a wing aerosleigh, auxiliary cold-starting aid kits, prefabricated huts for the Marine Corps, low-temperature lubricants, hydraulic oils, and snow compaction. Investigations were also made on various kinds of arctic clothing.

On 4 June, CWO S. W. Eszengi completed his assignment as OICC of NCBD 1801 and was relieved by LTJG Frank W. Galbraith, CEC, USN.

CORPS OF ENGINEERS

Purdue University under contract with the Corps of Engineers, U. S. Army, sent Robert E. Frost and James W. Hittle to Pet 4 in June to investigate and develop air-photographic interpretations of soil and permafrost conditions as aids in road, airfield, and other types of construction. They recognized the elevated beach line that runs a short distance inland between Barrow and Wainwright as the most likely site in the region for any additional airstrips. They were unsuccessful in finding airfield sites in the Oumalik area and deter-

mined the nearest gravel to be on the Ikpikpuk and Titaluk Rivers from 20 to 50 miles away.

OTHER ACTIVITIES

In January electronic equipment for measuring ice thickness was tested in the Reserve by specialists from the Radio Corporation of America. The results of the tests were to be used in an attempt to develop a better means of measuring ice thickness.

At the end of May the National Medical Research Institute sent a team into Pet 4 to extend the Institute's research into mosquito control in the Arctic. Much was learned about the kind and habits of the mosquitoes in the area, and the mosquitoes were greatly reduced in number in the vicinity of Umiat through frequent sprayings.

In June, representatives of the CAA discussed with Navy representatives additional navigational aids in Pet 4 and desirable changes in flight regulations. As a result minimum-flight requirements for Navy operations were eased because of the experience of Alaskan pilots under the contract.

The U. S. Coast Guard icebreaker *Northwind* reached Barrow on 24 July and anchored offshore until 26 July. After leaving on the 26th, the icebreaker was forced back by bad ice conditions on 27 July and remained until 1 August. About the middle of August the Canadian supply ship *Snowbird II* rounded Point Barrow with the aid of an RCAF aircraft for scouting ice.

SUMMARY OF 1948

At the start of 1948 it had seemed that the year would be a relatively quiet one with a somewhat reduced scale of operations. As the year went on, however, plans developed for a sharply increasing scale of activities, and these plans were substantially activated later in the year. In general, the year was a good one in Pet 4. Major advances were made, and the stage was set for more effective operations in the future.

By 1948 the program had gone on long enough that results accumulating since the start in 1944 were supplying an ever-increasing and ever-improving background of coordinated data for more effective future planning, for closer pinpointing of the objectives of each project, and for more satisfactory interpretation of results.

To handle more effectively this larger background of information and to improve and expedite the services required of it, the Geological Survey expanded and streamlined its organizational and administrative pattern as related to Pet 4. In October Ralph L. Miller became head of the Survey's Navy Oil Unit.

In the Arcon organization changes were made also and especially a new position of chief of exploration was established. The position was to be occupied on 1 January 1949. Ted Mathews became assistant project manager. Howard Myers relieved John Legge as geophysical supervisor for the United Geophysical Co.

Pet 4 continued to support other activities, generally on a repay basis, within the area and thus made possible a wide variety of desirable projects that otherwise would not have been practicable.

During 1948, Simpson test well 1 was carried to the basement rocks in the Cape Simpson area. An encouraging stratigraphic test had been drilled on a structural feature in the Barrow area. Incomplete investigations to be continued in 1949 included further study of the so-called Barrow high or Barrow structure, and more investigation of a "high" extending from Barrow southeastward and which seemed possibly to divide the great sedimentary basin north of the Brooks Range into two parts.

SIXTH YEAR—1949

GENERAL PLANNING AND ADMINISTRATION

By the time the sixth year opened at the start of 1949, the program had been underway long enough that a considerable background of Arctic experience had been gained as to what could be done, when it could be done, and how it could best be done. Some activities were still somewhat in the experimental stage, but good progress was being made on them. In this category might be mentioned certain geophysical operations such as the use of the magnetometer and gravity meter and certain practices as to the preparation and maintenance of foundations for large rigs at sites where deep holes were to be drilled.

The first chief of exploration, E. W. Beltz, after a considerable study of the overall aspects of Pet 4, including familiarizing himself with many of the details, formally took office at Fairbanks on 1 January 1949.

On the geophysical and geological fronts, each new bit of information and each new or modified interpretation in turn led to new problems, new ideas, and new lines of investigation to be followed in order to proceed more directly toward the overall objective of a reasonable appraisal of the oil possibilities of Pet 4. The drilling that had been done, and was being done, was continually emphasizing the increasing need for reliable basic information in the selection of drill sites.

In Pet 4 at the beginning of 1949 were a total of 418 persons. Of these 349 were Arcon (Arctic Contractors) employees—330 at Barrow, 14 at Umiat, and 5 at Oumalik. The remainder totaled 69 and included Army, Navy, CAA, Alaska Airlines, United Geophysical Co. employees, and others.

As the year started, freighting to the Oumalik site was well underway, having started about 1 December

1948, almost 2 months earlier than the normal freighting season because of an early winter.

On 8 January, ADM A. E. Montgomery, Com 17 (Commandant 17th Naval District), and ADM C. A. Trexel along with a party of several officers arrived in Fairbanks. On the following day, and in company with the OICC (officer in charge of construction) and the ROICC (resident officer in charge of construction) at Barrow, the party flew by contract aircraft to Barrow to inspect the facilities there and to review the 1949 program of Pet 4. In addition, Admirals Montgomery and Trexel inspected the Arctic Research Laboratory of ONR, the Arctic Test Station of BuDocks, and the Clothing Research Unit of the Naval Supply Depot, Brooklyn, N. Y. All of these facilities were at Barrow. The Admirals' party left Barrow on 10 January.

A conference between the contractor, G. W. Rathjens, special consultant to the contractor, and specialists of the Geological Survey was arranged to discuss permafrost problems as related to the foundation of the Oumalik rig. Mr. Rathjens arrived in Fairbanks on 24 January, and Robert F. Black, J. H. Swartz, and G. R. MacCarthy, all of the Geological Survey, came in 2 days later. On the 27th all proceeded to Barrow and from there to the Oumalik site along with Assistant Project Manager Mathews. Mr. Rathjens returned from Barrow on 2 February and had further discussions with the contractor on 5 February.

In October of 1948 Stewart Folk, the technical advisor to the OICC, resigned and left Fairbanks. The position remained vacant until early February 1949 when C. E. Hamilton, who had been hired for the position, reached Fairbanks and immediately reported for duty.

Early in February, Commodore W. G. Greenman, DNPR, visited Fairbanks and Pet 4 for a general inspection of operations. He was accompanied to Barrow and return by the new chief of exploration. About the middle of the month the DNPR returned to the States but stopped at Kodiak enroute for discussions with Com 17 on Pet 4 matters.

On 3 February LCDR X. S. Hutchins, Jr., arrived in Fairbanks to relieve LCDR L. P. Frate as ROICC at Barrow. Lieutenant Commander Hutchins was held in Fairbanks for a few days for the purpose of indoctrination, but he shortly left for Barrow with Lieutenant Commander Frate, who remained in charge at Barrow until 17 February when Frate left and Hutchins took over. Lieutenant Commander Frate proceeded to Seattle where he took over as a contract officer, including cognizance of contract NOy–13360 in Seattle.

In recognition of the general policy of disseminating as widely as possible as much information as possible about Pet 4, Henson Baldwin, of the New York Times, went to Barrow in February to view and report on the operations. Unfortunately Mr. Baldwin was able to stay in the Barrow camp only a few hours and thence proceeded to other military establishments in Alaska.

COL W. K. Wilson, Jr., district engineer, St. Paul District, Corps of Engineers, U. S. Army, and Barney L. Trawicky, civilian head of the permafrost studies of the Corps of Engineers in Fairbanks, called on the OICC about the middle of March to discuss permafrost matters of mutual interest. Colonel Wilson assured the OICC of the continued availability to Pet 4 of such assistance in the permafrost field as might be practicable.

During the first half of 1949, there were repeated discussions between the OICC and representatives of the Alaska Native Service relative to the part-time use of Dr. Philip Maisonville, ANS doctor at the native village of Barrow, by the contractor. For one reason or another no arrangement was made, and the contractor decided to employ a doctor for Pet 4. Dr. Maisonville resigned and left Barrow about the middle of the summer. Early in July Dr. Duncan M. Chalmers, director, Division of Preventable and Communicable Diseases of the Alaska Department of Health went to Barrow and while there inspected the Alaska Native Service facilities.

The 10th regular meeting of the operating committee was held in the Navy Department in Washington on 12 and 13 April 1949 to receive reports from the Geological Survey, Arctic Contractors, and United Geophysical Co.; to discuss future drilling; to be briefed on the plans for Barex '49; to discuss the summer program; to appraise the financial situation; and to discuss other matters pertinent to Pet 4.

A proposal was discussed to modify the project of seismic party 45, that at the time was on a reconnaissance line near the Meade River, to permit it to do certain detailed profiling across one or more of the anticlines in the vicinity of the Meade River instead of continuing its reconnaissance. After long discussion a pattern satisfactory to the committee was proposed whereby a certain amount of detailing would be done in the vicinity in which the party then was, but that time would be budgeted so that seismic reconnaissance ties also would be completed.

Preliminary reports on much of the work of the Geological Survey had already been made at the November meeting, but the reports presented at the 10th meeting contained some new material and some modifications of the earlier interpretations. Karl Stefansson discussed the stratigraphy and structure of the area of the Avalik, Ketik, and Nigiaktuvik Rivers. George

Gryc summarized the status of geologic information on Pet 4 and adjacent areas and announced the completion of a geologic map of northern Alaska with stratigraphic sections, structure sections, facies diagrams, and a text. He pointed out that all new interpretations had been included on the map. Gryc especially described certain changes in nomenclature of geological units. The committee requested that these be shown on a diagram so that the new usages could be visualized more readily.

Mrs. Loeblich described her microfossil studies of material from South Barrow test wells 1 and 2 and from Simpson test well 1. She described the thickening of the Cretaceous section outward from the crest of an ancient ridge at South Barrow test well 2. The committee commended Mrs. Loeblich on her valuable contributions to Pet 4.

Mrs. Loeblich also summarized a report on the ostracodes and their significance that had been prepared by Professor Swain, of the University of Minnesota, for the Geological Survey. E. H. Lathram discussed the status of the work on heavy minerals in the Cretaceous and Tertiary sedimentary rocks, and the discussion brought out some of the limitations of the use of heavy minerals for correlation purposes. Mr. Lathram also reviewed the problem of correlation between the two South Barrow tests in which the lithologic, paleontologic, and geophysical evidences are somewhat incompatible.

Next Mr. Lathram presented a report by Professor Euster, of the Pennsylvania State College, on the analysis of samples from South Barrow test well 2, and two others by Prof. Paul Krynine, also of the Pennsylvania State College, on the petrology and reservoir properties of South Barrow test wells 1 and 2, and on an analysis of sand formation in a geosyncline especially as applied to northern Alaska.

William A. Fischer presented a regional interpretation of the structural geology that was based on photogeologic studies of a large part of the central Colville River area and on such surface studies as had been made. He also described several anticlines in some detail.

Stephen W. Dana completed the presentation of the Geological Survey technical papers with a discussion of the seismic evidence for the base of the Tertiary in the eastern part of Naval Petroleum Reserve No. 4.

Ralph L. Miller, Chief of the Navy Oil Unit, Geological Survey, reported that the proposed modification of the organizational pattern of the Navy Oil Unit was virtually complete. Thomas G. Roberts at that time was head of the Fairbanks laboratory of the unit. The committee complimented Mr. Miller on the excellent progress that the Navy Oil Unit had made. Mr. Gryc outlined the plans for geologic fieldwork for the season of 1949. These had not changed substantially since the plans were first laid out in November 1948.

Howard Myers of the United Geophysical Co. reported on the work of seismic parties 44, 45, 46, and 47 and on the possible interpretation of results. There was much discussion by the committee of the geophysical information in an attempt to use that information just as much as possible in developing a better understanding of the extensive coastal plain area over which bedrocks do not crop out. Only brief mention was made of the gravity-meter work. At the end of the discussion, the committee reversed its earlier stand and decided to cancel the detailed seismic work of party 45 in the Meade River area in favor of the original plan of reconnaissance seismic lines that would be tied together.

E. W. Beltz, the new chief of exploration, discussed in substantial detail the correlation of South Barrow test wells 1 and 2 and the correlation between them and Simpson test well 1. He interpreted the evidence in terms of the geologic environment and, from the interpretation, made inferences as to the oil and gas possibilities.

The second day of the 10th meeting began with a full discussion of the advisability of drilling a third test (South Barrow test well 3) on the so-called Barrow high and the depth to which it should be drilled in a location about 15 miles south and a little west of Barrow. The exact location was to be determined by the chief of exploration, the chief geophysicist, and the project manager, but the location was to be confirmed by mail vote of the operating committee. On the basis of the use of a Cardwell rig with an 87-foot derrick, it was roughly estimated that the test would cost $188,000 in cash plus about $113,000 worth of Government-owned materials.

The committee considered and approved additional magnetometer and gravity-meter work in the vicinity of the Barrow high to the extent that ground magnetometer work could be carried on without any substantial outlay of funds by using a weasel from existing camps plus such additional airborne magnetometer observations as could be made at nominal cost. The committee considered but decided to table a suggestion that a torsion balance be tried as an exploration tool in the Barrow area. The committee discussed the use of special seismic methods to attempt to determine the bottom of permafrost. Mr. Reed, of the Geological Survey, was requested to discuss with the Office of Naval Research the possibility of having attention given to this by the Geological Survey's permafrost project at the Arctic Research Laboratory.

Commander Fischer, the OICC, reported on the planning thus far for Barex '49. Mr. Gillespie, the project manager, reported on the progress and plans for the drilling and production program for 1949 of South Barrow 2 and 3, Oumalik test well 1, Fish Creek test well 1, and the Simpson core tests. He also reviewed the winter freighting season.

Mr. Curtice, as the representative of Arcon, announced that Bart Gillespie, the project manager, would be leaving Pet 4 to administer an exploration project in Mexico. Commodore Greenman and others commended Mr. Gillespie for his outstanding service to Pet 4.

The committee unanimously approved a motion of Mr. MacNaughton to the effect that the progress of the exploration of the oil possibilities of NPR 4 has been satisfactory and that the program should be continued until its objectives have been reached. Mr. MacNaughton noted that the program had consisted of (1) the mapping of the Reserve by geological and geophysical methods to determine the surface and subsurface structure of the sedimentary beds, and (2) the drilling of a number of shallow wells to obtain data on the stratigraphy; toward the objective of drilling; upon the basis of the above-mentioned work, a limited number of tests on selected prospects for the purpose of determining the existence or absence of commercial accumulations of petroleum.

The desirability was confirmed of a short seismic project near Chandler Lake to determine the seismic velocity of the Lisburne group where it crops out. It was noted that savings could be effected by coordination with geological parties in the area. Finally it was determined that the waterborne geophysical party planned for the 1949 summer would be postponed.

Arcon had interested Mr. E. L. Davis, chief of drilling and production, Signal Oil Co., in the position of project manager to replace Bart Gillespie. Davis visited Fairbanks and the Reserve between 23 April and 4 May. Mr. Davis accepted the position and on 31 May returned to Fairbanks and took over his new responsibilities.

The DNPR inspected the Fairbanks and Barrow facilities of Pet 4 between 12 May and 20 May. Special attention was given to the location of South Barrow test well 3.

In May, representatives of the Department of Agriculture arranged for the limited spraying with DDT of both the Umiat and Oumalik camps in an attempt to control the mosquitoes and make the camps more livable. Those two camps later were approved by the Air Surgeon, Alaska Air Command, for followup spraying. In July, representatives of the Public Health Service conducted a mosquito-control test at Umiat using a new type of sprayer operated from the ground. The results indicated the desirability of continuing ground control as it was cheaper than aerial spraying.

During June, July, and August, a substantial number of persons visited Naval Petroleum Reserve No. 4 as special guests. Many of these were representatives of oil companies; others were responsible Government officials and businessmen. Some of the visitors went to and from Barrow and the Reserve by way of Navy contract aircraft; others, in private aircraft. Such visitors numbered about 25 and included—

Paul L. Henderson, manager of exploration, Ohio Oil Co.
C. W. Tomlinson, president, American Association of Petroleum Geologists.
T. S. Peterson, president, Standard Oil Company of California.
Colonel J. P. Johnson, general manager, Alaska Railroad.
G. L. Skinner, president, Alaska Steamship Co.
G. A. Griffin, district manager, Morrison-Knudson Co.
Walter Greenfield, Signal Oil and Gas Co.
G. M. Cunningham, Standard Oil Company of California.

The visitors were in the Reserve from a few hours to several days. Many of those who visited the Reserve later wrote to the DNPR giving their reactions to Pet 4 and how the work was being carried out.

In addition, representatives of newspapers, magazines, and broadcasting companies visited the Reserve. Among these were:

Harvey V. Fondiller, to take photographs for an article for a current magazine.
A. G. Hiebert and Mr. Gaines, KFAR, Fairbanks, to record the Barex landing for radio broadcast.
W. E. Debman, news commentator, Smith Douglas network.
Thomas G. King, Jr., photographer, Life magazine.
Richard B. Kirkpatrick, Cincinnati Enquirer and Newsweek magazine.

Several significant personnel changes took place in the summer of 1949. In late May LT Norman M. Jackson reached Fairbanks to relieve LTJG C. F. Krickenberger as assistant to the OICC. On the next day a modification to Jackson's orders was received giving him additional duty as the ROICC at Barrow. LCDR Hutchins was ordered to report to Com 5 (Commandant, 5th Naval District), and on 2 June he was relieved at Barrow by Lieutenant Jackson. On 9 August, LCDR S. C. Gill relieved Lieutenant Jackson, who in turn immediately proceeded to Fairbanks where he reported as assistant OICC thereby relieving Lieutenant (Jg) Krickenberger. In late June CDR Jos. R. Wood relieved LCDR N. M. McLeod as aviation technical advisor to the OICC. On 19 July, CAPT Foster L. White, USAF, was assigned to Arcon as asst. petroleum engineer for Pet 4. This detail was carefully worked out by the deputy DNPR, the technical advisor

to the OICC, and Captain White. In addition, E. D. Spaulding was made chief engineer, Jack M. Adams, superintendent at Barrow, J. W. Dalton, assistant superintendent, and W. H. Larson, chief of drilling and production operations.

In early June a consultant from the Imperial Oil Company of Canada, Alex Hemstock, was called in to advise on the design of a gas pipeline from South Barrow test well 2 to the camp and on a gas distribution system in the camp.

COL O. F. Kotick, the deputy DNPR, spent the summer at Fairbanks and in Pet 4. He thoroughly familiarized himself with all phases of Pet 4 operations, participated as the DNPR's representative in many conferences, guided several representatives of the oil industry through the Reserve, and provided counsel in many of the problems that continually arose. He reached Fairbanks on 6 June and left for the States on 10 September. Walter A. English, technical advisor to the DNPR, also spent substantial time in Fairbanks and in the Reserve in the summer of 1949.

The Air Force, the City of Fairbanks, and the Navy's facility at Fairbanks all were furnished utility services by the Fairbanks Exploration Department of the U. S. Smelting, Refining, and Mining Co.

At the end of June Reinhold Brust, assistant superintendent of the Alaska Native Service, indicated to the OICC that the Native Service might request a core-drilling project to be carried out by Arcon to search for coal that had been revealed by shothole drilling in the area in 1948.

RADM F. W. Wagner and a party of officers were accompanied to the Reserve by the OICC on 1 July. Admiral Wagner inspected the detachment of Photographic Squadron VP–61 at Umiat. At Barrow a complete inspection was made of Pet 4 facilities as well as the Arctic Research Laboratory and the Arctic Test Station. The party returned to Fairbanks on 2 July.

On 30 July CDR M. H. Aubey, CEC, USN, arrived in Fairbanks as the relief for Commander Fischer as OICC. Commander Aubey familiarized himself with Pet 4, its operations and problems during August, and on 4 September he assumed the duties and responsibilities of the OICC. Commander Fischer departed on that date for the States in accordance with basic orders.

On 6 August RADM B. J. Rodgers, ComPhibPac (Commander, Amphibious Force, Pacific), and a party consisting of VADM G. F. Bogan, ComFirsTaskFlt (Commander, First Task Fleet), RADM C. A. Trexel, DirPacAlDocks (Director, Pacific and Alaska Division, Bureau of Yards and Docks), RADM J. M. Hoskins, ComAirPac (Commander, Air Force, Pacific), and several other officers went to Barrow along with the OICC to inspect Barrow and Barter Island and to witness the Barex '49 unloading operations.

Members of the operating committee or their advisors who were in Fairbanks and Pet 4 during the summer, in addition to those already mentioned, included Herbert Hoover, Jr., James Tully, A. A. Curtice, Rex Townsend, Earle Taylor, and John C. Reed.

With the appointment of a chief of exploration, it was believed that the usual fall interim meeting of the operating committee could be omitted and its place taken by a group designated the technical committee, to be made up primarily of representatives of the various operating segments of Pet 4, that would consider all pertinent data at the close of the field season and would propose a technically sound program for the following year. This program would then be considered, with much saving of time and expense, at the regular November meeting of the operating committee.

Following the above outlined pattern, which did in fact prove to be a substantial improvement, the technical committee met in Fairbanks on 5 and 6 September. In attendance were, for the Navy, COL O. F. Kotick, CDR M. H. Aubey, and C. E. Hamilton; as consultants, Walter A. English, and Earle Taylor, of DeGolyer and MacNaughton; for the Geological Survey, Ralph Miller and other members of the Navy Oil Unit; and for Arcon, E. L. Davis, E. W. Beltz, Howard Myers, and others.

Preliminary reports were received on the results of geological surveys, just completed, and of geophysical surveys to be terminated within a few days. A program of exploration was outlined for 1950 for the consideration of the operating committee.

Three geological parties were proposed to operate within the Reserve. A fourth, to be supported by Geological Survey funds, would operate outside the Reserve. Three additional parties were placed on a supplemental list to work outside the Reserve. Some doubt has been expressed as to whether or not the Navy could continue support work outside Naval Petroleum Reserve No. 4 even though the work was pertinent to an understanding of the geology in the Reserve. That matter was to be resolved later.

Three seismic parties were proposed, with a possible fourth party for a larger program. The technical committee called for further study of a gravity program that it considered advisable.

Proposed drilling included Simpson test well 2, probably with the National 125 rig, a second test to be drilled on the north flank of the Oumalik anticline either with the National 50 rig or preferably with the Wilson Super Titan rig if it was available, and a test with a National 50 rig of the Titaluk anticline.

The operating committee met on 17 November in the Department of the Interior building in Washington, D. C., to provide plans for the 1950 operating season. The 3 previous days had been allotted for review of data and for informal discussion by participants. Attendance included the following members and alternates of the Committee: Commodore W. G. Greenman, DNPR; COL O. F. Kotick, Deputy DNPR; W. E. Wrather, Director, Geological Survey; John C. Reed, Geological Survey; L. W. MacNaughton, DeGolyer and MacNaughton, Inc.; A. A. Curtice, vice president, Exploration Contractors, Inc.; CDR G. E. Fischer, BuDocks. Also present were Walter A. English, technical advisor to the DNPR; Herbert Hoover, Jr., president, Exploration Contractors, Inc., and president, United Geophysical Co.; Glen M. Ruby, vice president, Exploration Contractors, Inc.; Rex Townsend, vice president, Exploration Contractors, Inc.; James Tully, Exploration Contractors, Inc.; Earle Taylor, DeGolyer and MacNaughton; Milton Lebsack, ONPR (Office of Naval Petroleum Reserves), CDR M. H. Aubey, OICC; E. L. Davis, project manager, Arctic Contractors; Howard Myers, geophysicist-in-charge, Arctic Contractors; E. J. Rusing, chief accountant, Arctic Contractors; C. E. Hamilton, technical advisor to the OICC; T. C. Mathews, assistant project manager, Arctic Contractors; and from the Geological Survey's Navy Oil Unit, Ralph L. Miller, chief, and George Gryc, assistant chief, and T. G. Payne, geologist.

After discussion the following plan was aproved:

The geologic program for 1950 would include 6 Navy-financed geologic parties and 2 Survey-financed parties. The specific assignment of the parties would be determined early in February by the chief of exploration with the assistance of the Geological Survey. The Survey was given discretionary authority to operate one of the parties financed by it in 1951 if that proved to be more practicable. Advice was to be supplied by the chief of exploration, assisted by representatives from Exploration Contractors, DeGolyer and MacNaughton, the Geological Survey, and the technical advisor to the DNPR. In addition, the Survey was to carry out photogeologic studies—first, of areas required for assignment of the 1950 geologic parties; second, of areas within the Reserve and to the south of the Reserve; third, of the remainder of the outcrop areas of northern Alaska.

The geophysical program would include an air-transported gravity-meter party that would cover approximately 10,000 square miles in the western part of Naval Petroleum Reserve No. 4, with about 2-mile spacing between stations. The party would use helicopters and such ground vehicles as were necessary for support, all provided by Arcon. Use would be made of aerial-photograph mosaics provided by the Navy.

Seismic party A would work a long line in the western part of the Reserve. Seismic party B would work in the Fish Creek area, then run south to Umiat, thence westward to the Titaluk anticline, and then north to the east Ikpikpuk area. Party C would detail the Topagoruk area and include a tie line to Simpson test well 1. Party D would run a line from Oumalik to the Meade River and detail structural features west of that river. Party E would be a mobile party to make a refraction survey of the Driftwood anticline, and, if possible, another refraction survey farther north.

In regard to drilling, it was decided to postpone a Topagoruk test until further seismic work was done in 1950. A 6,000-foot test, Oumalik 2, was approved. It was to be on the east plunge of the Oumalik anticline and drilled with the Wilson Super Titan rig. It was agreed to deepen Oumalik 1 from 7,500 to 12,000 feet.

Barrow 2A (later called South Barrow test well 4) was to be drilled as a standby gas well on the Barrow gas trap. South Barrow test well 4 (later called the Elson test, but never drilled) was approved, to be drilled to 2,500 feet or to basement rocks by the Cardwell unit, about 4 miles east of South Barrow test well 2. Simpson test well 2 was to be drilled with the National 125 rig at a location to be selected by Messrs. MacNaughton, English, and Beltz. Meade River test well 1 was to be drilled west of the Meade River on an anticline found by the seismic work in 1949. Consideration of further core drilling in the Cape Simpson area was postponed until the April 1950 meeting.

The fiscal situation was reviewed and is summarized as follows:

Assets:	
Cash on hand, 31 Dec. 1949	$6,000,000
Appropriation expected by 1 Jul 1950	11,000,000
Value of buildings	500,000
Value of equipment	6,000,000
Value of inventory	5,000,000
Project costs, 1 Jan. 1946 to 31 Dec. 1949	19,000,000
Total	47,500,000
Liabilities:	
Funds appropriated and requested	$38,200,000
Government furnished, without exchange of funds	9,300,000
Total	47,500,000
Estimated cost of 1950 program	$ 8,731,000

In late September, Commodore Greenman again visited Fairbanks briefly on Pet 4 business. A month later, Fairbanks and Pet 4 were visited by a special subcommittee of the House of Representatives Mer-

chant Marine and Fisheries Committee. On 19 November LT L. C. Dickey, USAF, reported for duty as a petroleum engineer and on 9 December LT Gordon H. Oosting, USA, reported as a petroleum engineer to replace LT E. L. Powers.

OPERATIONS

BARROW EXPEDITION, 1949

All phases of Barex '49 are recorded in detail in a report entitled "Barex–49" that was transmitted on 20 August from the commander of the expedition to the Commander, Amphibious Force, Pacific Fleet, and which was widely distributed in the Navy Department. The commander of the expedition was CAPT R. M. Scruggs, who also was Commander Transport Division 11, Amphibious Force, Pacific Fleet. The ice pilot was again CDR John Backlund.

Planning for Barex '49 began in March with the issuance of the operation plan. A conference of all concerned was held in Coronado, Calif., on 19 and 20 April. That conference was attended by both the OICC for Pet 4 and the project manager of Arcon. A party of officers connected with, and interested in the expedition reached Fairbanks on 11 July. The group included CAPT N. M. Riker, commander of the Barter Island unit of the expedition; COL James Glore, Transportation Corps, USA; CDR R. C. Johnson, chief staff officer for Barex; Sibitzky, Barex beachmaster; and MAJ B. Bratcher, Transportation Corps, USA. The party went on to Barrow the same day and to Barter Island and back to Fairbanks on 12 July.

Training in the operation of boats and barges and in the handling of cargo was conducted between 20 May and 20 June in San Diego harbor.

Barex '49 was carried out by the Amphibious Force, Pacific Fleet, Transport Division 11. It was the largest Barex to that date, and the freight hauled to several points of discharge along the Arctic coast aggregated 31,380 short tons. The Barrow part of the cargo totaled 25,190 short tons valued at $1,400,000.

Three features are especially noteworthy in regard to Barex '49. The first was the participation of a large percentage of Naval Reservists in the operation; the cruise was made by 28 officers and 174 enlisted men of the Naval Reserve. The second was the delivery of fuel oil to Barrow in bulk instead of in drums; there was 40,000 barrels of this bulk oil. The third was the use of an inside passage by the LST's from Barrow to Barter Island.

Eleven ships composed the expedition—APA (attack transport ship) as flagship, the U. S. S. *George Clymer;* 4 AKA's (attack cargo ship), the U. S. S. *Seminole*, U. S. S. *Oberon*, U. S. S. *Achernar;* and U. S. S. *Union;* 4 LST's (landing ship, tank), *1110*, *1146*, *1123*, and *1126;* 1 AO (fleet oiler), the U. S. S. *Neches;* and 1 ice breaker, the U. S. S. *Burton Island.* The ships departed San Diego for loading ports on 20 June. Loading was at Port Hueneme, Point Molate, and Seattle. The bulk diesel fuel was loaded at Tidewater, Avon, Calif.

The *Burton Island* and the LST's left Seattle on 19 July. The larger ships departed Seattle on 26 July. The northbound passage was uneventful and was favored by unusually good weather and good ice conditions. The pack ice was 17 miles offshore at Franklin Point and 18 miles, at Point Barrow.

The *Seminole* stopped at Point Lay northbound and unloaded 241 short tons in 6 hours. The start of unloading was delayed for half a day because of heavy seas. The *Seminole* next discarged 2,449 short tons at Skull Cliff in 48 hours. All craft arrived at Point Barrow between 2 August and 7 August, the *Seminole* being the last because of her stops at Point Lay and Skull Cliff. The 2 LST's scheduled for Barter Island, LST's *1110* and *1146*, and the *Burton Island* reached Barrow on 2 August and left for Barter Island on 3 August.

When the ships were unloaded at Barrow, they departed independently for the States. The departures were between 5 August and 9 August, the flagship being the last to depart. The unloading of the bulk diesel fuel from the *Neches* to LST's and from the beached LST's to 10,000-barrel fuel storage tanks was an especially smooth operation, and the whole 6,000 tons of diesel fuel was unloaded in 2 days.

Meanwhile, the Barter Island unit was proceeding eastward. Captain Riker attempted to use leads between the ice and the shore as much as possible to avoid the difficulty and delay of following in the wake of the *Burton Island*, which could not operate in the shallower water. It was necessary after some miles, however, to follow the ice breaker to the vicinity of Cape Halkett. From there on, the LST's were in the shore lead and running in part behind the barrier sand islands in relatively ice-free water all the way to Tigvariak Island, which was reached on 6 August. At Tigvariak Island about 320 tons was unloaded for the Coast and Geodetic Survey in 6 hours by the use of LVT's (landing vehicle, tank).

While the LST's were at Tigvariak Island, the *Burton Island* lost one of her propellors and was forced to return to Barrow and on to the Long Beach shipyard. She was replaced by the U. S. Coast Guard ice breaker *Northwind*, and on 7 August the unit got underway for Barter Island. The LST's remained inshore as much as possible and, after some trouble with fog,

reached Barter Island on 8 August. Unloading was rapid; and early on the morning of 9 August, the unit started its return to Barrow, which was reached the next day. The return to the States was uneventful. The Barter Island unit had been greatly assisted by hydrographic charts prepared by the U. S. Coast and Geodetic Survey.

The sea was used also by Arcon for a special transportation job in late August. A 10-ton pumping unit for the Fish Creek test well 1 had to be moved out from Barrow. It was decided to freight it by LCM (landing craft, medium) rather than by plane. The LCM with a crew of 2 men hauled the load in 6 days. This was equivalent to 13 trips or 45 hours in a Norseman aircraft. The project illustrated the economy and practicability of such transportation where and when both ice and landing conditions permit.

OVERLAND FREIGHTING

SLED FREIGHTING

At the April meeting of the operating committee, the project manager was able to report that, to that time, the freighting by sleds (see fig. 48) during the winter of 1948–49 had aggregated almost 1.3 million ton-miles. This was done with 4 tractor trains. About 3,350 tons was laid down at the Oumalik site, 2,500 tons at Fish Creek, and 2,500 tons more for the geophysical parties. The remaining 2,000 tons was accounted for by backhaul, caches, and small miscellaneous hauling jobs. The cost was $0.374 per ton-mile. The above data, of course, include hauling in December 1948; it has already been pointed out that the heavy freighting season, because of an early freezeup, had started in early December instead of early February as was more usual. Visibility was far better than usual during the freighting season. It was estimated that the number of days of unimpaired visibility was at least double that in each of the previous 2 years. The depth of the snow was about half that of earlier years, and the ocean ice was largely free of dangerous cracks and overflows.

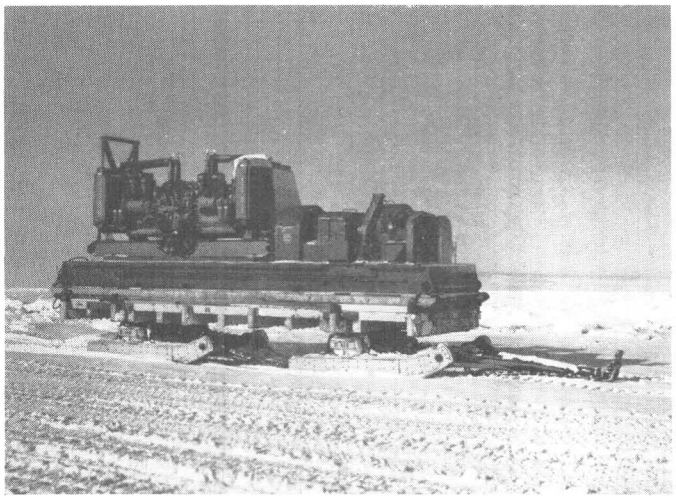

FIGURE 48.—View showing details of heavily loaded Micheler sled—a type widely used in Pet 4. Photograph by U. S. Navy.

The Oumalik trail, laid out in November '48, was an especially good one. An LVT with auxiliary fuel tanks, radio, and compass became a support vehicle. Ahead of the LVT a weasel-transported scouting party laid out the trail.

FREIGHTING BY LANDING VEHICLE, TRACKED (LVT)

Equipment and supplies, in items too large or too heavy to be moved by aircraft, were badly needed at Oumalik test well 1 in the summer of 1949. Therefore LVT's (landing vehicle, tracked) having a rated 4-ton capacity were assigned the job. Cargo included drill collars 31 feet long and weighing more than 2 tons and a kelly, 44 feet long and weighing about the same. These were carried to Barrow for repair and returned to Oumalik. Other cargo was baroid, cement, casing, and miscellaneous materials. In all, 322 tons was moved at an average load of 6.2 tons per vehicle. Two groups of three LVT's each were used. In spite of the heavy loads, the almost continuous operation, and the poor condition of the trail, maintenance and repairs were very light. The per ton-mile cost was $0.94.

AIR SUPPORT

The original contract with Alaska Airlines provided for service by that company, both of the linehaul between Fairbanks and Umiat and Barrow and of the bush flying for various purposes in northern Alaska from 1 July 1948 through 31 December 1949, with the period from 1 July 1949 through 31 December subject to the availability of funds. Funds were available; and, therefore, the contract was continued after 1 July 1949. It was decided that it would be better for several reasons to change contractors, if a change were to be made, in the summer rather than in the middle of winter, and it was therefore recommended that the contract be extended until 1 July 1950 and the job be readvertised then.

Early in August the CAB (Civil Aeronautics Board) suspended Alaska Airlines from continuing certain of its operations and shortly the question arose as to whether or not the contract flying for Pet 4 was included under the suspension order. After discussions and correspondence between various units of the Navy Department and the CAB, the Board on 2 September granted an exemption from its suspension for the Pet 4

FIGURE 49.—Loading 75-kw generator aboard a C54, aircraft at the Barrow airfield. Photograph by U. S. Navy.

activity to 31 December. This legalized the current operations but still would have required changing contractors in the middle of the winter. Finally on 1 December, the Chairman of the CAB formally notified the Deputy Secretary of Defense of the extension of its exemption until 30 June 1950.

The service performed by Alaska Airlines in 1949 included approximately 450 linehaul flights each way from Fairbanks to Umiat or Barrow. Northbound passengers totaled 2,217; and southbound, 2,261. Northbound freight aggregated 2,881,000 pounds; and southbound, 2,592,000 pounds. The larger linehaul planes (see fig. 49), in addition, flew about 90 missions within the Reserve on shuttle flights between points and in that work carried 36 passengers and 296,000 pounds of freight.

The bush flying, involving on the average much shorter flights, included about 3,600 missions, nearly 2,800 passengers, and a little more than 1 million pounds of freight.

GENERAL CONSTRUCTION AND MAINTENANCE

Generally, 1949 was a normal year as to camp construction and maintenance. Pet 4 was by then large and complex and was so organized that the normal load of such activities could be handled without difficulty. (See fig. 50.) An idea of the size of the activity is given by the record of 8,954 meals served in the Reserve in the week ending 13 February; 11,674 in the week ending 15 May; and 14,239 in the week ending 14 August.

From the description below have been omitted some of the major construction and maintenance activities performed for units not part of Pet 4. Such services performed for others are mentioned in part in the later section on Supported Activities.

About 45 wanigans were constructed in the first part of 1949 for geophysical parties and outfitting of a fourth tractor train. They included also a complete portable camp, consisting of 13 wanigans, for use in the core drilling near the Simpson seepages. This work was all completed by the latter part of April, the wanigans for use in the Simpson area being the last constructed.

Special foundation materials for Oumalik test well 1 were fabricated in the machine shop. The heavy-duty-equipment shop performed the regular overhaul of heavy equipment and, in addition, completely reconditioned 15 tractors that had been salvaged from Pearl Harbor. About 50 weasels (M29C) were processed in the light-duty-equipment shop for use during the summer of 1949.

Five 10,000-barrel bolted-steel tanks were assembled (see fig. 51) into a tank farm between the first of the year and the end of July, and about 1 million gallons of bulk diesel oil from Barex '49 was pumped into them. Four of these tanks were on a gravel pad, and the fifth

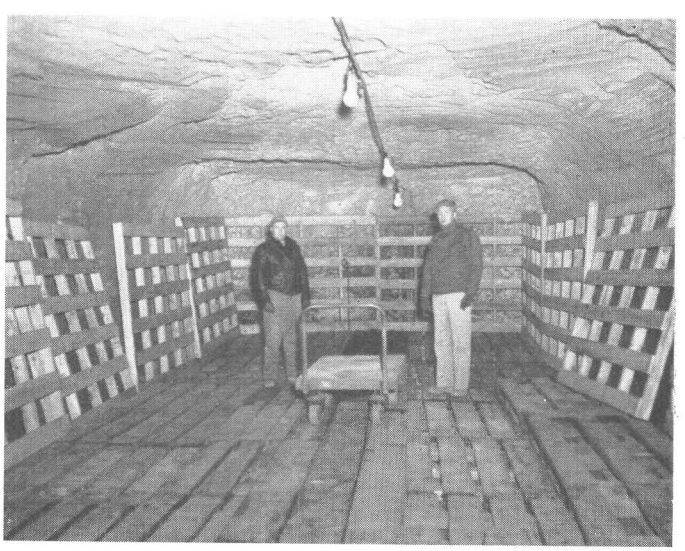

FIGURE 50.—Meat cellar, excavated in permafrost at Point Barrow, before receipt of meat on Barex. Photograph by U. S. Navy.

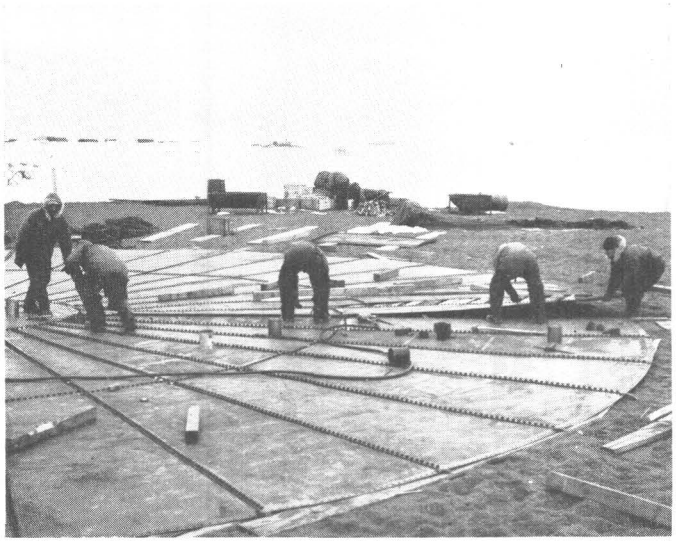

FIGURE 51.—Assembling bottom of tank 3 at Barrow tank farm, 30 May 1949. Photograph by U. S. Navy.

was on a piling foundation. (See fig. 52.) The fuel line for pumping the oil to the tanks from the beach was completed shortly before it was needed on the arrival of Barex.

A new powerhouse was begun and was well advanced by the year's end. By the end of January a soil-testing laboratory was completed and was used especially on Oumalik foundation problems. Early in January an addition to the messhall was ready for use. In the fall, additions were completed to the heavy- and light-duty-equipment and carpenter shops. A new laundry was completed in May, and an Eskimo messhall about Christmas time. A general warehouse and an additional temporary warehouse were finished before the end of July, and by mid-October an equipment-storage building and an aircraft-fueling system were ready for use.

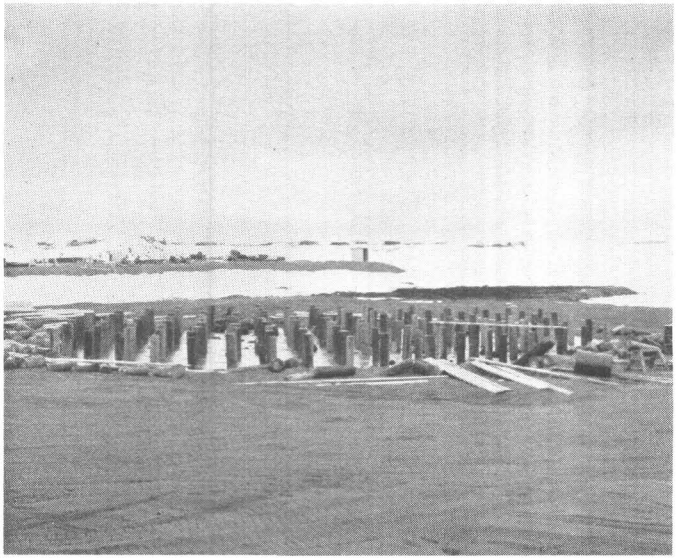

FIGURE 52.—Piling set for gasoline tank at tank farm, 30 May 1949. Photograph by U. S. Navy.

Two projects were undertaken in 1949 that require special mention. One was the unitization of one of the Cardwell rigs into large, but still mobile, units so that several shallow tests could be drilled in a given location with a minimum of rigging up. The derrick section was mounted on steel runners (see figs. 53, 54); and the pumphouse section, on Athey tracks. The other was the installation required for the use in the camp of gas from South Barrow 2. By mid-June the 4-inch pipeline was laid from the well to the camp, and the gas was turned into the line on 29 July at which time one boiler was fired by gas. About the end of August

FIGURE 53.—Substructure for unitized Cardwell drilling rig with runners attached, 23 December 1949. Photograph by U. S. Navy.

the gas-treatment plant was finished (see fig. 55); early in August the camp-distribution lines and the well-control house were ready; and before the middle of September a gas line was laid to the airport. The boilers and larger heating units had been converted to natural gas by fall.

In spite of an alert fire watch (see fig. 56) at all establishments, there were several fires within the Reserve in 1949, but none was very serious. In February overheating of the bake ovens caused a small fire in the bakery; in June a fire in the welding shop apparently was caused by a spark lodging in the building insulation; in September a heating unit at South Barrow test well 2 set fire to the wooden base on which it was mounted; on 29 September the careless lighting of a match ignited the gas from Simpson core test 16, the man's hands were badly burned; finally, on 5 Novem-

ber a fire was caused in the new power house by the heat from an exhaust pipe—damage was negligible.

GEOLOGY

At the 10th meeting of the operating committee in April 1949, several papers on some of the geologic aspects of Pet 4 were presented and discussed. These have been mentioned briefly in the section on General Planning and Administration for 1949 and will not be further discussed here.

Between the April and the November meetings of the operating committee, some of the special studies were further advanced and were therefore reported at the latter meeting. Mrs. Loeblich described certain changes in the correlations in the Simpson area based on her micropaleontological studies. She also had new and more precise evidence on correlations between the coastal plain and more southerly parts of the Reserve. Harlan R. Bergquist presented at the November meeting new developments in the solution of Pet 4 correlation problems by means of microfossils. He also tied in earlier micropaleontologic correlations with the micropaleontology and with Mr. Payne's facies interpretations.

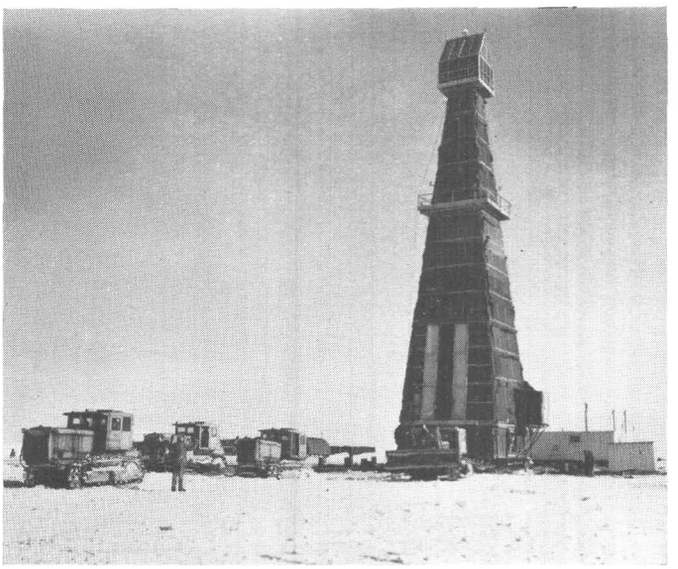

FIGURE 54.—Unitized Cardwell rig being moved from South Barrow test well 4 to South Barrow test well 2 location, 22 April 1950. Photograph by U. S. Navy.

During the summer Florence Robinson, of the Fairbanks laboratory of the Geological Survey, and Thomas G. Roberts, the head of that laboratory, had studied and interpreted the geology of the Simpson seepage area based on all available data including information from the Simpson core tests. The results were presented at the meeting. Thomas G. Payne had analyzed the past and proposed drilling in Pet 4 in terms of his interpretation of facies zones.

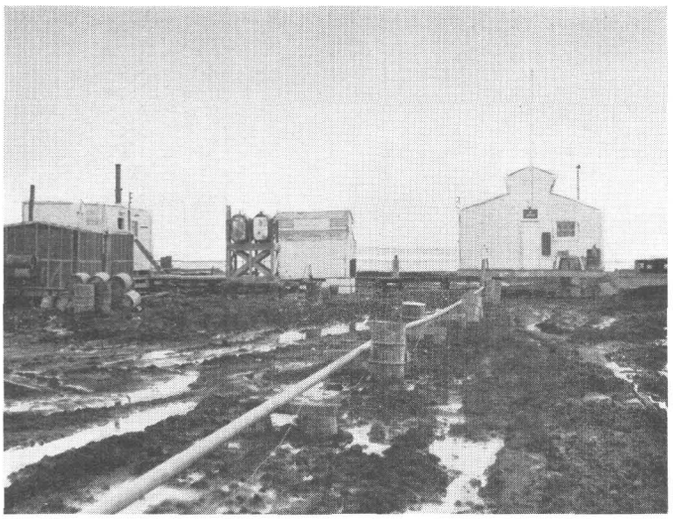

FIGURE 55.—South Barrow test well 2 gas-treatment plant. Photograph by U. S. Navy, 7 September 1949.

At the meeting of the technical committee in Fairbanks in September, the Survey was requested to prepare photogeologic analyses of the Driftwood, Awuna, and Carbon Creek anticlines (see fig. 12) before the 11th meeting of the operating committee in November. This was done and reports were presented at the 11th meeting by William A. Fischer, but the precision of the analyses was limited because at that time only trimetrogon photography was available for most of the three anticlines.

By the time of the November meeting, Ralph L. Miller, chief of the Navy Oil Unit, Geological Survey, re-

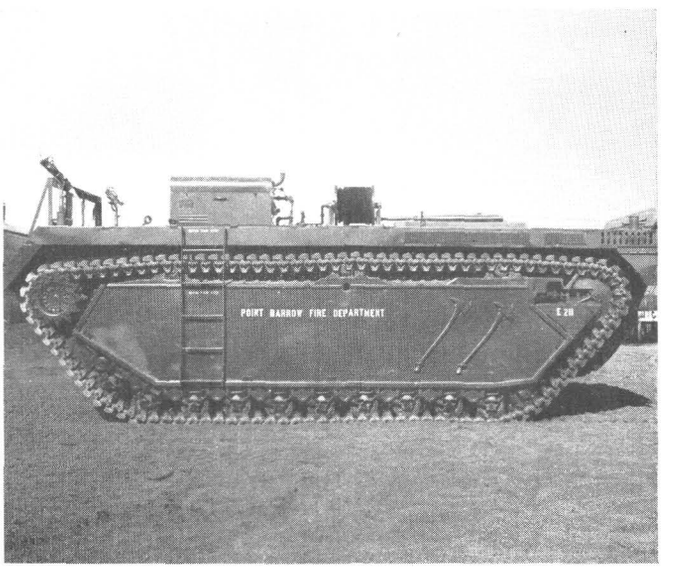

FIGURE 56.—LVT converted to fire engine, Point Barrow, August 1949. Photograph by U. S. Navy.

viewed the geological information that had been accumulated to that date and stated several salient concepts relative to the geologic environment that by that time were well understood:

1. Structure is not the most important factor in the accumulation of oil in the Reserve. * * *.

2. Favorable facies, that is, favorable sediments for the accumulation of oil, has been our major stumbling block in prospecting to date * * *.

3. Undrilled and relatively unknown sequences of Jurassic(?) and of Paleozoic(?) age probably exist within the Reserve, * * *.

4. The Lisburne group is our best known Paleozoic formation that might possibly be favorable for oil, where it is under cover. * * *."

The Fairbanks laboratory of the Survey operated throughout the year. At the laboratory, samples from the drilling and from surface outcrops were processed. Porosities and permeabilities were determined, micropaleontologic studies were made, and a wide variety of related services were performed.

During the summer of 1949, six Geological Survey parties were in the field. (See pl. 3.) The preliminary results of the work of those parties were made available both at the September meeting of the technical committee and at the 11th meeting of the operating committee and were used in making plans for 1950.

Party 1, under W. P. Brosgé, assisted by A. N. Kover, was assigned the study of the Titaluk anticline (see fig. 12) that lies north of Maybe Creek. The main purpose was to define are areas of closure along the axis of the anticline. The 6-man party was transported by 3 weasels. The season was from 5 June, when the party left Umiat, until 28 August, when it returned there. Two high places along the axis were contoured—one, just east of the Ikpikpuk River has a closure of about 370 feet; and the other, near the head of Maybe Creek, a closure of about 50 feet.

C. L. Whittington, assisted by A. S. Keller, led party 2, which worked the Carbon Creek anticline by weasel between 9 June and 27 July and the upper Meade River area during August. In the Carbon Creek area the sedimentary rocks seen totaled about 6,000 feet in thickness. No closures were proved, but it was thought that there might be some minor closures in the eastern part of the area.

In the Meade River area a zone of reverse faults was found to extend for the total length of the area studied. Some sands were found that fulfill minimum requirements for potential reservoir beds. Structural traps may occur adjacent to the zone of reverse faulting.

Party 3, under A. L. Bowsher, included also J. T. Dutro and, for a part of the season, Allen Feder. The party was supported by bush aircraft on skis in the early part of the season and on floats after the snow and ice had gone. The party studied an area along the north front of the Brooks Range and east of Anaktuvuk Pass and known generally as the Kanayut Lake area. The primary objective of the project was to attempt paleontologic and stratigraphic zonation of the Mississippian rocks and the structure of that part of the Brooks Range.

Among the conclusions were that the Lisburne group is about 2,100 feet thick in the area and has initial porosity that makes it a favorable reservoir rock, that recognition of thin stratigraphic units within the Mississippian rocks is possible but difficult, and that the northern part of the Brooks Range was deformed by intense thrusting.

Party 4, traveling by weasel, operated west of the Chandler River in the foothills close to the Brooks Range, in the Okpikruak and Kiruktagiak areas. The party was led by W. W. Patton, Jr., and included 5 other men, 1 a geologist, I. L. Tailleur. A 220-foot rock sequence in that area is dark and has a definite oily odor. Oil shales are present in some parts of another sequence of rocks. Asphaltic material is common as fracture fillings in some of the rocks, and at one place such material cements a conglomerate. No good reservoir sands were recognized.

M. D. Mangus was the chief of party 5, which worked in the southern part of Pet 4 in the vicinities of the Etivluk, Kuna, and Nigu Rivers, along the Colville River from the Kuna to the Ipnavik, in the headwaters region of the Killik, and around Howard Pass. The party included, in addition to the chief, two geologists, R. L. Detterman and A. H. Lachenbruch, and a third geologist, M. C. Lachenbruch for a part of the season. Work was by foot, boats and bush plane. Poor exposures, complex structure, and many thrust faults made mapping difficult. The geologic structural features did not seem favorable; for the accumulation of oil and rocks of good porosity were scarce.

Party 6 worked in and west of the western part of Naval Petroleum Reserve No. 4 along the Kokolik and the Kukpowruk Rivers. Most of the travel was on the rivers with three 18-foot folding canvas boats. The party was moved by bush plane to, and, on occasion, within the field. The party chief was R. M. Chapman, who was assisted by E. G. Sable, geologist, and three temporary employees. Ralph Solecki, an archeologist of the Smithsonian Institution who was working on an ONR (Office of Naval Research) project, was attached to the party and assisted most commendably in the geologic work as well as carrying on his own activity.

Very few favorable conditions for petroleum are indicated in the area. Neither favorable porosity and permeability nor structural features were seen, except

that some of the older rocks in the area may have some possibilities as source beds.

GEOPHYSICS

Explorative geophysics studies were carried on as a part of Pet 4 in 1949 by the United Geophysical Co. and under the immediate supervision of W. H. Myers.

Four seismic crews shot a total of 740 miles of continuous line. (See pl. 3.) All of the seismic work (see fig. 57) that was assigned at the 10th meeting of the operating committee in April was accomplished, and some additional detailed work was done in the Meade River and Topagoruk areas. The production was substantially greater than in earlier years.

The work included one air-transported gravity-meter survey. The area completed was 2,700 square miles, or about two-thirds of that outlined for accomplishment. Full accomplishment was inhibited by poor flying weather. Detailed ground gravity-meter work was done over about 90 square miles in the Barrow area during the breakup season when the aircraft used for transporting the gravity meter was unable to fly until the ice was gone sufficiently to permit operation on floats.

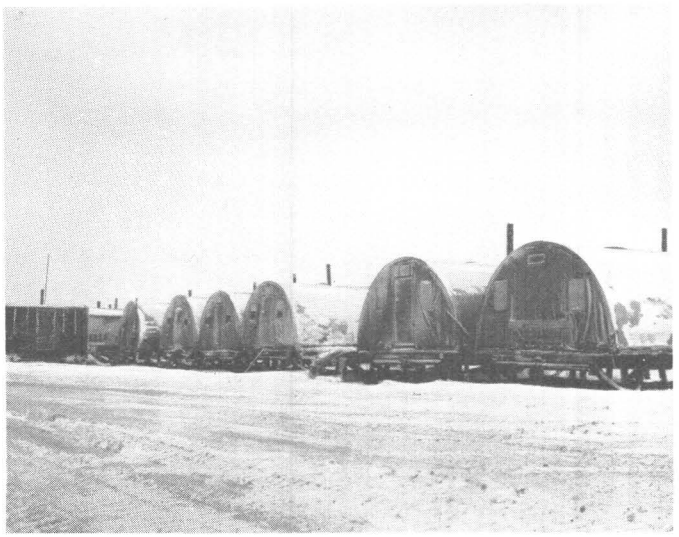

FIGURE 57.—Jamesway huts mounted on sleds for use of geophysical parties, 14 November 1949. Photograph by U. S. Navy.

PARTY 44

Party 44 was directed by Calvin Post. The season started on 7 March and lasted through 7 September. Both reflection and refraction work was done—176 miles of the former and 34 miles of the latter. The area covered lies between the Topagoruk and Ikpikpuk Rivers and north of the Oumalik test site. The work revealed a shallow zone, considerably folded, that extends to a depth of approximately 3,000 feet. Beneath the folded zone is a zone of discordant dips about 2,000 feet thick at the north but lensing out to the south. Still farther down, a basin appears to extend to a depth of more than 20,000 feet in the southwestern part of the area.

PARTY 45

Seismic party 45, headed by Arnold Palenske, worked in the Meade River area from the vicinity of the Meade River gas seepage northward to the confluence of the Meade and Nigiaktuvik Rivers. From the above-mentioned line, another line was surveyed seismically eastward across the Meade River to within 15 miles of Oumalik. Several loops were closed northwest of there. Four seismic refraction profiles were made. Total line length surveyed was 160 miles; 1,284 single profiles were used.

Strong echelon folding was found with several closures west-northwest of Oumalik. An unconformity separates a deep undisturbed zone from an upper folded section. A discordant zone of slow velocity overlies the unconformity.

PARTY 46

Under A. B. Sanders party 46 conducted seismic operations in the Dease Inlet and Barrow areas from 6 March to 25 August. Subsurface coverage was 145 miles with 1,462 equivalent single profiles shot. The Dease Inlet and Barrow areas were tied to the Simpson area by a line across Oarlock Island. The Barrow area was covered in the latter part of the season.

Detailed work at Barrow showed a circular zone of disturbance with indicated peripheral and radial faulting. Semidetailed work on the north flank of the Barrow structural feature showed pinchouts toward the crest.

PARTY 47

Party 47 worked from 6 February to 3 September. Two months was spent in the discovery, and in making a detailed seismic survey, of an anticline in the Barrow area. Three months was spent in a reconnaissance of the area of the Inaru River, the northern, lower course of the Meade River, and the area between the Meade and the Topagoruk Rivers. The remaining 2 months was spent on a semidetailed seismic survey of an area west of the Topagoruk River. Eugene Wiancko was chief of party 47.

Altogether the party ran 259 miles of reflection line and about 12 miles of refraction coverage. The anticline in the Barrow area has from 100 feet to 300 feet of closure. A regional unconformity appears to be present in the Barrow-Inaru-lower Meade River area, but no anticlines were found. The detail in the Topagoruk River area revealed a series of folds in the deeper

zones that may be related to basement conditions, and a small anticline was discovered with a closure of about 150 feet.

DRILLING

Total footage drilled in 1949 was greater than in any other year since the start of Pet 4. The total footage was approximately 35,000 feet in 17 holes. Furthermore, the test holes were widely scattered over the Reserve (see pl. 3), thus complicating the logistics and other operating problems.

SOUTH BARROW TEST WELL 2

South Barrow test well 2, which was about 5 miles southwest of Barrow camp and about 4 miles south of South Barrow test 1 (see fig. 58), was spudded in on 18 December 1948. On the first of the year it was 900 feet deep. By the time of the operating committee meeting in April, a great deal of difficulty was being experienced with cementing the casing. Mr. Gillespie discussed the situation at the committee meeting and explained that Arcon had to learn as it went along about handling such a well as South Barrow 2, as there was no previous experience with a high-pressure gas well under permafrost and other Arctic conditions.

Every effort was made to be sure that there was a sufficient reserve of gas at South Barrow test well 2 to justify the expense of investing in surface lines, well-head installations, etc. In this connection, a specialist from the firm of DeGolyer and MacNaughton visited Barrow and studied the situation. His estimate was that there was at least a 20-year supply at the usage rate of Barrow camp. The flow of the well was tested in early May. The total depth was 2,505 feet. The total production in 1949 was 30,124,000 cubic feet of gas that contained about 97.95 percent of methane, 1 percent of ethane, very little propane and butane, and 0.73 percent of nitrogen. It was estimated by Mr. Gillespie that the use of the gas would save about $275,000 a year in fuel oil.

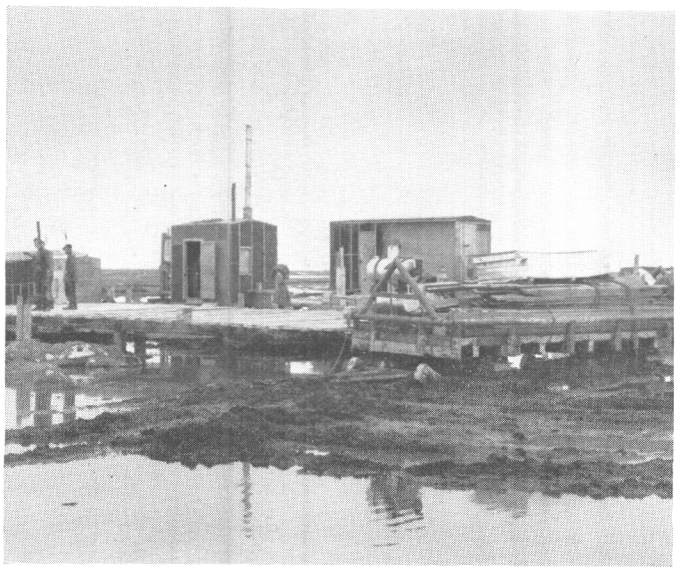

FIGURE 58.—Equipment platform at South Barrow test well 2. Photograph by U. S. Navy.

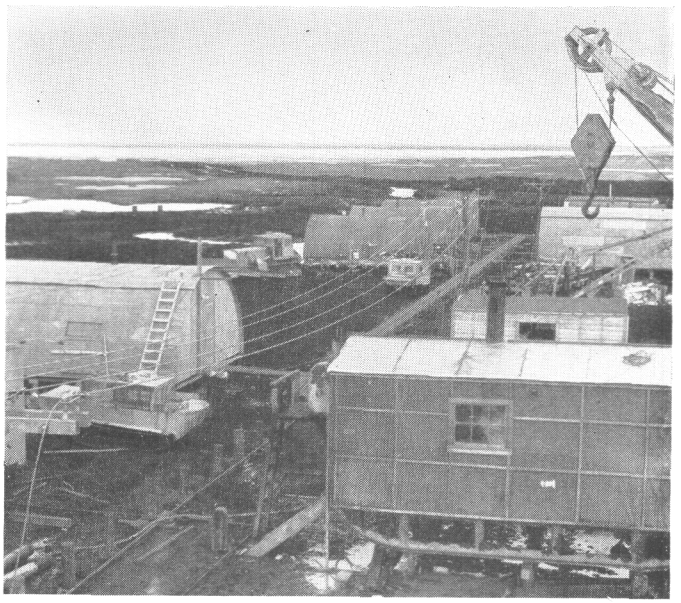

FIGURE 59.—Camp at South Barrow test well 3. Photograph by U. S. Navy, 30 June 1949.

SOUTH BARROW TEST WELL 3

Construction for South Barrow test well 3 started near the end of May (see fig. 59). The test was about 6 miles south of No. 2. The thaw had already begun, and the tundra around the site was soon badly cut up and eventually became virtually impassable. Difficulty was encountered in freezing-in the piling. The hole was spudded in on 23 June. There was a shortage of lumber and some other materials for the righouse because it originally had been planned to drill the test after materials had come up on Barex 49. The derrick had to be left open except for windbreaks.

No special difficulties were encountered in drilling the test which was completed on 26 August at a depth of 2,900 feet. The test was a dry hole, but it did yield much geologic information of value. It was felt that the oil possibilities of the Barrow "high" were not yet sufficiently tested.

FISH CREEK TEST WELL 1

Fish Creek test well 1 was drilled near the Fish Creek oil seepage in the center of an area of a large gravity anomaly. The seismic work did not indicate any substantial closure but did accord with an interpretation of deltaic deposits and possible stratigraphic traps.

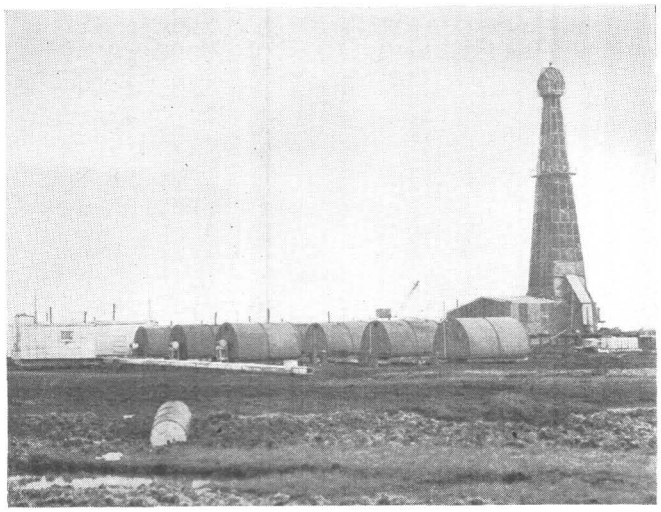

FIGURE 60.—General view of camp at Fish Creek test well 1, 7 September 1949. Photograph by U. S. Navy.

It primarily was considered to be a stratigraphic test. The location was about 17 miles south of Atigaru Point and about 16 miles west of the westernmost mouth of the Colville River.

Construction at the site (see fig. 60) began on 15 March, and the well was spudded in on 17 May. A National 50 rig was used. (See fig. 61.) By the end of June the drill had reached almost to 5,000 feet, and by 14 August the full depth of 7,020 feet was attained. The foundations for both camp and rig were of driven timber pilings, and there was no indication of any instability because of permafrost in spite of heavy loads, severe vibrations, and mud temperatures as high as 102°F.

Some oil and gas shows were seen but were not considered worthy of much further testing. A formation test was made of the section from 2,925 to 3,060 feet. There was a moderate gas blow. The drill pipe contained 180 feet of heavy black slightly gas-cut oil and 380 feet of mud with gas and oil. The porosity of the sands was roughly tested as between 25 and 31 percent. The hole was tested between 10 September and 25 October, and the total oil recovered was 444 barrels.

OUMALIK TEST WELL 1

Oumalik test well 1 was to be drilled with the Wilson Super Titan rig and was expected to be a deep hole. There was grave concern that the foundation in the permafrost might not last if the hole was long in drilling unless special precautions were taken. COL G. W. Rathjens was retained by the contractor to consult on the foundation. A testing station was established at Barrow to test such features of the frozen ground as tensile and compressive strengths, points and kind of deformation, and heat transfer. The preliminary testing indicated that special precautions should indeed be taken. The precautions were of 2 types—to attempt to retain the strength of the foundation by keeping it frozen and to prevent so far as possible the transfer of heat to the ground from the hot mud coming up the hole.

The crew arrived at the site on 16 February. Steel piling made from 8⅝-inch casing was designed as the foundation piling. They were fitted so that a refrigerant could be circulated through them. Three 4-inch surface refrigeration pipes were installed near the hole, and the tundra was retained so far as possible undisturbed. The piling was all set by 15 May, and the erection of the derrick began. (See fig. 62). The hole (see fig. 63) was spudded in on 12 June. By November it was 6,000 feet deep.

An attempt was made to isolate an air space for insulation between the surface 22-inch casing and the 13⅜-inch casing and to a depth of 150 feet in order to keep heat from the drilling mud from spreading into the ground. The foundation was fully equipped with temperature-measuring devices in order to keep track of the safety of the rig and the hole. A great deal was learned from the applied research at Oumalik relative to foundations in permafrost. It was an expensive job, and it seems likely that greater than necessary precautions were taken, but that could not have been predicted. By 1 January 1950, Oumalik test well 1 was 9,622 feet deep and going on. A refrigerant was being circulated in the pipes and piling nearest the hole.

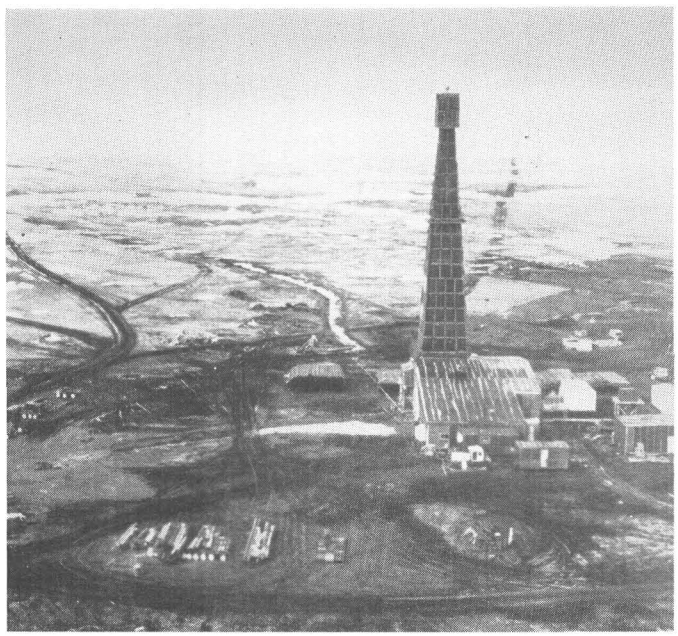

FIGURE 61.—National 50 rig at Fish Creek test well 1, summer of 1949. Photograph by U. S. Navy.

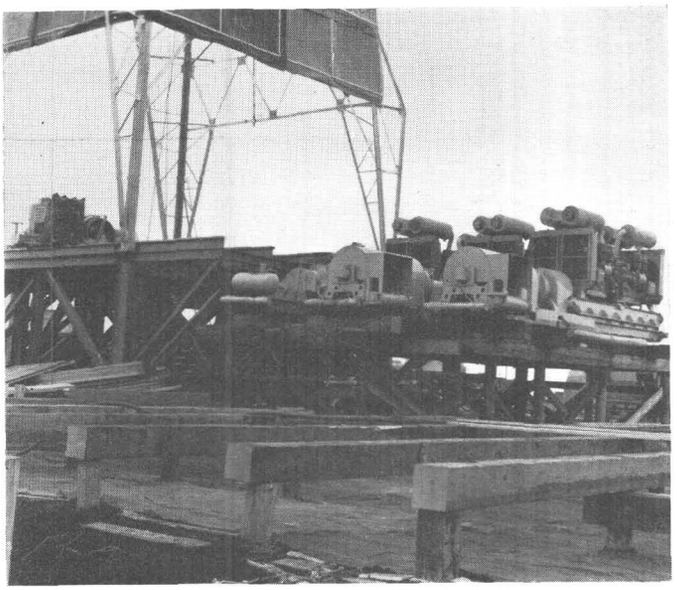

FIGURE 62.—Rig foundation at Oumalik test well 1 on 30 May 1949 showing draw works, power units, and ground insulation. Photograph by U. S. Navy.

SIMPSON CORE TESTS

Thirteen core tests were drilled in 1949 in the general vicinity of the Simpson oil seepages. These holes ranged in depth from 290 feet for Simpson core test 14A to 1,502 feet for Simpson core test 21. The tests were numbered 13 and 14, 14A, and 15 through 24. The line of seepages and a gravity anomaly in the vicinity led to the special interest in the Cape Simpson area. The total footage drilled was 13,660, of which a little more than 2,100 feet was cored. Even when all the work was done in 1949, it was generally agreed that neither an acceptable interpretation of the geology nor a determination of the petroleum potential of the vicinity could yet be made.

Core test 13 was spudded on 9 June and abandoned in July. It was 1,438 feet deep. Some difficulty was had with loss of circulation during drilling, and the hole was cored only to 1,212 feet, but an electric log was run all the way. A cable equipped with thermistors for temperature measurement was left in the hole when it was abandoned.

Core test 14, which was spudded on 21 July, was cored only intermittently. Dropped material was abandoned in the hole at 1,214 feet, although the hole was drilled to 1,270 feet, and an electric log was run to the depth of the dropped metal. Between 310 feet and 615 feet were some minor showings of oil and gas. Core test 14A was drilled only 70 feet away from 14 and was designed to intersect a near surface fossil zone that had not been cored in 14. It was 290 feet deep and was spudded on 14 August.

Data on the remaining core tests drilled in 1949 are shown in the table below.

Core test data, 1949

Core test	Spudded in	Depth (feet)	Completed	Remarks
15	16 Aug	900	23 Aug	Some oil showings.
16	24 Aug	800	30 Aug	Some gas.
17	31 Aug	1,100	8 Sep	Gas and a little oil.
18	10 Sep	1,460	21 Sep	
19	23 Sep	1,061	29 Sep	
20	5 Oct	1,002	11 Oct	
21	13 Oct	1,502	27 Oct	
22	29 Oct	903	5 Nov	
23	8 Nov	1,035	16 Nov	
24	22 Nov	901	28 Nov	

The later holes (see fig. 64) were spot cored only at appropriate places. Difficulty was encountered in using the manually operated Schlumberger, and a Widco logger therefore was purchased for use in holes up to 2,500 feet deep. The Simpson core tests were all drilled with a Failing 1500–S rig. (See fig. 65.)

On the completion of Simpson core test 24, the equipment was moved to high ground and blocked up, and the project was abandoned for 1949.

SUPPORTED ACTIVITIES

As in earlier years, Pet 4, by its presence and facilities in the Arctic, made possible many other activities not related, or only slightly related, to the oil exploration project. Pet 4 continued to lend every effort to assist such other activities in all reasonable ways. It

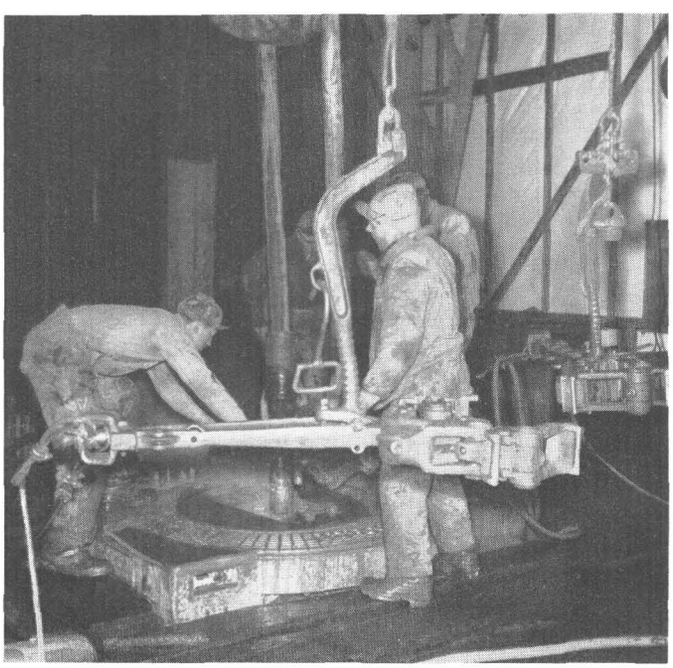

FIGURE 63.—Derrick floor scene at Oumalik test well 1 on 7 February 1950. Photograph by U. S. Navy.

would be impracticable to list all persons and organizations that were assisted in any way by Pet 4—the list would be too long and would throw out of balance the main purpose of this report. Some of the principal outside organizations so assisted, however, included the following—the National Bureau of Standards, the U. S. Air Force, the Naval Ordnance Laboratory, the U. S. Army Corps of Engineers, the Bureau of Yards and Docks, the Office of Naval Research, the Army's Airways and Air Communications Services, the Civil Aeronautics Administration, the Alaska Communication System of the Army Signal Corps, the U. S. Coast and Geodetic Survey, and the U. S. Weather Bureau.

Some of the above activities were financed by advances or transfers of funds from the agencies concerned to the Bureau of Yards and Docks and were then blanketed under the contract through appropriate change orders. Some of these in 1949 were included in change order P, issued in August, and provided $57,580 for a radio-propagation field station for the Bureau of Standards and certain construction and services for the Air Force at Barter Island at a cost of $94,500. Facilities for seismic observations at Umiat for the Naval Ordnance Laboratory estimated to cost $81,000 were covered by change order Q, dated 3 October. Change order R of 8 November provided for support of the Arctic Test Station of BuDocks for $17,900 and for the Arctic Research Laboratory of the Office of Naval Research estimated to require $60,900.

Some mention is made below of a few of the construction projects for some of the supported activities, but the descriptions are by no means inclusive.

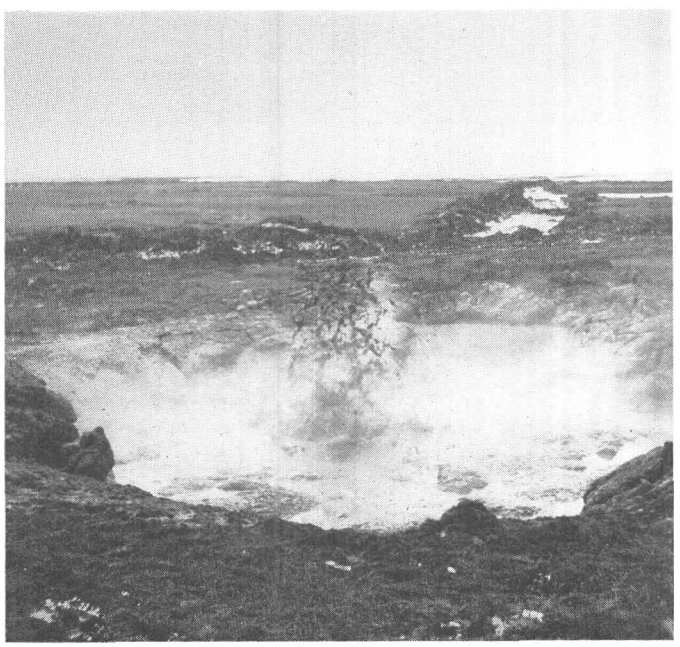

FIGURE 64.—Gas rising from Simpson core test 16. Photograph by U. S. Navy, 7 September 1949.

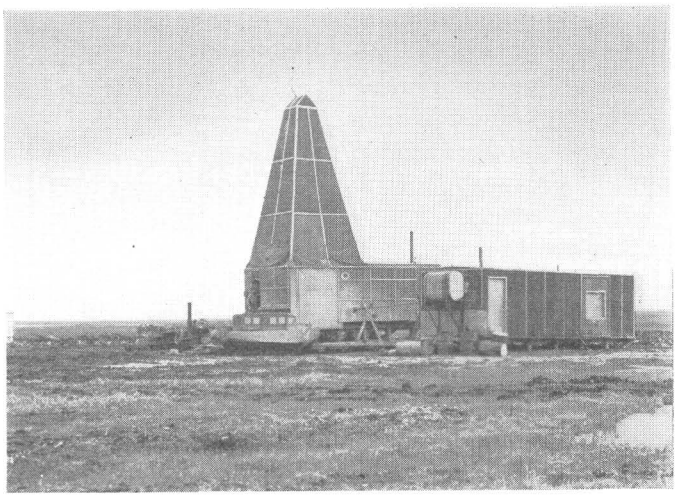

FIGURE 65.—Failing drill rig on location at Simpson core test 17. Photograph by U. S. Navy, 7 September 1949.

The radio-propagation field station for the National Bureau of Standards, Department of Commerce, consisted of an operations building, antenna system, and miscellaneous accessory facilities such as a garage and plumbing installations. The work was completed early in December.

The Arctic Research Laboratory of the Office of Naval Research was supported throughout the year. In addition to the continuing support, work for the ARL included the virtual completion of a new family-quarters quonset hut by the end of the year and by the middle of October the construction of a connecting building between ONR buildings 250 and 251.

A new power house and other construction for the Air Force at Barter Island were finished in November. Two or three weeks earlier Arcon had completed the construction of 6 observation facilities and appurtenant works including barometric gear and power facilities for the Naval Odnance Laboratory installation at Umiat. In November a butler hut (a specialized arctic-type shelter) with a concrete floor slab was completed for the Arctic Test Station. Earlier, in September, a power line and cable had been installed for the Weather Bureau.

A magnetic-absolute and a magnetic-variations building were built for the Coast and Geodetic Survey. The painting of the Skull Cliff tower was completed.

Earlier plans for the building of another 625-foot Loran tower at Barter Island were finally abandoned after study of foundation conditions and the costs involved. Similarly, it was decided to postpone the construction in 1949 of additional radar towers as navigation aids along the Arctic coast.

SUMMARY OF 1949

In year 1949 the greatest activity in Pet 4 up to that time was seen and, in fact, not much below the peak 2 years that were to follow. The size of Pet 4 in 1949 can be roughly measured by the money spent—approximately $7.5 million including funds received by the contract from others for services performed.

The average number of Arcon employees in 1949 was 528: 330 at Barrow, 16 at Umiat, 114 in the field, 49 at Fairbanks, and 19 at Seattle. There were 399 employed during the first week of January; this increased to a peak of 683 in early July.

The base plant at Barrow was enlarged steadily through the year to accommodate the expanding drilling program and the increasing requirements of others for services. Four seismic and six geologic parties were supported as part of the 1949 program. A series of core holes was drilled in the seepage area near Cape Simpson, and South Barrow test well 2 was brought in as a gas well.

Outstanding among the personnel changes during the year was the leaving of Bart W. Gillespie, who had been associated with Pet 4 since its inception. Other important personnel changes were the appearance on the Pet 4 scene of E. W. Beltz as the first chief of exploration, E. L. Davis as project manager, and CDR M. H. Aubey as OICC.

Special effort was made by the operating committee and the involved personnel to coordinate and focus more closely the rapidly increasing body of basic information that was becoming available through the efforts of the United Geophysical Co., the Geological Survey, and others. The creation of the position of chief of exploration in 1948 was indicative of this trend.

The drilling footage in 1949 was substantially greater than in any previous year. It was expected that even more drilling could be accomplished in later years because of preconstructed righousings, standardization of layouts, and increased experience.

Among the notable specific accomplishments of 1949 were—

1. Winter freighting in the total amount of 1.3 million ton-miles.

2. Greatly increased information and experience in the design of safe, heavy-rig foundations.

3. The completion of South Barrow test well 2 as a gas well and the bringing of gas service to the Barrow camp.

4. The establishment and use of bulk fuel storage at Barrow.

5. The successful experiments with LVT and boat freighting within Naval Petroleum Reserve No. 4.

SEVENTH YEAR—1950

GENERAL PLANNING AND ADMINISTRATION

By the beginning of the seventh year of Pet 4, in January 1950, the plant, facilities, and equipment had very largely been accumulated and installed. Henceforth, the accomplishment of the job itself would be the main item of business with fewer activities that were part of getting ready to do the job. (See figs. 66, 67, 68.) As the year began, one test hole—Oumalik test well 1—had already been drilled to a little more than 9,600 feet; winter freighting was underway; and Barrow 2 gas well was supplying an average of about 430,000 cubic feet of gas a day to the camp.

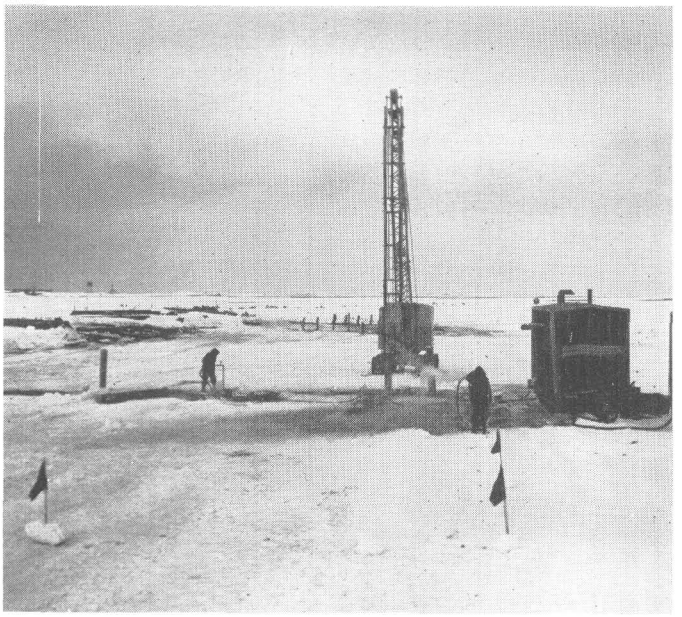

FIGURE 66.—Construction of float-plane dock in lagoon at Barrow. Holes are being steamed through lagoon ice; piles will later be driven through the holes into the mud bottom. Photograph by U. S. Navy.

On 9 January the OICC (CDR M. H. Aubey) and the assistant project manager for ARCON (Ted C. Mathews) went to Anchorage to attend a conference relative to a survey for a petroleum pipeline from the coast to interior Alaska. For the purpose of obtaining firsthand information about Pet 4, a party headed by the Chief of Staff, Com 17, departed for Barrow, along with the OICC on 20 January and returned to Fairbanks and left for Kodiak on 26 January.

Ever since the 11th meeting of the operating committee, it had been generally known that E. W. Beltz would probably not be continuing as chief of exploration for ARCON after the termination date of his contract, which was 31 January 1950. There was considerable discussion as to whether a replacement would be sought or the position abolished and its duties redistributed. It was determined to continue the position,

and on 28 January, R. G. Reese, formerly of the Standard Oil Company of California, reported in Fairbanks to take over the position. Also on 28 January, Hugh B. Fate, M. D., reached Fairbanks on his way to Barrow to take up his new duties as the doctor for ARCON in the Reserve.

The OICC on 20 January sent a memorandum to the Director, Naval Petroleum Reserves requesting substantial changes in the 1950 program as approved at the November meeting of the operating committee because of new data that had become available between the November meeting and late January 1950. These changes were recommended by the combined technical staff in Fairbanks. In essence they consisted of postponing the drilling of a deep test at East Simpson 1 (Simpson 2 as recorded in the minutes of the 11th meeting of the operating committee) and substituting a shallow test to be designated North Simpson 1 and a deep test at the Topagoruk site—the location to be based on new seismic data. The Fairbanks staff estimated that the change would cost an additional $336,000 but would advance the exploration very substantially.

The Director, Naval Petroleum Reserves polled the operating committee by mail on receipt of the above-mentioned memorandum and, after receiving the members' individual reactions, on 2 February made the following decisions:

1. East Simpson 1 will be deferred.
2. A decision on the drilling of North Simpson 1 will be held up until the 12th meeting of the operating committee in April.

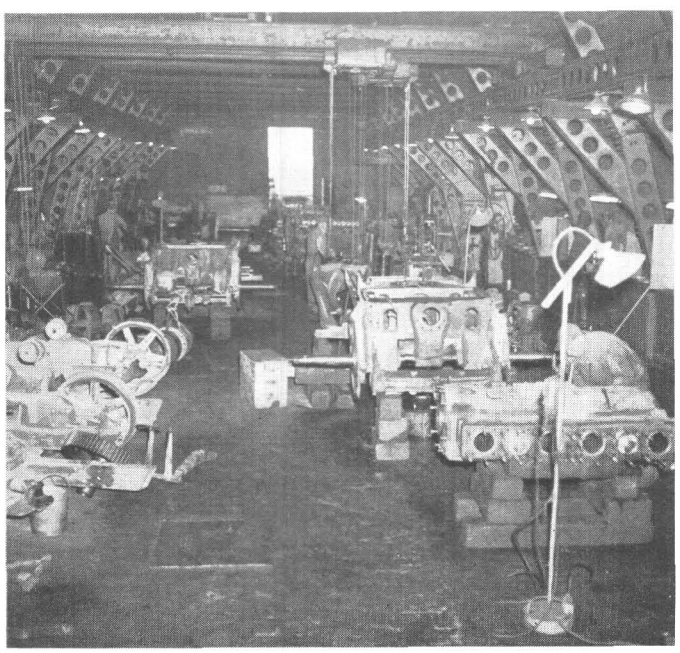

FIGURE 67.—Interior of heavy-duty-equipment shop at Barrow, September 1950. Photograph by U. S. Navy.

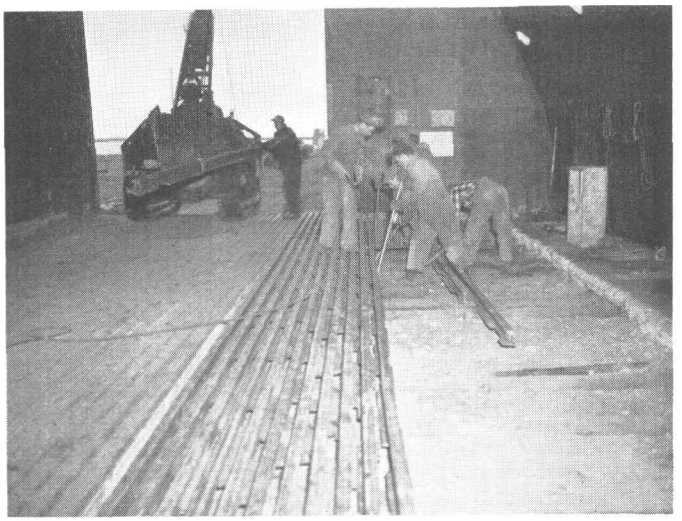

FIGURE 68.—Rails being placed in concrete to form floor of sled shop at Barrow, September 1950. Photograph by U. S. Navy.

3. Geophysical work at Topagoruk will proceed. Selection of location will be made at a conference in Los Angeles, Calif., as soon after 15 March as the additional geophysical data are available.

It will be recalled that at the 11th meeting of the operating committee it was determined that a subcommittee would work with the chief of exploration in the development of a geological field program for 1950. This subcommittee met in Washington, D. C., on 20 February. In attendance were Lewis MacNaughton and Earle Taylor, of the firm of DeGolyer and MacNaughton; Glen Ruby, A. A. Curtice, and Rex Townsend, of Exploration Contractors, Inc.; Walter English, technical advisor to the Director, Naval Petroleum Reserves; W. E. Wrather, Ralph Miller, George Gryc, and John C. Reed, of the Geological Survey; the Deputy Director, Naval Petroleum Reserves; and the Director, Naval Petroleum Reserves.

The subcommittee recommended that—

1. Party 1 map the Driftwood anticline. The use by Party 1 of a light-weight portable drill would be investigated.
2. Party 2 make stratigraphic studies in the vicinity of the Siksikpuk and the Nanushuk Rivers.
3. Party 3 make stratigraphic studies and appraise the reservoir characteristics of the Lisburne group in the following areas: Sagavanirktok Lake, Kanayut Lake, Chandler Lake, Kurupa Lake, and Feniak Lake in the headwaters of the Noatak.
4. Party 4 make structural studies of the western part of the Carbon Creek anticline and of the Ketik anticline.

5. Party 5 make a detailed study of the Aupuk anticline and then work south and west as far as possible.
6. Party 6 make structural and stratigraphic studies between the Kiruktagiak and the Kuna Rivers.
7. Party 7 work in the area of the Kuguroruk and Nimiuktuk Rivers as far downstream as the Noatak River.

The subcommittee also discussed the current drilling situation and recommended that—

1. Arcon be authorized to proceed with plans for and the drilling of North Simpson 1 as proposed.
2. Arcon be authorized to freight necessary equipment and supplies for two Cardwell tests in the vicinity of the Simpson seepages.
3. The 1,200-foot hole in the center of Lake Minga to test permafrost conditions be drilled and equipped with thermistors.

On 2 March the OICC visited Ladd Air Force Base in order to brief 21 visiting officers of the Royal Canadian Air Force on Pet 4 operations. On 13 March the OICC held a conference with LTJG R. B. Carleton; LT Norman Jackson; Messrs. Mathews and Spaulding, of Arcon; and T. G. Roberts, of the Geological Survey, to discuss helicopter support in the Reserve.

As agreed at the 11th meeting of the operating committee, another subcommittee of the operating committee to consider the drilling program and related matters met in Los Angeles, Calif., on 16 March. The subcommittee was under the chairmanship of COL O. F. Kotick, Deputy Director, Naval Petroleum Reserves. Also in attendance were Messrs. Lewis MacNaughton, of DeGolyer and MacNaughton; E. L. Davis, project manager, Arcon; R. G. Reese, chief of exploration, Arcon; Glen Ruby, Exploration Contractors, Inc.; Howard Myers, United Geophysical Co.; and R. L. Miller, Geological Survey. Herbert Hoover, Jr., attended a part of the meeting. The first conclusion of the subcommittee was unanimous to the effect that the proposed Topagoruk test be drilled in 1950. Next a specific location was selected for the test. A majority of the subcommittee was in favor of closing down Oumalik 1 in time to move the rig to the East Oumalik site. The subcommittee discussed the desirability of further exploring the Barrow "high." Finally, it recommended that a light drill rig not be sent with the geologic party to the Driftwood anticline.

The 1950 drilling program was further discussed in Fairbanks on 22 March by the OICC; E. L. Davis, Ted C. Mathews, Drex Spaulding, Howard Myers, E. C. Hamilton, R. G. Reese, of Arcon, and T. G. Roberts, of the Geological Survey.

On 19 April, the operating committee and others connected with Pet 4 again assembled in building T3, Navy Department, Washington, D. C., for the 12th regular meeting of the committee. The meeting continued for 3 days—19, 20, and 21 April. This was an important meeting; for, in addition to approving certain modifications of program that had been suggested since the 11th meeting the previous November, the committee was to appraise the program to date and present recommendations for the future to the Secretary of the Navy.

All members of the operating committee were present, including Commodore W. G. Greenman, Director, Naval Petroleum Reserves; COL O. F. Kotick, Deputy Director, Naval Petroleum Reserves; W. E. Wrather, Director, Geological Survey; A. A. Curtice, vice president, Exploration Contractors, Inc.; L. W. MacNaughton, DeGolyer and MacNaughton; and CDR G. E. Fischer, CEC, USN. Among others present were Walter A. English, technical advisor to the Director, Naval Petroleum Reserves; Herbert Hoover, Jr., president, Exploration Contractors, Inc., and United Geophysical Co.; Richard Reese, chief of exploration, Arctic Contractors; and Ralph L. Miller, geologist in charge, Navy Oil Unit, U. S. Geological Survey.

The following is a brief resume of the salient features of the meeting:

Drilling

1. East Simpson test well 1 (Simpson test well 2 as reported in the record of the minutes of the 11th meeting) would be deferred. This test had been approved at the 11th meeting. It was felt that further exploration of shallow horizons in the area should precede another deep test and that the National 125 rig would be of more immediate value at the proposed Topagoruk site.

2. Topagoruk test well 1 would be drilled with the National 125 rig to a depth of about 12,000 feet. The site was to be the location selected by the subcommittee when it met in Los Angeles, Calif., in March. In addition to being in a strategic location to yield much needed geologic information, the hole would test a suspected unconformity at about 10,000 feet and 150 feet to 200 feet of structural closure in the deeper horizons.

3. North Simpson test well 1 would be drilled to a minimum depth of 3,600 feet to explore a seismic reversal of about 400 feet between a depth of 3,500 feet and 4,000 feet. The committee agreed unanimously to drill North Simpson 1 to a minimum depth of 3,600 feet in order to penetrate any reservoir rocks, to establish a correlation with Simpson test well 1, and to determine if an unconformity existed at approximately 4,000 feet.

4. The committee approved the recommendations of a subcommittee that provided for the following drilling in the Simpson seepage area with the Cardwell rig:

a. The drilling of a test due east of core test 22 and due south of core test 20 to about 2,500 feet to determine if the oil-bearing sand at the seeps also carries oil down the dip.

b. The drilling of 3 core tests to a maximum depth per hole of 1,500 feet and including about 3,000 feet of coring in the vicinity of seepage 3 in order to determine the structure of the beds underlying the seepage.

5. The committee decided to suspend the drilling of Oumalik test well 1 at its depth at that time—11,872 feet. That had been recommended by the subcommittee that met in March in Los Angeles, Calif., and was occasioned by the need of moving the rig to the East Oumalik site by 15 April, by the poor condition of the Oumalik test well 1 hole because of sticking of tools at 3,600 feet and of constricted hole at 5,000 feet, and by the poor outlook for any substantial oil finds below the depth already reached. The gas zone between 2,672 feet and 3,600 feet had been tested with negative results, and a velocity survey of the hole had shown a constant velocity of the rocks penetrated as 10,700 feet per second. This latter information permitted a new interpretation of the section at the Topagoruk site that would place the basement there at about 10,000 feet.

6. The earlier decision to drill Umiat (Ruby) test well 1 to test the practicability of drilling the permafrost zone in the Umiat field with cable tools, using a brine drilling fluid, was confirmed.

7. The committee confirmed the decision to drill a hole under Lake Minga to find out the permafrost conditions there. The seismic work showed a seismic sag under the lake, and it was felt that that might be due to an unfrozen condition under the lake. The answer was required to help interpret the structure of the Cape Simpson area and as a generality for use in interpreting seismic conditions near other lakes.

Unitization of second Cardwell rig

After a discussion of the possibility of more shallow drilling to search for condensate reservoirs in the Barrow area and elsewhere, the committee authorized the purchase of the necessary materials to unitize a second Cardwell rig and ship them to Barrow during the summer of 1950. The committee felt that possible requirements for the use of such a mobile rig were great enough to fully justify its procurement.

Geophysical surveys

Howard Myers, chief geophysicist, described the progress of the geophysical activity up to the date of the meeting. He announced that the United Geophysical Co. had employed L. B. Luhrs to reevaluate the gravity and magnetometer work done during the summer of 1950. He also noted that the gravity project, to be transported by helicopter, would start about 1 June. The Bureau of Yards and Docks had authorized Arctic Contractors to subcontract with the Bell Helicopter Co. for the helicopter support. The committee recommended that the Director, Naval Petroleum Reserves request funds for 2 geophysical parties in the field in 1951 and 2 in 1952.

Geologic surveys

Members of the Geological Survey reported on the results of recent geologic work and made some new interpretations of older work. The committee decided that the Survey's laboratory should continue its studies of porosities and permeabilities from outcrop and well samples. It was agreed to suspend photogeologic work during the summer of 1950 in order to permit W. A Fischer to visit the field for studies that would aid in later photogeologic interpretations. George Gryc pointed out that the planimetric map compilations were now being made by the Survey's Trimetrogon Unit in Washington, D. C., rather than in Denver, Colo., as in the past. Some quadrangles, about 16, would have to be recompiled because of the poor control available earlier. The Director, Naval Petroleum Reserves indicated that he could not provide funds for geologic work outside Naval Petroleum Reserve No. 4 that did not contribute to the Pet 4 program. The committee recommended four geologic parties for the season of 1951 and none for 1952.

Arcon report

The contractor reviewed various aspects of Pet 4 operations including personnel, costs, rate of accomplishment, amount of drilling, and related items. It was pointed out—and the committee agreed—that it probably would be more economical to spread the remaining work through calendar year 1953 than to add additional capability to finish in 1952. It was estimated that the work could be done in the longer period for about $350,000 less. It was decided that the timetable would be given further consideration at the close of the 1951 season and after a report had been submitted by a committee to be appointed by the Secretary of the Navy to evaluate results.

Termination of Pet 4 and future planning

The Director, Naval Petroleum Reserves pointed out that it had been visualized previously that the objective of Pet 4 could be attained by the end of 1952. This had been accepted by the Secretary of the Navy and endorsed by the Department of Defense, the Bureau of

the Budget, and the interested committees of the Congress. He insisted that any extension of time would have to be justified by substantial evidence. The discussion that followed showed that, as Pet 4 had progressed, the increasing evidence of the presence of petroleum over so vast an area was so pronounced that success always appeared to be just around the corner. This situation, in the absence of a discovery, was bound to make a decision to terminate at any given time increasingly difficult. The committee did not wish to recommend any extension of time at the meeting then underway but proposed that the Secretary of the Navy designate a special group to evaluate results. The Director, Naval Petroleum Reserves stated that he would have to discuss the matter with the Secretary before recommending any change in the timetable of Pet 4.

It was decided to hold an interim meeting of the committee on 13 September in Fairbanks. The meeting adjourned at 1100 on 21 April. The minutes and recommendations were approved by Assistant Secretary of the Navy, John T. Koehler on 1 June.

On 2 May, CAPT Foster L. White, USAF, petroleum engineer, was detached from duty in Naval Petroleum Reserve No. 4. On 24 July Sam R. Broadbent, of the Bureau of the Budget, spent nearly the entire day at the Arcon offices in Fairbanks studying the procedures used in budgeting the contract. The next day Mr. Broadbent flew via linehaul plane to Barrow to observe operations in the field. W. Wain Gifford reported to the OICC on 4 August to become his technical advisor replacing Mr. Hamilton, who had previously resigned.

During the summer of 1950, it was agreed to constitute a Fairbanks joint staff to be made up of the heads of the various units at the Fairbanks level. These officials included the OICC, the head of the Navy Oil Unit of the Geological Survey, in Fairbanks, the head of the geophysical activity under the United Geophysical Co., the project manager, the chief of exploration, and any representatives of the Director, Naval Petroleum Reserves or members of the operating committee who happened to be available. The function of the Fairbanks Joint Staff was to review the program and operations as might be desirable to expedite study and action by the operating committee at its regular or interim meetings.

The Fairbanks Joint Staff met in Fairbanks on 11 and 12 August. Present were COL O. F. Kotick, Deputy Director, Naval Petroleum Reserves; CDR M. H. Aubey, OICC; W. Wain Gifford, technical advisor to the OICC; Walter A. English, technical advisor to the Director, Naval Petroleum Reserves; Howard Myers, head of the United Geophysical Co. operations; T. G. Roberts, head of the Navy Oil Unit in Fairbanks; Ralph L. Miller, head of the Navy Oil Unit; R. G. Reese, chief of exploration; Ted Mathews, assistant project manager; and E. L. Davis, project manager. Marvin Heany and Harold W. Hoots were present as observers.

Ralph L. Miller described the operations of the Geological Survey field parties and some of their tentative conclusions. Howard Myers reported on the operations of the geophysical parties, including the gravity-meter party. Some modifications of the geophysical work were recommended, and these were considered to be within the authority of the joint staff. Mr. Miller also described the present interpretation of the Umiat structure. In response to a request from Colonel Kotick, Mr. Reese reported that Marvin Heany was assembling available data for making more refined facies maps.

The agenda for the forthcoming interim meeting of the operating committee in September was discussed. The following locations for possible test wells were mentioned: a shallow test at the Topagoruk site, a deep test at the Topagoruk site, shallow tests on the Gubik, Weasel Creek, West Meade, and Utukok-Kuk anticlines, and on the northeast part of the Oumalik anticline.

Mr. Miller described some of the geologic situations in the foothill belt near the mountain front, and Ted Mathews commented on some of the operational problems in that region, including the requirement for a landing strip. The foothill region was dismissed as an area for the operation of a mobile geophysical party. The joint staff did not concur in a proposal by Walter English that the Meade test well 1 be redrilled to obtain satisfactory cores of sandy zones. Ted Mathews reviewed the proposal to convert LVT's (landing vehicle, tracked) to diesel power and estimated that such revamping of 5 LVT's would cost roughly $100,000.

On 12, 13, and 14 September an interim meeting of the operating committee was held in the offices of Arcon in Fairbanks. The purposes of the meeting were to review exploration during 1950 and to outline a tentative program for 1951. Committee members and alternates present included Commodore Greenman, Colonel Kotick, Mr. Wrather, A. A. Curtice, Earle Taylor for Lewis W. MacNaughton, Commander Aubey, and Walter A. English. Others present were CAPT R. H. Meade, CEC, USN, prospective relief for Commodore Greenman; LCDR J. C. Bomke, prospective relief for the fiscal officer in the Office of Naval Petroleum Reserves; Herbert Hoover, Jr.; Glen W. Ruby; Rex Townsend, vice president, Exploration Contractors, Inc.; James Tully, secretary, Exploration Contractors, Inc.; Ralph Green, president, Green Construction Co.; W. W. Gifford, petroleum advisor to OICC; M. J. Lebsack, Office of Naval Petroleum Reserves; E. L. Davis; R. G. Reese; T. C. Mathews; J. M. Adams, general superintendent for Arcon at Barrow; R. B. Block,

chief of drilling and production; Karl VonderAhe, chief petroleum engineer; 1st LT G. H. Oosting, USA; C. A. Everett, John Bollenbocher, and M. Heany, geologists of Arcon; Howard Myers, J. R. Woolson, and L. Luhrs, of the United Geophysical Co.; John C. Reed, Ralph L. Miller, George Gryc, T. G. Roberts, Harlan R. Bergquist, C. L. Whittington, Florence Robinson, and Florence Rucker, of the Geological Survey.

CAPT R. H. Meade, CEC, USN, was introduced formally by Commodore Greenman as his prospective relief as Director, Naval Petroleum Reserves.

Commodore Greenman outlined several policies that would be followed during the rest of Pet 4:

1. Pet 4 will terminate at the close of 1952 except for necessary closeout work thereafter.

2. All usable material will be returned to the States in the summer of 1953.

3. In the event of a major oil discovery, the project will be restudied as to the desirability of continuance.

4. Expenses are to be kept to a minimum to permit drilling of test wells in all promising areas.

5. A minimum amount of drilling will be employed to indicate the productive limits of the Umiat and Simpson fields.

6. Oil sands of consequence will be given drill-stem tests as a basis for production estimates.

7. No wells will be completed for production tests unless a major discovery is indicated.

8. Geologic and geophysical work will be limited to detailed delineation of areas selected for drilling that can be completed before the end of 1952.

9. No shallow drilling outside the Reserve will be considered until those possibilities inside are tested. The Gubik anticline may be an exception.

Commander Aubey presented general comments on the operation. Mr. Davis, with the help of Messrs. Rusing, Mathews, and VonderAhe, gave a general review of 1950 operations, including a financial discussion. After a review of the Barrow gas situation, it was decided that the contractor should make a study to determine what steps should be taken to insure a gas supply for the camp until the end of 1952. The 1950 geologic fieldwork was reviewed by Ralph Miller, George Gryc, and others of the Geological Survey's Navy Oil Unit. A review of the geophysical activity was presented by Howard Myers.

Arcon was asked to prepare by the November meeting a regional map outlining the areas considered most favorable for future exploration. After detailed discussion the committee formulated a tentative future program as follows:

1. The productive limits of the Umiat oil field were to be further delimited by drilling up to 3 additional wells. These would cost about $30,000 each. Also, the contractor was to estimate by the November meeting the cost of 2 additional wells. The exact location of the 3 wells was left to the Fairbanks joint staff. It was hoped that the wells proposed would indicate whether the oil is moved by gravity, water pressure, or gas pressure.

2. Up to $60,000 was authorized for additional core holes in the Simpson area. Arcon was requested to prepare a program for consideration at the November meeting for exploration south of the area that had been drilled at Simpson.

3. Mr. English's proposal to test anticlines similar to Umiat and farther west for about 80 miles was approved. Arcon was asked to prepare by November a program with cost estimates including comparisons in the use of the Cardwell, Failing, and cable-tool rigs.

4. The contractor by November was to have estimates for testing the West Meade anticline, and it was agreed that all data on the West Meade area should be reviewed and discussed at the November meeting.

5. Because of the possibility that the rocks in the Kaolak area may be lower stratigraphically than in the Meade area, Arcon was instructed to prepare estimates for a 3,000- to 5,000-foot test in that area. The Survey was to restudy all data, especially any stratigraphic information, that might be gained from shothole cuttings.

6. The contractor was requested to make estimates for a test in the vicinity of the petroliferous outcrops on the Kokolik River. Drilling there was to be further considered at the November meeting.

7. Further drilling in the Barrow area, including the previously authorized Elson test, was deferred because of the slight possibility of finding any substantial oil field.

8. By November the contractor was to provide cost data for drilling the Gubik anticline to a depth of 3,500 to 5,000 feet. Drilling is to be further considered and will require seismic work early in the spring of 1951.

9. Agreement was reached to consider testing further the shallow Topagoruk structural feature about 25 miles southeast of the deep Topagoruk 1 test. Such drilling could be considered in lieu of the Elson test mentioned in 7 above.

10. Any decision regarding the Topagoruk deep test was deferred until November.

11. The same decision as above was made regarding the North Oumalik test.

12. Approval was given to Mr. Curtice's recommendation that seismic work be performed in search of west plunge on the Sentinel Hill anticline north of Umiat.

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Arcon was asked to estimate on that as well as on depths and equipment for a drill test.

13. Approval was given to Colonel Kotick's suggestion to do additional seismic work to delineate further an anticline in the Wainwright area.

14. Colonel Kotick was designated to meet with representatives of the Geological Survey to study the whole Lisburne problem with a view to selecting a drill location to be tested before the close of Pet 4, if a suitable location on the Driftwood or other anticline can be found.

Also approved for final discussion at the November meeting were proposals that—

1. All available information be marshaled for the Square Lake anticline about 20 miles northwest of Umiat.

2. A core test be drilled between core tests 10 and 12 on the Simpson Peninsula to substantiate the theory of submarine erosion.

3. Three core tests be drilled to about 1,500 feet across the seepage at Tom Brower's place on Admiralty Bay.

4. If the core tests at Simpson indicate hopeful sands in the upper E horizons, a seismic program be initiated in February 1951 north of Teshekpuk Lake and elsewhere south and east of Simpson.

5. A geophysical program be started for the following: Gubik anticline, Wainwright, in the area of the Lisburne group, and for 1–4 just above.

6. The Navy Oil Unit of the Geological Survey suggest a geological field program keyed to the rest of proposed exploration program.

7. Gamma-ray logging be considered.

Immediately after the interim meeting, Admiral Moeller and Captain Wesanen traveled to Pet 4 with Captain Meade, Commander Aubey, and others to look over the project on the ground. Most of the party returned to Fairbanks on 19 September. On 4 October the OICC was visited by the Senate Subcommittee for Alaskan Defense. On 6 November LCDR J. V. Jones and LTJG H. J. McGarr reported in to relieve LCDR S. C. Gill, ROICC and to become technical assistant to the OICC, respectively. The Secretary of the Air Force, Mr. Finletter; the Assistant Secretary of the Army, Mr. Johnson; General Kepner, CINCAL (Commander in Chief, Alaska); General Armstrong; General Baker, and staff members visited the OICC for a briefing on Pet 4 on 12 November.

The 13th meeting of the operating committee convened in building T3 in Washington, D. C., on 27 November. The meeting lasted through 1 December. The purpose of the meeting was to recommend a program for 1951. Operating committee members in attendance included Commodore Greenman, who chairmanned his last meeting as Director, Naval Petroleum Reserves; Captain Meade and Colonel Kotick, Deputy Directors of Naval Petroleum Reserves; W. E. Wrather, A. A. Curtice, L. W. MacNaughton, and Commander Fischer. Also present were about 50 others representing various segments of the Pet 4 organization.

On the first day of the meeting, discussions of the results of fieldwork in geology were presented by 9 party chiefs of the Geological Survey, each one reporting on the area covered by his party.

The first day of the meeting was closed with a review by George Gryc of the geologic situation as then understood based on the past season's work and previous work. Mr. Gryc's review was supplemented by a short discussion by W. A. Fischer of certain structural features as revealed by photogeologic work.

On the second day of the meeting, 28 November, the results of some of the special studies by the Geological Survey were presented to the committee. At the start of the afternoon session, the geophysical aspects of the 1950 season's work were presented by Howard Myers, of the United Geophysical Co. First he briefed the results of the field parties as follows:

1. Fish Creek-Colville River-Titaluk area, party 144. Party chief, A. B. Sanders.
2. Middle Meade area, party 145. Party chief, Arnold Polenske.
3. Wainwright-Utukok area, party 146. Party chief, H. B. Chalmers, Jr.
4. Topagoruk-Simpson area, party 147. Party chief, F. E. Wianko.
5. Driftwood refraction survey, party 148. Party chief, Samuel Allen.
6. Gravity-meter survey, 1950 season, party 249. Party chief, L. B. Luhrs.

Mr. Myers then discussed general interpretations of underground conditions in the light of all the geophysical data to that time. Next he interpreted the situations at several local areas of interest in terms of the general interpretations. There was substantial discussion that is fully recorded in the transcript of the meeting.

The chief of exploration, R. G. Reese, reviewed the 1950 drilling operations including Oumalik test well 1, South Barrow test well 4, Minga velocity hole 1, Meade test well 1, North Simpson test well 1, 3 test wells in the Umiat area (Ruby 1, 2, and 3), 4 core tests in the Simpson area, Topagoruk test well 1, and East Oumalik test well 1. E. L. Davis, project manager for Arctic Contractors, presented a report entitled "Review of 1950 Operations"; the report was followed by discussion. Next Mr. Reese discussed "Favorable Areas for Exploration"; this was followed by detailed technical

discussion, especially as to application of the developing geologic understanding to drill sites or areas under consideration.

LCDR J. C. Bomke, of the Office of Naval Petroleum Reserves, then outlined the fiscal situation. The total estimated cost of the 1950 program was a little more than $9.1 million. Captain Meade, who was taking over as Director, Naval Petroleum Reserves outlined his philosophy for the remainder of Pet 4.

Next the operating committee got down to the main task of the meeting—to develop an integrated Pet 4 program for 1951. Mr. Davis led this discussion by the presentation of the program recommended by the Fairbanks Joint Staff.

The Umiat area was taken up first. A location was proposed to test the Ruby sands immediately south of the zone of steep surface dips and then to drill deeper to intersect a suspected south-dipping fault and determine if the Ruby sands are present in the footwall block. A cable-tool hole would be located near Umiat test well 1 in the thought that Umiat 1 was not an adequate test.

Tentatively, the committee accepted the proposals as regards the two locations at an estimated additional cost of perhaps $130,000. The meeting was recessed until the next day.

The next morning, 29 November, the committee tentatively approved a relatively shallow test drilling program in the Maybe Creek area and a production test and research program at the Umiat field. There was full discussion of other areas where drilling was proposed by the Fairbanks Joint Staff, including the Knifeblade, Aupuk, Titaluk, and Gubik anticlines, the East Topagoruk area, and the West Meade, Simpson, Barrow, Driftwood, and other areas. This discussion went on into and through the next day, 30 November. The major items of the program to be recommended for 1951 were evolving by the end of this session.

These items were concluded on 1 December as follows:

Drilling

Test wells recommended included—

	Approximate depth (feet)
Umiat anticline, crestal area	2,000
Wolf Creek anticline	1,500
Weasel Creek anticline	1,500
Knifeblade Ridge, north	1,500
Knifeblade Ridge, south	1,500
West Titaluk anticline	4,000
Gubik anticline	5,000
Kaolak anticline	7,000
Brower seep core tests (3)	1,500

By a later directive an additional shallow hole at East Topagoruk was approved.

Additional tests in known oil-bearing structural features were recommended as follows: Umiat (Ruby) 4, 5, and 6, which had previously been approved at the September meeting—1,500 feet each; six tests in the Simpson area with an expenditure limitation of $100,000—500–1,500 feet each.

It was recommended that $1.3 million be set aside to drill one or more deep tests if results of the Topagoruk or East Oumalik wells, then drilling, or early 1951 seismic work indicated that such wells should be drilled in 1951.

Geophysics

Three seismic field parties were recommended to work—

1. On the Gubik anticline, starting about 15 December 1950, to seek the best location for the Gubik test well and to proceed to the area east and southeast of Skull Cliff after about 6 weeks for reconnaissance to locate a possible later South Barrow test.

2. On the Kaolak anticline, beginning about 15 February 1951. This project to include also a refraction survey across the highest part of the Carbon Creek anticline.

3. On the Driftwood anticline, beginning about 1 April 1951, for about 1 month to locate a possible deep-test site on the south flank of the anticline.

Geology

Four field parties were recommended. The projects were to be chosen by the Geological Survey with the advice of the Director, Naval Petroleum Reserves, the operating committee, and Arctic Contractors. The maximum expenditure to 31 December 1951 to be $145,000, in addition to funds allotted to date.

The Survey program also was to include—

1. A geologist to work with the Arcon geologist relative to the drilling at Wolf Creek, Weasel Creek, and Knifeblade Ridge.

2. A geologist to work with the United Geophysical Company's crew on the Driftwood anticline.

Production tests

Sixty- to ninety-day production tests in the Umiat field were recommended.

The fiscal outlook as seen at the close of the meeting was about as follows:

Cash available 31 Dec 1950	$8,350,000
Appropriation expected 1 Jul 1951	6,800,000
Total	$15,150,000

Calender 1951 program:	
Fixed costs	$4,665,000
Drilling program	1,580,000
Conditional drilling program	1,300,000
Geophysical program	790,000
Total 1951	$8,335,000
Calender 1952 program:	
Fixed costs	$3,356,750
Prospective drilling program	3,136,000
Prospective geophysical program	322,250
Total 1952	$6,815,000

It was anticipated that fiscal year 1953 funds in the amount of $2,075,000 would be requested to finance the closeout program. Closeout plans were discussed in a special meeting in the afternoon of 1 December attended by Captain Meade; CDR G. E. Fischer, of BuDocks; CDR M. H. Aubey, OICC; CDR P. W. Roberts, of BuDocks; E. L. Davis; Ted Mathews; and A. L. Webb, of BuDocks.

On 12 December, LT N. M. Jackson was relieved as assistant OICC at Fairbanks by LT John F. Beaver, CEC, USN. On the same day 1st Lieutenant Gordon Oosting, petroleum engineer, was detached from duty with NPR 4 and departed for the United States.

OPERATIONS

AIR TRANSPORTATION

During 1950 the linehaul moved 1,680 tons of freight into Barrow from Fairbanks in 358 flights. Also during the year the air-support contract changed from Alaska Airlines to Transocean Airlines. The Alaska Airlines contract was to expire at the end of June, but it finally was continued until the first of August in order to allow time for Transocean to prepare for the job. This changeover caused some delay in air service. As an example of linehaul operations, it is noted that during the week ending 15 January there were 8 northbound flights that carried 39 passengers and 97,120 pounds of cargo.

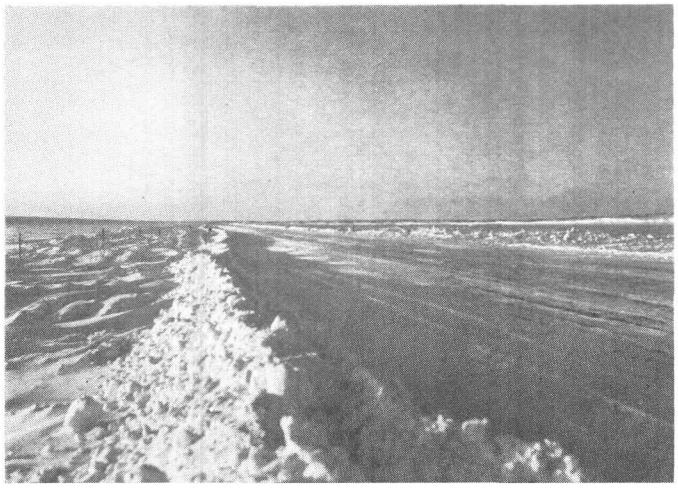

FIGURE 69.—Airstrip on frozen lake at East Oumalik, April 1950. Photograph by U. S. Navy.

FIGURE 70.—Ski-equipped C47 and Bell helicopter on floats, Barrow airstrip, 1 May 1950. Photograph by U. S. Navy.

At the close of Alaska Airlines' service the OICC reported officially that the company's operations "* * * were considered highly acceptable and during periods of maximum work demand performed airlift operations which can rightfully be classed as outstanding." He assigned Alaska Airlines' success to "* * * (1) A sincere interest in their work; (2) Excellent pilots and mechanics; and (3) A large reserve of planes of various types together with standby pilots."

The year 1950 was exceptional for the large amount of air freighting within the Reserve. Under certain conditions and when the planes were used on the longest hauls, it was found that the cost of air freighting was comparable to that of moving freight by sled trains. This fact was thereafter useful in planning freighting operations. The operation dubbed "Riglift" during April resulted in 981 tons of supplies being flown into East Oumalik and Driftwood in 376 flights of C46's and C54's. The freight was landed on a lake 3 miles from the East Oumalik location. (See fig. 69.)

A ski-equipped C47 hauled 330 tons in 456 flights to make caches for geologic parties and to support drilling operations. Altogether 2,775 flights of single-engine aircraft to all parts of Pet 4 moved 315 tons of supplies and materials. A few bottlenecks developed from time to time in the bush-plane work because of damage to aircraft.

The Bell Company supplied and operated helicopters in connection with the gravity-meter work. (See fig. 70.) The following is quoted from the official Pet 4 Project History for 1950 in regard to that work.

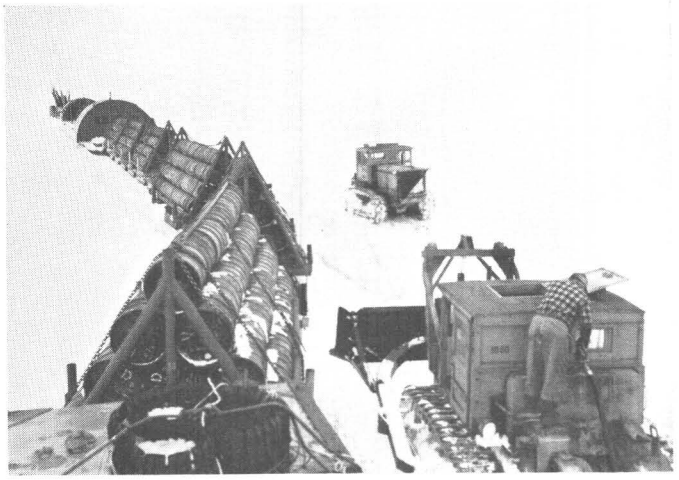

FIGURE 71.—Tractor train on Elson Lagoon bound for Topagoruk test well 1. Photograph by U. S. Navy.

FIGURE 72.—Tractor train being unloaded at Topagoruk test well 1, 30 April 1950. Photograph by U. S. Navy.

The Bell helicopters, operated by personnel of the Bell Company performed a very noteworthy operation with the flying gravity-meter program. The three helicopters furnished by this company flew a total of 874 hours and visited 3,980 stations at a rate of 4.59 stations per operating hour. Not an accident or mechanical difficulty was recorded and the machines were able to operate in weather that grounded other bush aircraft.

The helicopter is not to be considered an efficient freight moving airplane. The cost per unit of work is high, running about $134.00 per hour. However, there are many times when other operations are dependent upon such transportation, and delays resulting from lack of it are very costly.

The success of this operation has led the Contractor to recommend that a helicopter be stationed within the Reserve as a part of the air contract for logistic support of operations.

On 10 May an Alaska Airlines Norseman plane, Pilot Galbraith, was lost somewhere east of Barrow with Roger D. Hamilton of the ARL aboard. Search missions continued until 23 May, but no trace of the plane or occupants ever was found.

LAND TRANSPORTATION

During the winter of 1949–50, it was necessary to supplement sled-train hauling (see figs. 71, 72) by airlift as described above because of the extensive drilling program in the summer of 1950. This meant, of course, that the winter sled freighting was pushed to the limit of available equipment. The winter sledding season started on 23 December 1949 when the first train left Barrow for Oumalik carrying fuel, lubricants, and oilfield supplies. In general, the weather conditions for tractor-train operations were poor, and the season started late because of a late freezeup. Nevertheless, 4 trains hauled 12,586 tons of freight 11,378 miles, averaging 2,844 miles each, for a total of 1,432,029 ton-miles. (See figs. 73, 74.) Two changes in train operation were

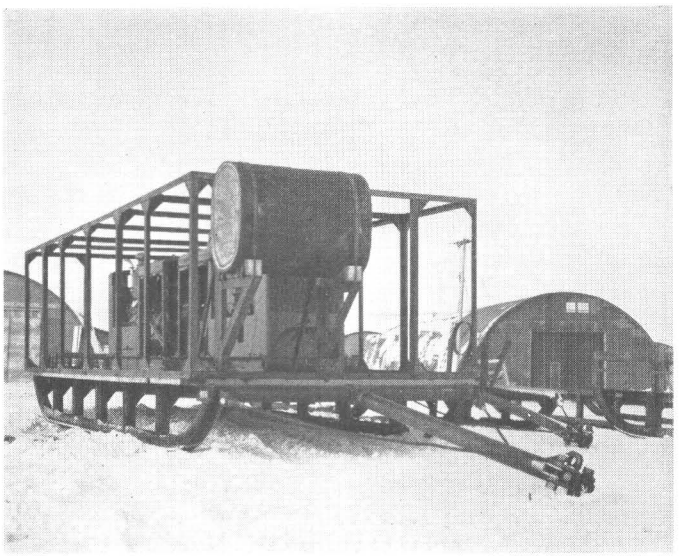

FIGURE 73.—Construction of power-plant wanigan, equipped with two 75-kw Caterpillar generators. Photograph by U. S. Navy.

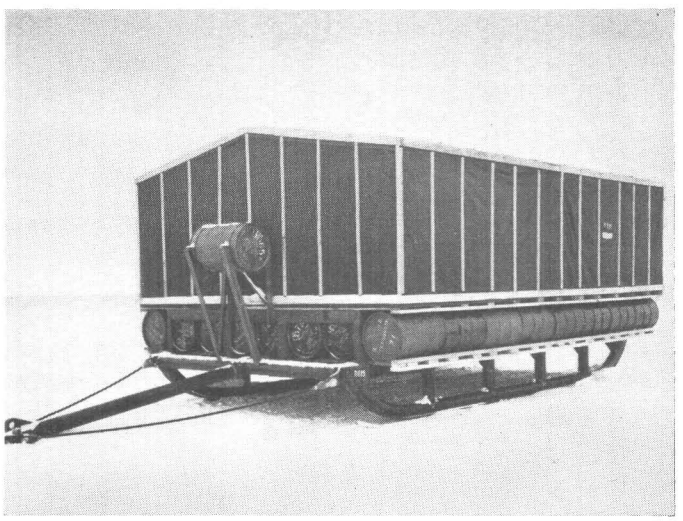

FIGURE 74.—Amphibious food wanigan, April 1950. Photograph by U. S. Navy.

FIGURE 75.—Tractor-train equipment parked at Barrow base camp at end of 1950 freighting season. Photograph by U. S. Navy.

made over previous years—an additional tractor and operator were assigned to each train, and the oiler accompanying the train was eliminated.

LVT's were increasingly used as freighting vehicles. They were used for odd local freighting jobs; and, in addition, 90 tons of miscellaneous freight was carried by LVT (landing vehicle, tracked) from Barrow to the Meade and Topagoruk locations.

A typical freighting report is that made by the contractor for the week ending 19 March:

> A total of 96,624 pounds of freight were received via line-haul. Cat Train #1 is still out and is due to arrive at Icy Cape March 20. Cat Train #2 should arrive at Umiat by March 21. Cat Train #3 is out 15 miles southwest of the Kuk River. Train #4 made a trip during the week leaving the 13th, returning the 19th delivering fuel and oil-field equipment to the Topagoruk Site.

The Arctic Test Station of BuDocks supplied some assistance in the sled freighting. Three of the four sled trains were retired for the season before 15 May. The other kept operating between Oumalik and East Oumalik until 20 May when it started for Barrow, where it arrived on 23 May to end the winter freighting season. (See fig. 75.)

RIVER AND LAKE TRANSPORTATION

Water transportation was used to a very limited extent in Naval Petroleum Reserve No. 4 during the summer of 1950. An LCM (landing craft, medium) was used to ship 314 tons of freight from Barrow to points near Fish Creek, Simpson, and Topagoruk. From these points the loads were taken to the sites by LVT's. That type of transportation proved to be cheap and expeditious, but its use is practicable only under exceptional conditions.

BARROW EXPEDITION, 1950

Barex '50 was, as usual, an improvement over the expedition of the preceding year. This large and complex operation, after 6 years, was becoming routine. A very substantial amount of experience was being accumulated for operations in the Arctic Ocean, and the experience of the past was used in each year's Barex.

The CNO on 5 December 1949 designated BuDocks to coordinate preliminary arrangements for Barex '50. On 20 March the CNO assigned the operating responsibility for Barex '50 to the Commander in Chief, Pacific Fleet. An operation plan (see fig. 76) was issued by the Commander, Amphibious Force, Pacific Fleet on 4 April, and was modified by a substitution of ships on 10 April. The plan designated Commander, Transport Division 11, CAPT L. D. Sharp, as ComBarex 50 (Commander, Barex '50). Later Captain Sharp was replaced by CAPT G. B. Helmick.

Captain Sharp held a conference in Coronado, Calif., on 26 April attended by many interested in the expedition, including the OICC, the ROICC in Seattle, the assistant project manager of Arcon, and the procurement officer of Arcon. The operation order was issued on 15 May by the Commander, Transport Division 11.

Loading and delivery to proper debarkation points was planned and carried out by LCDR R. Eicher, the loading officer, in close coordination with the ROICC in Seattle. Lieutenant Commander Eicher performed his duties so well that he earned a commendation from the OICC after Barex '50.

On 12 and 13 June, Captain Helmick, the Commander of Barex '50; CDR John Backlund, who again was ice

FIGURE 76.—Radar target erected at Franklin Point, April 1950. Photograph by U. S. Navy.

pilot; and the assistant OICC; made a reconnaissance of ice and unloading conditions at Point Barrow (see figs. 77, 78, 79), Barter Island, Icy Cape, and Tigvariak Island.

The value of cargo and supplies for Barex '50 and for Pet 4 alone was $2.5 million and approximated 25,000 measurement tons. Cargo was received and inspected at the debarkation points of Port Hueneme, San Pedro, and Point Molate, Calif., and at Seattle and Bangor, Wash.

The ships involved included the following:

Type	*Name or number*
AKA	*Seminole*
AKA	*Washburn*
AKA	*Oberon*
LST	*1110*
LST	*1126*
LST	*1146*
AO	*Ashtabula*
AGB	*Burton Island*

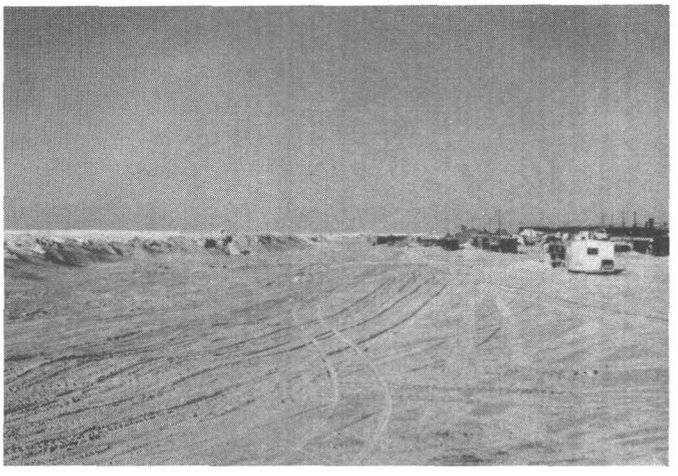

FIGURE 77.—Ice shoved up on beach at Point Barrow, 2 April 1950. Photograph by U. S. Navy.

Movement group Able, consisting of the three AKA's departed Puget Sound on 26 July. On arrival at Barrow the *Seminole* unloaded in an elapsed time of 71 hours, and the other ships finished within a few hours thereafter. All boats were hoisted, and the ships ready to proceed at 0800 on 7 August. The *Seminole* and *Washburn* were delayed until 1030 to replenish the fresh-water supply of LST *1146*. The *Oberon* sailed at 0800 with orders to proceed to Nome for cargo for the States. The *Washburn* and *Seminole* sailed at 1030 and proceeded to Puget Sound.

Movement group Baker consisted of the icebreaker *Burton Island* and the 3 LST's. They departed Puget Sound on 17 July and arrived at Point Lay and loaded U. S. Coast and Geodetic Survey cargo for Pitt Point.

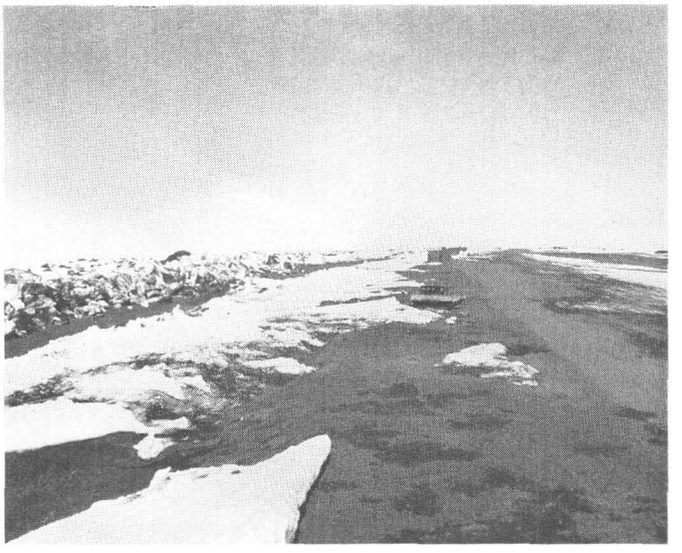

FIGURE 78.—Ice on beach at Point Barrow, 5 June 1950. Photograph by U. S. Navy.

They then proceeded to Point Barrow and arrived there at 0200 on 31 July. The earlier arrival of the LST's at Barrow permitted them to be unloaded (see figs. 80, 81) before the arrival of the AKA's.

Accompanied by the *Burton Island*, on 1 August LST *1146* departed Barrow for Barter Island with Air Force cargo. Both ships reached Barter Island on 3 August, the LST running inside the barrier islands and the icebreaker remaining outside. The LST was bound on the return trip for Tigvariak Island with U. S. Coast and Geodetic Survey cargo. The ship incurred ice damage on the way, and one compartment was flooded, but she was able to proceed. Unloading at Tigvariak was completed, and she left for Pitt Point

FIGURE 79.—Shore ice melting at Point Barrow, 7 July 1950 Photograph by U. S. Navy.

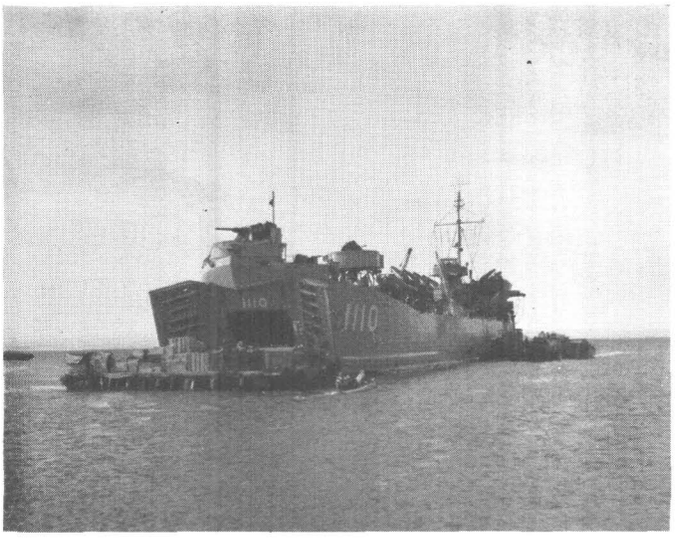

FIGURE 80.—LST *1110* discharging cargo off beach 3 during Barex '50. Photograph by U. S. Navy.

on 4 August. More cargo was unloaded at Pitt Point, and on 6 August the LST with the *Burton Island* returned to Barrow where emergency repairs of the ice damage were made.

The 3 LST's left Barrow at 1030 on 7 August, the *1146* bound for Puget Sound, *1110* for Port Hueneme, and *1126* for San Diego. The *Burton Island* remained in the Arctic for other operations.

Movement group Charlie was the *Ashtabula* (AO 51). After fueling 2 U. S. Coast and Geodetic Survey ships on the way, she arrived at Barrow at 0630 on 2 August. Unloading was completed at 1015 on 3 August (see fig. 82), and the ship sailed at 2300 that day. After again topping off the 2 Coast Survey ships at Port Clarence, she stopped at Dutch Harbor to transfer fuel to the tank farm there and left for the States at 1630 on 8 August.

FIGURE 81.—LST *1126* discharging bulk fuel during Barex '50. Photograph by U. S. Navy.

Beach operations at Barrow ran smothly—the experience of previous years was most valuable. Arcon provided for beach use 16 cranes, 1 tractor train, 4 forklifts, 9 tractors with bulldozer blades, 3 other tractors, and 32 Athey wagons. Also provided were 1 beach foreman, 2 assistant beach foremen, 70 equipment operators, and 180 laborers.

Captain Helmick received the commendation of the OICC for his contribution as commander of Barex '50.

FIGURE 82.—Unloading drummed fuel at beach 4 during Barex '50. Photograph by U. S. Navy.

CONTRACT CHANGES

Change orders S through W were issued during 1950 to authorize the program as approved. The various items with estimated costs were as follows:

Project No.	*Title of project*	*Cash and Government-furnished material*
31	Continue drilling Oumalik test well 1 to 12,000 ft	$420,000
44	Drill East Oumalik test well 1 to 6,000 ft	625,000
46	Drill South Barrow test well 4 to 2,500 ft	175,000
47	Drill Elson test well 1 to 2,500 ft	175,000
48	Drill Meade test well 1 to 6,000 ft	642,000
49	Geophysical operations	2,277,000
50	Maintain and operate camps	1,700,000
51	Logistic planning	275,000
52	Support other activities	209,000
53	Barex '50	1,900,000
54	Drill North Simpson test well 1 to 3,500 ft	215,000
55	Drill Topagoruk test well 1 to 12,000 ft	944,000
56	Drill Umiat (Ruby) test well 1 to 1,000 ft	50,000
57	Drill Lake Minga velocity test to 1,200 ft	17,000
58	Drill 3 wells at Simpson seepages	141,000
59	Temperature survey	16,000
60	Special engineering project	13,000
61	Drill Umiat (Ruby) test wells 2 and 3	33,000
16	Support Arctic Test Station	150,000
18	Support Arctic Research Laboratory	50,939

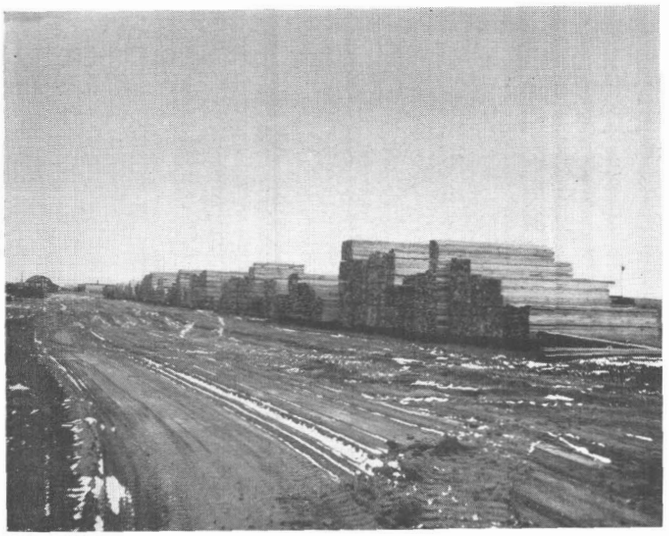

FIGURE 83.—Lumber storage at Barrow, 16 September 1950. Photograph by U. S. Navy.

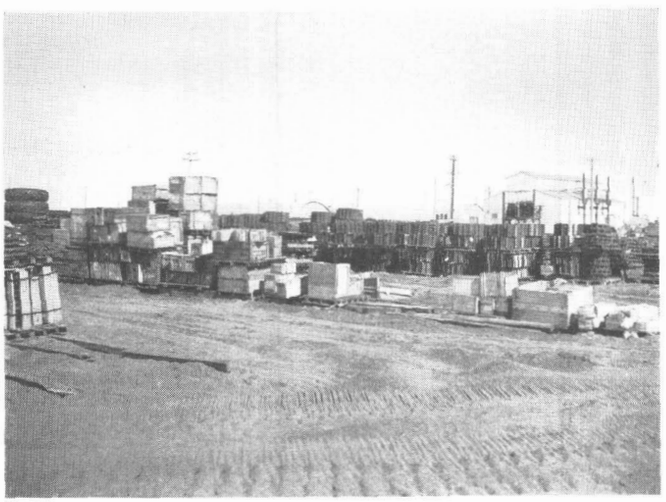

FIGURE 84.—Open storage of spare parts, fall of 1950. Photograph by U. S. Navy.

CONSTRUCTION

By 1950 the facilities required for Pet 4 were virtually complete. (See figs. 83, 84.) Therefore, new construction and major changes were relatively small. Additions to the base camp at Barrow consisted of a theater, an addition to the dry-cleaning plant, a gymnasium, a tent warehouse, a beachmaster's hut, and an airport warmup vehicle storage. A new family-quarters hut was completed for the Arctic Research Laboratory, and building 251 was remodeled for the ARL. A family-quarters hut was built at Umiat. A study was made of the settling of the concrete floor of the hangar at Barrow, and remedial measures were taken.

Refrigerated rig foundations (see figs. 85, 86) had proved practicable and reasonably inexpensive. The usual type was made of 12- by 12-inch sills laid on the ground and underlaid with 1-inch steel pipe through which a refrigerant was circulated.

Pipeline studies were continued throughout the year. COL G. W. Rathjens served as consultant to Arcon in those studies. Test installations were made at Ladd Air Force Base, at Gulkana, and at Barrow.

Quonset and jamesway huts and wanigans were prefabricated (see figs. 87, 88) at Barrow for such outlying camps as Simpson, Meade, East Oumalik, and Titaluk.

The unitization of the second Cardwell rig was largely completed (see figs. 89, 90), and the unitization of the first Cardwell rig was completed. The unitization of the second differed in some respects from that of the first, partly because of the experience with No. 1.

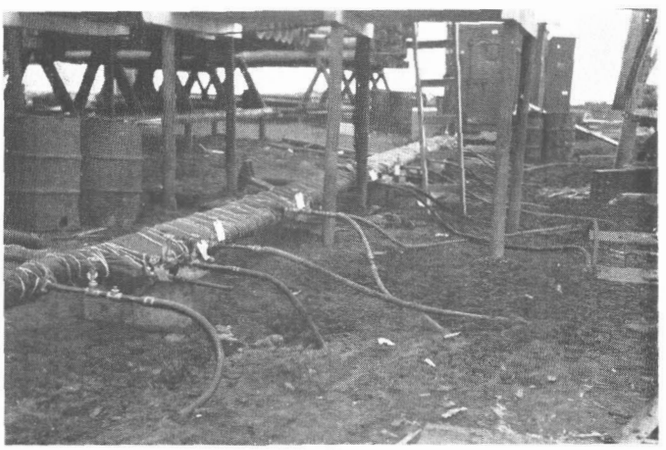

FIGURE 85.—Connections for foundation refrigeration at Topagoruk test well 1, 23 May 1950. Photograph by U. S. Navy.

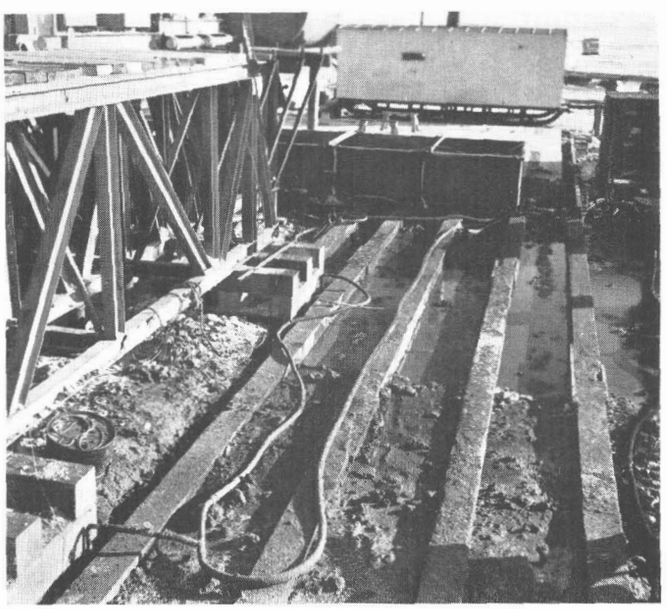

FIGURE 86.—Refrigeration of sills for foundation at Topagoruk test well 1, 17 April 1950. Photograph by U. S. Navy.

Tests of the conversion of LVT's from gasoline to diesel power continued through the summer of 1950. Test runs indicated less fuel consumption and more power, but on long hauls difficulty was encountered in performance owing to overheating of engines and trouble with transmissions.

FIRE RECORD

About 10 fires occurred in Pet 4 during 1950; all but one of these was in or near the Barrow camp. Most of the fires were minor, and no persons were injured, and the causes of most of the fires could be determined. For example, there was a flash fire in the camp street owing to ignition of gas accumulated from a leak in the distribution system, and there was a small fire in the power house caused by welding-machine sparks.

FIGURE 87.—Standard quonset hut under construction in carpenter shop at Barrow camp, April 1950. Photograph by U. S. Navy.

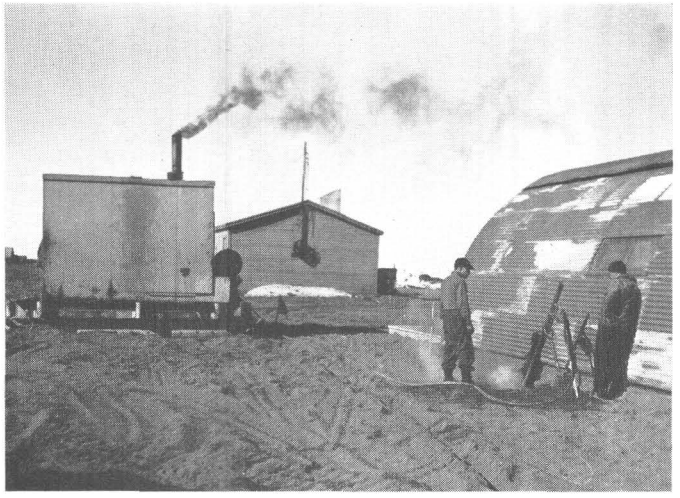

FIGURE 88.—Steaming hole for setting a power pole at Barrow camp, 15 June 1950. Photograph by U. S. Navy.

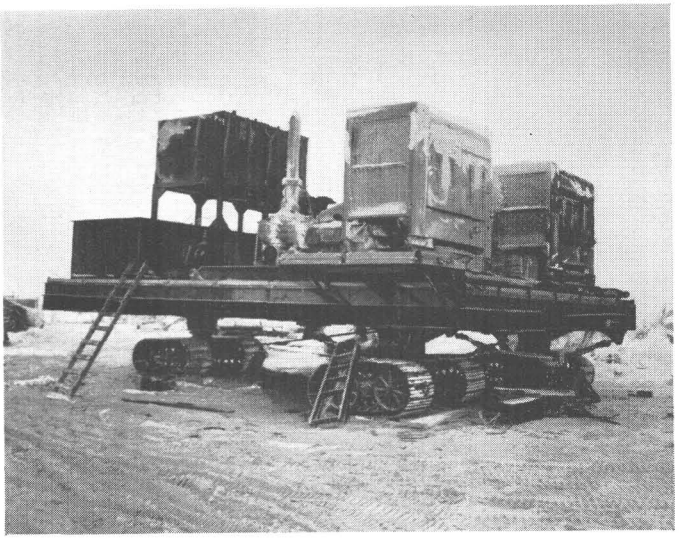

FIGURE 89.—Pump section of Cardwell mobile rig under construction. Pumps and tanks are mounted in position, 23 January 1950. Photograph by U. S. Navy.

FIGURE 90.—Pump section of mobile rig on move from South Barrow test well 4 to Barrow camp, 19 April 1950. Photograph by U. S. Navy.

The most serious fire resulted in the complete destruction of the gas well and production installation of South Barrow test well 2. (See figs. 91, 92.) This occurred on 5 April and was probably due to the striking of a spark from a bulldozer blade hitting the bleeder line from the well house. The tractor was clearing the area of snow in preparation for repairs to the well. The fire was brought under control and finally extinguished by closing the valves on the "Christmas tree" and pumping mud into the cellar. Mud was then pumped into the well and the well killed.

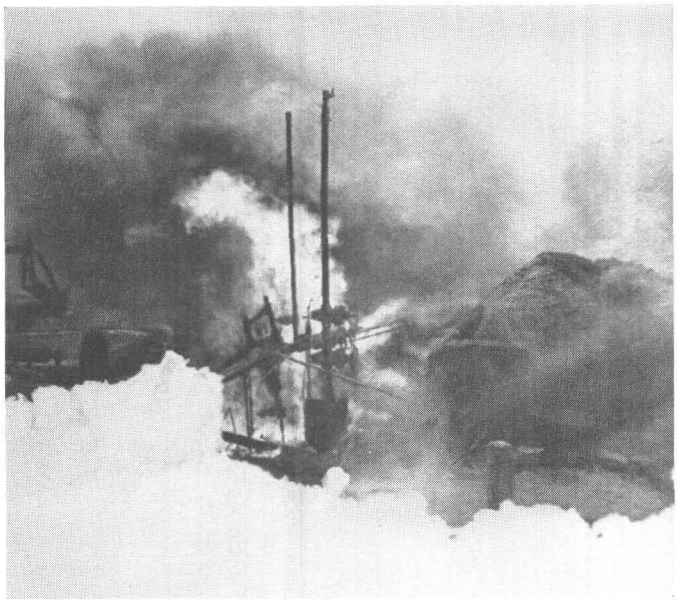

FIGURE 91.—Fire at South Barrow test well 2 about 3 hours after start, 5 April 1950. Photograph by U. S. Navy.

BARROW GAS SUPPLY

Appraisals of the Barrow gas supply by the DNPR's technical staff and by DeGolyer and MacNaughton indicated a sufficient reserve for all requirements of Pet 4 for many years. The trap is believed to be rather small, but sufficient data as to size, thickness of gas-bearing strata, and porosity and permeability were not available, and therefore satisfactory estimates of reserves could not be made.

The casing of South Barrow test well 2 had collapsed even before the fire, and it was felt that other wells in the field might also collapse unless some means was found to inhibit casing collapse by freezing in the permafrost zone.

Some water is present with the gas, and, because of the low temperatures in the permafrost zone, care must be taken to prevent freezing of the moisture as it comes up with the gas. Such freezing could completely stop production. As at South Barrow test well 4 care was taken in design of the well to protect against freezing. The plan was to produce alternately through the annulus between the 7-inch and the 10¾-inch casings and the annulus between the 2½-inch and the 7-inch casings. Ethylene glycol would be injected into whichever annulus was not being used for production.

Because of the uncertainty of the Barrow gas supply, a sufficient reserve supply of diesel fuel had been kept continuously at Barrow. Whether or not the diesel reserve would be needed because of possible failure of South Barrow test well 4 was not known in 1950.

In 1950 a total of 40,205 mcf (thousands of cubic feet) of gas was produced from South Barrow test well 2 before the fire, and 70,031 mcf was produced and used from South Barrow test well 4.

GEOLOGY

During 1950 there was substantial increase in the personnel of the Geological Survey engaged in photogeologic interpretation. Also during the summer of 1950, the Navy Oil Unit of the Geological Survey carried out the largest geologic field program of any year of Pet 4. The geologic activities are discussed below under three headings—field projects, special investigations, and Fairbanks laboratory.

FIELD PROJECTS

Reports on the fieldwork in the summer of 1949 were prepared during the early part of 1950 and were presented for use by the operating committee at the April meeting.

The 1950 program comprised 7 field parties, 6 entirely financed and supported by the ONPR (Office of Naval Petroleum Reserves), the seventh financed by the Survey but with logistic support by Arcon. In addition, local geologic investigations were made by small groups of geologists working out of Umiat. Examples of such studies are a traverse of the geologic section on the Canning River and a special study of the Gubik anticline. The 1950 field program resulted in much valuable new information on the petroleum potential of northern Alaska, especially in the southern part of the foothills belt near the front of the Brooks Range. The work was directed largely through a field base at Umiat (see figs 93, 94) with plane and radio contact to the field parties. There was a subsidiary base at Noluk Lake to facilitate the servicing of parties in the western part of the area.

The spring caching for the parties was carried out under the direction of A. Samuel Keller and Irvin L. Tailleur.

FIGURE 92.—Condition of gas well on morning of 6 April, about 18 hours after fire started. Photograph by U. S. Navy.

Party 1, under the leadership of Edward G. Sable, traveled by weasel. The party spent part of the season mapping the Driftwood anticline, near Driftwood Creek in the southwestern part of the Reserve, and the remainder along the upper parts of the Utokok and the Kokolik Rivers. No proof of closure of the Driftwood anticline (see fig. 12) was found although the evidence indicated that closure is likely. The distance down to Lisburne group along the axis of the anticline probably is 5,400 to 6,500 feet.

Weasels were also used by party 2, which was led by William W. Patton, Jr. The party conducted structural and stratigraphic studies in the area of the Siksikpuk and the Nanushuk Rivers. Four structural belts were defined in the area, but rocks with good reservoir characteristics were not found.

Party 3, under William P. Brosgé, studied the Lisburne group in the foothills and northern mountains of the Brooks Range. This was a helicopter party, supported by Navy helicopters. During the summer an accident resulted in the loss of one of the helicopters and in the drowning of one of the geologists, Vincent Shainin.

Parts of the Carbon Creek and Ketik anticlines were mapped by weasel-transported party 4 under Charles L. Whittington. The Carbon Creek anticline (see fig. 12), in the vicinity of Carbon Creek, a tributary of the Utokik River, is probably faulted. The Ketik anticline is a low fold on which no plunge is indicated. The sandstones that crop out have low porosities.

Party 5, led by G. Donald Eberlein, used weasels in traversing the southern foothills from the Killik River to the Etivluk River and in mapping the Aupuk anticline, which lies along the Colville River above the mouth of the Killik. The area is structurally complex, and the Aupuk anticline is poorly exposed and could not be contoured. There is no evidence of western closure, but a minimum of 1,000 feet of eastern closure was inferred.

FIGURE 93.—General view of Umiat on 10 May 1950. Photograph by U. S. Navy.

FIGURE 94.—Loading C46 at Umiat with Geological Survey supplies for parachuting, 1950. Photograph by U. S. Navy.

Irvin L. Tailleur's weasel-transported party 6 operated in a structurally complex area in the southern foothills between the Etivluk and Kiligwa Rivers.

J. Thomas Dutro led party 7 down the Nimiuktuk and the Kugururok Rivers in boats to their confluences with the Noatak River and thence down the Noatak to its mouth. The dominant structural feature noted was imbricate thrust faulting. Petroleum possibilities are considered unfavorable in the area.

SPECIAL STUDIES

Several special investigations were carried on during 1950 by the Geological Survey because of the application of the studies to the exploration program.

Micropaleontologic studies went on continuously in Fairbanks and in Washington, D. C. In Fairbanks, Harlan Bergquist emphasized the establishment of faunal zones, correlations for current wells, and correlations between current wells, earlier wells, and outcrop sections. In Washington, D. C., Helen Tappan Loeblich made taxonomic studies of faunas and worked on regional correlations in and near Pet 4. Her work was closely coordinated with that of Mr. Bergquist.

Macropaleontologic services were rendered as required by specialists of the Branch of Paleontology and Stratigraphy of the Geological Survey. Among the specialists were Ralph Imlay, Jurassic and Cretaceous mollusks; J. B. Reeside, Jr., Cretaceous faunas; Arthur

L. Bowsher, Sr., Mississippian faunas; Helen Duncan, Mississippian corals; I. G. Sohn, ostracodes; and Roland Brown, plant fossils.

Prof. P. D. Krynine, a part-time employee of the Geological Survey, carried on intensive petrologic studies of the Lisburne group as a potential oil reservoir rock. The work suggested that zones of appreciable thickness in the Lisburne may indeed constitute adequate reservoirs.

Investigation of the heavy minerals contained in the sediments from Pet 4 was stepped up and moved into an interpretive stage during 1950. Robert H. Morris carried on that work that then appeared to have real possibilities eventually as an aid in stratigraphic correlation.

In the fall of 1950 certain systematic porosity and permeability studies were undertaken in an attempt to determine trends and patterns of reservoir beds. In spite of certain inadequacies of material with which to work, the studies seemed to indicate certain favorable and unfavorable trends.

Basic facies patterns for Pet 4 were originally worked out and presented by T. G. Payne in 1947. Facies studies continued, and the accumulating data made possible certain refinements in understanding of the facies patterns. The basic pattern of favorable and unfavorable belts remained about as propounded by Mr. Payne in 1947.

Subsurface correlations were continuously attempted by the Geological Survey. Because of the nondistinctive nature of the Cretaceous sedimentary rocks, the paucity of diagnostic fossils, and the relative uniformity of the rocks throughout great thicknesses, the subsurface correlation apparently would continue to be difficult and tentative.

In the fall of 1949 the Survey began a project to map photogeologically all the area north of the Brooks Range. By November 1949 five quadrangle maps on a scale of 1 : 96,000 had been completed. By April 1950, 47 additional quadrangle maps were completed and printed. The work was drastically curtailed in favor of fieldwork in the summer of 1950. A series of photogeologic maps on a scale of 1 : 250,000 was prepared for use in regional studies and planning. A few special photogeologic jobs were done, such as a restudy of the western end of the Umiat anticline and a restudy of the Torok anticlinorium north of the field area of party 6.

FAIRBANKS LABORATORY

The Fairbanks laboratory of the Geological Survey continued under the leadership of Thomas G. Roberts. Indicative of the laboratory's activities is the following list from a report of the laboratory's work from November 1949 to April 1950:

Cores described		98
Cores described	feet	800
Ditch samples described	feet	15,671
Samples picked for microfossils		1,603
Samples washed and prepared		5,184
Porosity determinations		147
Permeability determinations		133
Quantitative tests for calcareous cement		92
Qualitative tests for oil saturation		43
Heavy-mineral samples prepared and separated		191
Written and graphic logs distributed		6
Written and graphic logs distributed	feet	7,530

At the end of the year the personnel of the laboratory consisted of 4 geologists, 1 microfossil preparator, 4 laboratory assistants (2 part time), and 1 clerk. A new wing was added to the core shed during September.

GEOPHYSICS

The following summary of geophysical operations in 1950 is condensed from a summary report by W. H. Myers, the geophysical supervisor of the United Geophysical Co. for Pet 4, prepared for the 13th meeting of the operating committee in November.

In the Driftwood area approximately 900-miles of continuous line and a refraction profile were shot by 4 seismic crews. The work included detailed work in the Topagoruk and Meade River areas and reconnaissance work in the eastern and western parts of the Reserve.

The significant data obtained by each geophysical party is briefly summarized.

PARTY 144

Seismic party 144 under A. B. Sanders worked in the Fish Creek-Colville River and Titaluk areas. There is an east- to southeast-plunging nose in a shallower horizon at Fish Creek, and the location of Fish Creek test well 1 is well up on the north flank of the anticline. Eastward toward the Colville River the regional dip in shallow horizons is west, indicating that the low point of the basin is near the river. Deeper zones in the Fish Creek area are complex with considerable faulting. The gravity anomalies south of the Fish Creek location apparently are not due to structure although the one at Sentinal Hill probably is due to structure. The Sentinel Hill anticline has about 400 feet of reversal along the 152d meridian and has east plunge to the Colville River. The core test near the river is several hundred feet below the high point of the axis. The Gubik anticline has good reversal to a depth of 5,000 feet. A minimum of 150 feet of west plunge was mapped by seismic work. The Sentinel Hill and Gubik anticlines are about 3,200 structurally lower than Umiat test well 2. Deeper horizons dip uniformly south with no expression at Umiat, Sentinel Hill, or Gubik. The Titaluk anticline has a minimum of 150 feet of west

plunge. A reversal of 400 feet was mapped 10 miles north of the Titaluk anticline on what may be the western extension of the Wolf Creek anticline.

PARTY 145

Party 145 was led by Arnold Palenske. It operated in the middle Meade River area. The survey between Meade test well 1 and Oumalik test well 1 with the 1950 seismic work indicated that the Meade well is about 250 feet stratigraphically higher than the Oumalik well in the shallower horizons. In the deeper horizons the Meade well may be 1,100 feet higher than Oumalik. Still deeper, in a zone of considerable faulting, no expression of the Meade anticline was detected. The West Meade location is about 100 feet stratigraphically above Meade test well 1 and has about 450 feet of closure. The two anticlines are connected by a saddle of approximately 300 feet. West of the Meade anticline the regional dip is west to southwest; east of the anticline it is east to southeast. Between the Meade and the Kaolak areas the shallower horizons thicken from 2,000 to 2,500 feet.

PARTY 146

Party 146 worked in the Wainwright-Utokok area under the leadership of H. B. Chalmers, Jr. The seismic sections resemble those in the Topagoruk area. There is a southeast-plunging nose in all horizons in the Wainwright area. All horizons thicken southward from Wainwright. There seems to be no correlation between structure and gravity anomalies in the area. There are several east-trending folds south of latitude 70° N. and west of the Kaolak River in the shallower zones. The northernmost of the folds has a minimum closure of 200 feet, and it may be as much as 400 feet.

PARTY 147

The chief of party 147 was F. E. Wiancko. The party worked in the Topagoruk and Simpson areas, where the first job of the season was to detail the area where Topagoruk test well 1 was being drilled. Other structural features were found to the northeast and appeared to be related to faulting. The faulting appears to die out upward in the section. The deep faults in the older strata appear to be large. An anticline with a closure of 100 feet was found in the younger strata about 12 miles east of Topagoruk test well 1.

PARTY 148

Party 148 under Samuel Allen did refraction work on the Driftwood anticline. The results were negative. The highest recorded velocity was 16,400 feet per second, and no high velocity refractions sufficiently thick to give positive results were found.

PARTY 249

Party 249 was a gravity-meter party and was led by L. B. Luhrs. The gravity survey covered 7,000 square miles between 1 June and 1 September. The spacing of roughly 2 miles was accomplished by helicopters using aerial photographs for control. Vertical control was by electrorecording altimeters. The operation was very successful.

There is a broad anomalous area west of the so-called Meade River arch. It extends to the western boundary of the Reserve, and it is bounded on the south and west by a U-shaped geosyncline. The sharp gravity gradient in the vicinity of the Kaolak River probably indicates older horizons nearer the surface and may indicate extensive faulting. The geosyncline mentioned above is crossed by the folds in the Meade and Kaolak areas. The gravity conditions in the Wainwright area are similar to those in the area from Simpson to Barrow.

COMPILATION OF GEOPHYSICAL DATA

By the November operating-committee meeting, the results of all seismic data to that time had been compiled on structural contour maps of four different levels of acoustic horizons. At that time, a similar compilation of the results of regional magnetometer and of gravity surveys was underway. A general correlation of regional trends as revealed by the gravity and magnetic surveys seems to hold. The relation of the trends to structure was not clear.

DRILLING

Drilling problems continued to be encountered in 1950, and these mostly had their origin in the isolation of the area and the arctic operating conditions. In spite of the difficulties, a total of 36,316 feet was drilled at 16 sites during the year. Oil was produced from five of the wells.

Deficiencies in communications caused substantial delays. Further delays arose from lack of all year-round dependable transportation. Shortages of readily available materials and services resulted in further delays and in use of substitute methods of operations in some instances.

Trouble was encountered in some of the deeper drilling because of caving shale and the sticking of drill pipe and bits. Several expensive and time-consuming fishing jobs resulted. The collapse of the casing in South Barrow test well 2 at 600 feet proved the necessity of guarding against collapse by refreezing of the moisture in the permafrost zone. Sufficient cement was not at hand to completely cement the casings through the permafrost zone of all wells. A plan was devised to use brine and oil in the annular space as a preventative.

Oil was used near the surface where it was impractical to use brine of high enough salinity to prevent freezing at exceptionally low temperatures. Brine was used between the top of the cement and the oil.

Production from the permafrost zone, and below that, introduced many problems not previously encountered in oil-field practice. These problems are generally of two types: first that of casing collapse already mentioned; and second, the formation of ice and hydrates in flow strings and lines because the fluids originate in formations that are below freezing or must pass through such formations to reach the surface. Where no water was present, no special production problems were encountered.

Cable-tool drilling, as recommended by Mr. Ruby, was tried at Umiat and was found to be very satisfactory. When brine was used in the mud, there was no difficulty with freezing of the fluid in the bottom of the hole, and only a little ice built up on the walls. Damage to productive sands was reduced because almost no fluid penetrated the sands to freeze and seal off the oil.

The drilling at each of the holes during 1950 is described very briefly below.

OUMALIK TEST WELL 1

Oumalik test well 1 was started early in 1949, and by 1 January 1950 it was 9,622 feet deep. The hole was completed to its final depth of 11,872 feet and abandoned on 23 April. A good deal of difficulty was met in the drilling of that deep test. Some of the casing used was badly worn and had to be replaced. On one occasion the drill pipe parted; once the derrick girts were bent; the drill pipe stuck several times. Some of the fishing jobs were difficult and time consuming.

Gas was found at several levels in the hole, occasionally under high pressure, but the poor reservoir characteristics of the sands indicated the likelihood of only a small volume. Most of the gas shows seemed to be from above 3,855 feet and that was a considerable factor in the decision to drill East Oumalik 1.

It was thought that Oumalik test well 1 should be deepened if the drilling at Topagoruk test well 1 revealed a deeply buried reservoir rock. Before the well was abandoned, a thermistor cable was installed in it for later temperature determinations by a Geological Survey project being carried on at the Arctic Research Laboratory. Unfortunately, it was possible to drop the cable into the hole to a depth of 730 feet only.

SOUTH BARROW TEST WELL 4

South Barrow test well 4 was spudded in on 9 March. Drilling progressed without special difficulty, and the final depth of 2,538 feet was reached in less than a month. The section penetrated was similar to that found in South Barrow 2, and the gas-bearing zones were found as expected. The well was drilled as a standby well for South Barrow 2 and was completed at just about the time South Barrow test well 2 was destroyed by fire.

MINGA VELOCITY TEST 1

The Minga velocity test was to be drilled from the ice in Lake Minga, a relatively large lake in the general Simpson area. The objective was to obtain information on the seismic and permafrost conditions under a typical lake. There was evidence that large zones under at least some lakes were not frozen, hence had different seismic characteristics, and therefore resulted in confusing interpretations of seismic survey data.

The hole was spudded in on 29 April and reached its final depth of 1,233 feet before the middle of May. No oil or gas showings were noted, but the cuttings and cores did yield fossil and lithologic information that was very useful in regional geologic interpretation.

A velocity survey was made of the hole, and a thermistor cable was installed in the hole by the Geological Survey. Unfortunately the cable leads were carried away when the ice broke up in the lake later in the summer.

MEADE TEST WELL 1

A piece of metal that fell into Meade test well 1 could not be removed and prevented further testing, and thus the amount of information obtained from the well was disappointingly small. The hole was spudded in on 2 May. (See figs. 95, 96.) A nonmarine section containing coal was penetrated to a little more than 1,000

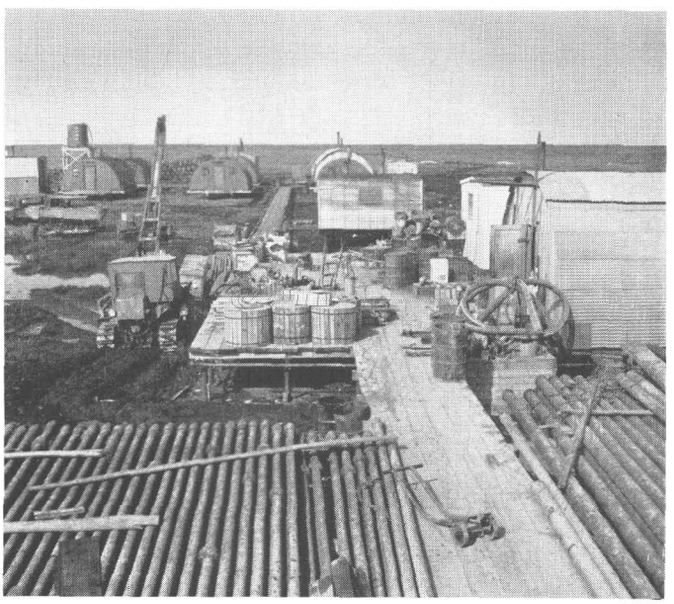

FIGURE 95.—Camp at Meade River test well 1, 1950. Photograph by U. S. Navy.

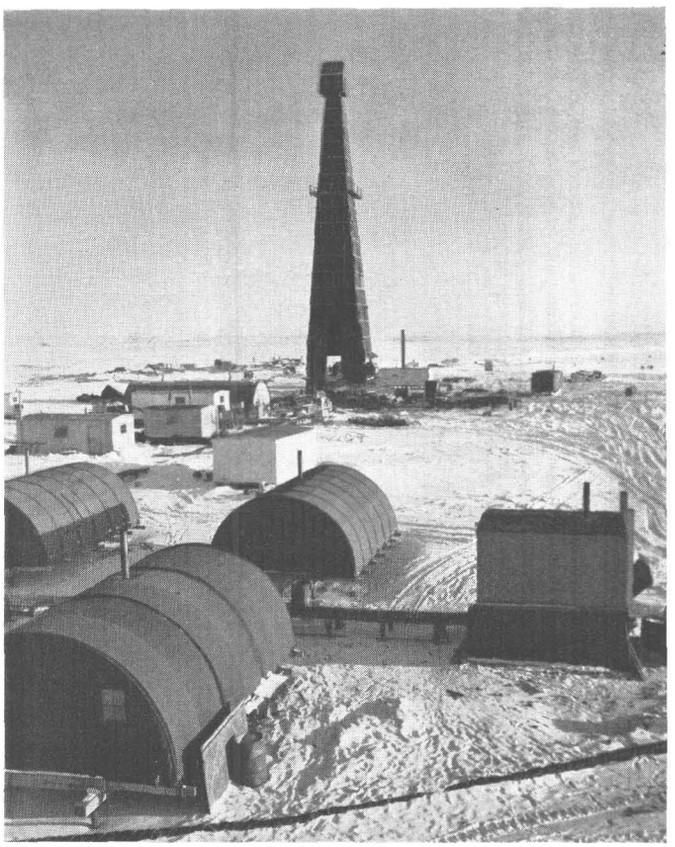

FIGURE 96.—Meade River test well 1 derrick on 17 April 1950. Photograph by U. S. Navy.

feet. Gas shows, some of them very substantial, were found at several places down to a depth of about 4,200 feet. The final depth of 5,305 feet was reached the middle of July, but incomplete testing attempts, plagued by packer failures and other difficulties, went on until about 20 August when it was decided to dismantle and abandon the well. The favorable gas indications from Meade test well 1 led to the recommendation that West Meade test well 1 be drilled.

NORTH SIMPSON TEST WELL 1

North Simpson test well 1 was spudded in on 6 May. Drilling was stopped on 3 June at a total depth of 3,774 feet. For all practical purposes, the drilling penetrated shale only, and no oil or gas shows were found. The data from the hole were useful in geologic interpretation, especially in developing a more adequate understanding of the geology of the petroleum reservoir in the Cape Simpson area.

UMIAT TEST WELL 4

Umiat test well 4 (formerly Umiat Ruby 1) was drilled with cable tools to see if that type of drilling would result in better yields from the Umiat sands. It was spudded in on 26 May and reached its final depth of 840 feet about the end of June. Material was dropped in the well, and the hole was finally abandoned. However, the upper Umiat sands were found as expected and, as expected, were oil-bearing. The upper zone was from about 352 feet to about 427 feet below the surface. The top of the lower zone was identified at about 748 feet. Various bailing tests and pumping tests were made, and these went on until the middle of August. The report of Arcon for the week ending 20 August records that the pumping tests indicated a steady production in excess of 75 barrels per day.

UMIAT TEST WELL 5

Umiat test well 5 (formerly Umiat Ruby 2) was drilled with cable tools to a total depth of 1,075 feet between 5 July and the middle of September. Both Umiat oil-sand zones were penetrated. Drilling was suspended for testing of the upper zone during the latter part of August. The average production was about 70 barrels per day. Water was found in the deeper sands as well as oil. For a short time the well flowed oil at the rate of 23 barrels per hour; but, because of the water present, the tubing iced up, and the tests were inclusive.

UMIAT TEST WELL 6

Umiat test well 6 (formerly Umiat Ruby 3) was another shallow hole to test further the size and capabilities of the Umiat anticline. It was drilled to a depth of 825 feet between 14 August and 3 September but was soon plugged back to 783 feet. The hole made a good deal of water with the oil, which caused icing problems. As a result the well was not satisfactorily tested but on a 13-hour pumping test produced 28.5 barrels of oil and 11 barrels of water. There was some gas.

After winterizing the rig, Umiat test well 6 was reentered about mid-November to resume production testing of the upper sand. Operational difficulties developed, and no satisfactory test resulted.

UMIAT TEST WELL 7

Umiat test well 7 (formerly Umiat Ruby 4) was spudded in on 14 December and at the end of the year was at 827 feet, and drilling continued. Oil and water sands were found at several horizons as was expected.

The drilling of the "Ruby" wells at Umiat demonstrated that oil could be produced from within the permafrost zone and that, under the conditions there, cable-tool drilling is superior to rotary drilling. This information was used in appraising the possibilities of structures similar to the Umiat anticline.

TOPAGORUK TEST WELL 1

Great hopes were held for the possibilities of Topagoruk test well 1. Unfortunately, the oil and gas showing were very minor, but the hole did yield a vast amount of useful information for the better interpretation of a large part of the geosynclinal basin of deposition. Furthermore, several difficult jobs of recovering material dropped in the hole developed and resulted in expensive and time-consuming delays.

The hole was spudded in on 15 June with a 12¼-inch bit to 111 feet; it was reamed with a 26½-inch bit to 107 feet; and 18⅝-inch casing was set to that depth. At 5,193 feet, the drill pipe stuck at 1,710 feet on 27 August. About the middle of September the pipe was recovered. On 18 September the hole reached 5,268 feet; the hole diameter there was 12¼ inches. A little gas showed at 5,959 to 5,988 feet; and some oil, at 6,140 to 6,144 feet. At about 6,100 feet there was another recovery job. By 26 October the dropped material was recovered, and the hole was at 6,490 feet. At 7,154 feet the hole was sidetracked.

SIMPSON CORE TEST 25

Simpson core test 25 was drilled to 1,510 feet between 3 July and mid-August. There were some oil and gas showings to about 905 feet.

SIMPSON CORE TEST 26

Difficulty was encountered in drilling Simpson core hole 26, which was spudded on 13 August and reached 1,171 feet in the latter part of September. There was a good oil flow, 110 barrels per day initially, from between 300 feet and 500 feet.

SIMPSON CORE TEST 28

Simpson core test 28 was started on 5 September, and it was abandoned on 24 September at 2,505 feet. No oil or gas shows were found. Thermistor cables were placed in the hole.

SIMPSON CORE TEST 29

Simpson core test 29 was spudded on 31 October. There were a few minor oil shows below 300 feet. The hole reached its final depth of 700 feet in the latter part of November.

SIMPSON CORE TEST 30

Simpson core test 30, about 1,500 feet N. 75° E. of test 29, was started on 30 November. Several oil sands were encountered below 300 feet. The hole at the end of the year had reached 630 feet, and drilling continued.

The Simpson core holes yielded much information about the size, nature, and capabilities of the Cape Simpson area.

EAST OUMALIK TEST WELL 1

East Oumalik test well 1 was spudded on 23 October. By the end of the year it had reached a depth of 6,034 feet, and preparations were being made to abandon it. There were occasional minor oil and gas showings from 1,693 to 3,873 feet but none below that depth.

SUPPORTED ACTIVITIES

Pet 4 continued to supply support and assistance to several Federal activities both military and civilian other than those that were integral segments of the exploration program. Some of them, such as the U. S. Coast and Geodetic Survey, the CAA, the ACS, the AACS, and the Weather Bureau, were engaged in work that was of direct or indirect assistance to Pet 4. Others were of no special concern to Pet 4. In the latter category were certain activities of the Naval Ordnance Laboratory, the Naval Electronics Laboratory, the Arctic Research Laboratory of the Office of Naval Research, the Arctic Test Station of BuDocks, the Beetle project of the Air Force, radio propagation research by the National Bureau of Standards, the U. S. Fish and Wildlife Service, the St. Paul District of the Corps of Engineers engaged in permafrost work, Wien Alaska Airlines, the Bureau of the Census, and others.

In some instances charge was made for the services or supplies rendered and in others not, depending on the estimated interest of Pet 4 in the activity.

The services consisted of a variety of help such as permission to use the airfields, receive gasoline, messing and billeting, receiving and transportation of freight, local transportation by aircraft and tracked vehicles. Some construction work was done for the ARL such as revision of building 251 and the placing of shelving in the laboratory.

An example of the service rendered is the caching of some gasoline for the Fish and Wildlife Service, use of facilities of the camps by visitors, and permission for a plane of that Service to land at Barrow and at Umiat to carry out certain observations.

Activities directed toward non-Pet 4 use were not as extensive in 1950 as in some previous years.

SUMMARY OF 1950

The seventh year of Pet 4 was notable for its accomplishments in terms of actual drilling—more than 36,000 feet was drilled at 16 sites. The camps at Barrow and Umiat had been largely completed before 1950, so that construction work was mostly on improvements, additions, and maintenance. Construction connected specifically with the increased drilling was greatly increased.

During the year 5 seismic parties, 1 gravity-meter party, and 7 geologic parties were maintained. The information gained from the 1950 program was extensive and generally favorable as regards oil possibilities. Both Umiat and Simpson showed possibilities of major discoveries, and gas and oil showings were revealed in several other localities.

The whole program operated more economically in 1950 than ever before. This was believed to be due in part to improvements resulting from increasing experience and in part to greater integration of various segments of Pet 4.

Rig-foundation costs were notably reduced; the success of the unitized Cardwell rig was realized, and more careful planning of sled-train loads minimized costly interim air and LVT freighting and substantially reduced shutdowns while waiting for needed parts or equipment. The helicopter had proved to be a useful piece of equipment for certain specialized arctic jobs. Such savings as those indicated are difficult to measure, but the program in 1950 actually cost about $900,000 less than had been originally estimated.

The Navy had continued to insist on better communication services between Point Barrow and Fairbanks. In 1950 the ACS provided a continuous workday instead of scheduled service. This was an improvement but still not as good as a voice channel.

The peak of Arcon employees was 658 in August; the low was 443 in January. The yearly average was 516, of which 453 were in Pet 4, 48 in Fairbanks, and 15 in Seattle. The percentage man-hours lost due to accidents was 0.0086; this was the highest accident rate that had occurred in Pet 4.

EIGHTH YEAR—1951

GENERAL PLANNING AND ADMINISTRATION

On 22 December 1950 the Assistant Secretary of the Navy sent to the Director, Naval Petroleum Reserves a statement of policy relative to Pet 4. That statement had an immediate effect on the trend of the program and was the guiding principle for Pet 4 from the time of its issuance. The two pertinent paragraphs are quoted as follows:

> 2. A program for the exploration of this Reserve during calendar year 1951 has been approved, based upon recommendations of the Operating Committee appointed for the purpose of advising the Secretary on this subject. This program will be executed under the direction of the Director, Naval Petroleum Reserves, who may make modifications in the approved program within the limitations of available funds. The Director, Naval Petroleum Reserves, will keep continuously under review the necessity for continuation of all or any part of the exploration program, and make such reductions in the program as he may consider appropriate.
>
> 3. Decision as to the continuation of the exploration program beyond 21 December 1951 will be made on 1 July 1951, or on a date as near thereto as practicable. Unless very favorable results are obtained prior to 1 July 1951, the exploration program will be terminated on or about 31 December 1951; thereafter, the activities under the direction of the Director, Naval Petroleum Reserves, in Petroleum Reserve No. 4 will be reduced to the extent required to close-out the exploration program, salvage materials, write a full report, and exercise custodial function.

The OICC officially passed on the new policy to Arcon by memorandum on 15 January 1951. The following quoted paragraph is of interest as regards the program:

> b. Inasmuch as a decision cannot be reached relative to the continued exploration program for 1952 until 1 July 1951, it will be necessary to plan procurement on the basis that such a program will be carried out. In the event that the 1 July decision dictates that there will be no exploration program carried out during calendar 1952, it will then be necessary to ship on Barex '51, only those items which will be required during the closeout portion of the Contract. Accordingly, this means that the Contractor, at an early date, must arrive at two separate lists of items of supplies for Barex '51, namely, (1) that for a full 1952 program, and (2) that to be segregated out to keep Barrow Camp supplied under minimum personnel conditions during the closeout period of the Contract which will take place during the latter part of 1951 and the first few months of 1952. It is essential that these two lists be made up at an early date to assist the procurement office in Seattle in spotting materials awaiting shipment, as well as to allow for planning for disposition of those items which may not be shipped.

On 19 February representatives of Arcon met with the DNPR in Washington, D. C., to discuss Pet 4. Among other items discussed and decisions made, it was agreed that estimates of petroleum in the ground should be made on the basis of discoveries made up to that time. The DNPR undertook to have such an estimate made by the U. S. Bureau of Mines. A. A. Curtice agreed to have one made by one of the major oil companies. The group was told by the DNPR that Assistant Secretary of the Navy John T. Koehler expected to attend the June operating committee meeting in Fairbanks.

The results of the meeting on 19 February and other information were passed on to members of the operating committee by memorandum from the DNPR. His memorandum pointed out that it had been decided to plan the Barex '51 procurement on the basis of a 10-hole drilling program in 1952. These are assumed to be shallow holes that can be drilled with a Cardwell or smaller rig. Four of the holes are estimated at 3,500 feet, one at 2,000 feet, and the rest at 1,500 feet. Such assumptions as outlined were necessary in order to give Arcon some basis for procurement. The DNPR reminded the committee that, if the decision was finally

made to continue Pet 4, the program would have to be limited by the materials that came up on Barex '51.

In January the ROICC in Seattle, LCDR L. P. Frate, was relieved by LT N. M. Jackson. LCDR R. E. Sparks, Assistant to the DNPR, arrived in Fairbanks on 12 March to work with the OICC in regard to closeout plans for Pet 4. On 15 March a group of officers and civilian scientists left Fairbanks by linehaul for connection with an arctic oceanographic project sponsored by ONR and termed "Operation Skijump." W. G. Harris, Assistant Engineer in Chief of the British Admiralty, arrived in Fairbanks on 1 May: he traveled to Barrow by linehaul on 5 May to study Pet 4. He returned and left Fairbanks for Seattle on 12 May. On 2 May Mr. Eggleston, chief petroleum engineer of the Union Oil Co., arrived in Fairbanks. Mr. Eggleston had been requested by the DNPR to estimate the petroleum potential of the Umiat field. He departed for Barrow the next day. Between 8 and 10 May the OICC guided around Pet 4 a party including Robert Hooper, mayor of Fairbanks; Maurice Johnson, president of the Fairbanks Chamber of Commerce; Terris Moore, president of the University of Alaska; and CAPT C. R. Howard, USA.

Again on 25 May the DNPR reminded the members of the operating committee that at the June meeting the prime question would be whether or not to continue the exploration program.

On 18 June the 14th regular meeting of the operating committee convened in Fairbanks. In attendance as members or alternate members of the committee were CAPT R. H. Meade, DNPR and chairman; COL O. F. Kotick, deputy DNPR; CDR G. E. Fischer, BuDocks; John C. Reed, U. S. Geological Survey and alternate for W. E. Wrather; L. W. MacNaughton, DeGolyer and MacNaughton; A. A. Curtice, Exploration Contractors, Inc.

Captain Meade made an introductory statement outlining the objectives of the meeting. The project manager for Arcon, E. L. Davis, outlined the discoveries that had been made. There followed a considerable discussion of the productive possibilities of the Umiat field. Estimates of reserves in the field were presented in submittals from W. S. Eggleston of the Union Oil Co.; DeGolyer and MacNaughton; M. J. Lebsack, of the ONPR; U. S. Bureau of Mines; Andrew Milek; and LT H. J. McGarr, of the office of the OICC, Fairbanks.

The average of 6 informed opinions is that about 70 million barrels could be recovered from the Umiat field. The transcript of the meeting contains the following summary of this item:

> The question of the number of such fields which would justify the operation of NPR 4 as a whole, remains open for discussion. Opinion has been expressed that the daily output of approximately 60,000 barrels through a pipeline might be considered commercial for export. The viewpoint has been expressed that further testing of the field in its present state of exploration, particularly production tests, are necessary for a more accurate evaluation of the field.

Next, the Simpson seepages were discussed; and, in view of the poorer quality of the oil and the small apparent reserve, it was agreed that no further work in that area was then justified. It was reported that the South Barrow gas field contained a gas reserve of about 10,000,000 mcf. Other discoveries, including the Meade gas reserves, were evaluated and discussed.

Arcon summarized the history and status of the test wells then drilling and a few that had recently been abandoned. T. G. Roberts, head of the Geological Survey laboratory at Fairbanks, interpreted the subsurface geology as revealed by the test holes mentioned above, and George Gryc outlined the surface geology as thus far found by the four parties then in the field. Howard Myers presented the results of the season's geophysical work up to the time of the meeting. There was long discussion from various viewpoints of the potential for petroleum of the Reserve and surrounding areas and of the best way of determining the nature and extent of the reserves if the Pet 4 program continued.

It was announced that Ralph L. Miller had been promoted in the Geological Survey to Chief of the Fuels Branch and that he would therefore be leaving the direction of the Navy Oil Unit. He was to be replaced by George Gryc.

The financial status of the contract was reviewed by E. J. Rusing. Captain Meade noted that about $1.5 million would be available for closeout at the end of the year if it was decided to suspend Pet 4 and an additional $750,000 might be recovered from refunds on Barex '51 purchases.

COL O. F. Kotick presented an economic review of the whole Pet 4 operation and its outlook. His views were discussed by many of the committee and others but primarily by Mr. Davis. It was finally decided to proceed with the agenda and to postpone formulation of conclusions until after further discussion.

Next was taken up the proposed program of operations for the remainder of 1950. Mr. Davis and Mr. Reese presented a proposed drilling program. Ralph L. Miller summarized the geological program that was underway. Howard Myers, for the United Geophysical Co., reviewed the geophysical work underway and said that that was all his company could accomplish except perhaps some refraction work at Driftwood as proposed by Ralph Miller. Mr. Hoover estimated that that would

cost about $75,000. E. L. Davis reviewed production testing to date. Finally Mr. Rusing presented a chart showing the estimated cost of the drilling program outlined by Arcon.

After considerable discussion the operating committee made the following unanimous recommendations:

1. That Topagoruk test well 1 be continued as planned whether or not Pet 4 continues beyond 1951.
2. That the Kaolak well be drilled as scheduled.
3. That Gubik test well 1 be completed to 6,000 feet or until the objective sands have been penetrated.

Regarding the 1951 program the committee recommended as follows:

1. Against drilling at the proposed Elson Lagoon location.
2. Unanimously against the drilling of South Barrow test well 5.
3. Approval of a well at the so-called Volcano location in the South Barrow area.
4. Unanimously for completing Titaluk test well 1 as planned.
5. Retaining on the drilling schedule, as conditional and subject to further recommendations and review, the use of the Cardwell No. 2 rig for a second well at Titaluk or Square Lake.
6. The moving of the rig on Umiat test well 5 to a new location for Umiat test well 9, thence to Weasel Creek test well 1, and thence on to Knifeblade test well 2.
7. The drilling of Weasel Creek test well 1 as planned.
8. The location of Umiat test well 9 on the same contour as Umiat test well 5, due north of previously determined position, and that it be completed.
9. The drilling of South Knifeblade as planned.
10. Approval of North Knifeblade.
11. Against further drilling in the Simpson area.
12. Continuation of the testing of Umiat test well 8, to be pumped for about 2 weeks, then deepened to 2,000 feet as scheduled.
13. That the Cardwell spudder be moved to Gubik test well 2, south and east of Gubik test well 1, as soon as Umiat test well 8 is completed. The depth of Gubik test well 2 was estimated at 2,000 feet.
14. That the production testing of the Umiat field be given the highest priority for the remainder of the year.
15. Completion of the geological and geophysical programs as previously approved.

All of the above took from 18 June through 21 June. On 22 June, John T. Koehler, Assistant Secretary of the Navy, and his party joined the operating committee meeting. The Assistant Secretary's party included: John Tyssowski, special consultant: CDR W. M. Huey, Office of Asst. SecNav; MAJ D. J. Mallory, USMC, Office of Asst. SecNav; VADM W. M. Callaghan, Commander, MSTS; RADM J. F. Jelley, Chief, BuDocks; RADM L. N. Moehler; CAPT L. K. Reynolds, and CAPT W. F. Wessanen.

At the DNPR'S request, A. A. Curtice reviewed Pet 4 to date for the Assistant Secretary and his group. Mr. Koehler then commented in general terms and especially stressed the byproduct value of the Pet 4 experience. He said, "We have obtained byproducts out of this (Pet 4) which were touched on by the speaker and which are important. At the inception of the program, we had no idea that the byproduct, with the trend that history has taken, would assume such importance. People have learned to work in the Arctic the year-round and a lot of valuable exploration work has been done * * *."

Considerations in favor of continuing Pet 4 were presented by the chief of exploration, R. G. Reese, and by Herbert Hoover, Jr. It was stated that Umiat already could assure a production of 20,000 barrels per day. Next the Deputy DNPR, COL O. F. Kotick, discussed the arguments against continuation.

Mr. Koehler stated that he would like to defer a decision until he had gone into the matter more thoroughly, both in the field and in Washington, D. C., but Captain Meade indicated that some decision was necessary because of the imminence of the sailing of Barex '51.

Mr. MacNaughton, of DeGolyer and MacNaughton, then presented considerations, conclusions, and recommendations of the operating committee as already outlined above. Following this the DNPR summarized by saying that the majority of the committee recommended continuing. One vote was to close at the end of 1951. Two votes were to continue only to the extent of what could be done with $8 million.

On 23 June Mr. Koehler, along with Vice Admiral Callaghan, RADM J. F. Jelley, Captain Reynolds, Captain Meade, Commander Huey, Major Mallory, Mr. Tyssowski, Herbert Hoover, Jr., A. A. Curtice, Glen Ruby, L. W. MacNaughton, W. A. English, John C. Reed, and Commander Aubey, traveled to Barrow in the Assistant Secretary's aircraft for an "on-the-ground" review and returned on 24 June.

On 25 June the meeting reconvened, with representatives of Arcon not in attendance, and the discussion continued. The Assistant Secretary stated that he had determined not to take action that would close Pet 4 at the close of 1951. He stated that his final decision had to be deferred, pending discussion with the Secretary of the Navy and the Chairmen of the House and

Senate Armed Services Committees. He pointed out that it followed that he authorized the full Barex '51 shipment. He said that where Pet 4 goes after 1951 will depend on what happens between the present and the close of the year.

On 3 July the Assistant Secretary of the Navy and the DNPR met with Carl Vinson, Chairman of the House Armed Services Committee. It was decided that Pet 4 should continue until a reasonable evaluation had been made of the Reserve's oil-producing potential, continuation would be on a year-to-year basis, that $5 million additional would be requested for 1952 if the results in the remainder of 1951 justified such a request, and that an operating committee meeting to appraise results would be held in Denver before November.

In June the ONPR in Washington, D. C., was closed and reopened in July in the Mining Exchange Building in Denver, Colo.

On 19 July the DNPR wrote to the Chief, BuDocks concerning Pet 4. He pointed out the Asst. SecNav's decision and indicated that if the program in the rest of 1951 was favorable, the DNPR would sponsor a request for additional funds after 1 January 1952. Because it was expected that drilling would be emphasized in the remainder of Pet 4, he requested that BuDocks add to the contractor group a contracting organization especially skilled in drilling oil wells. He further requested that the operating committee be abandoned and in its place an advisory committee be instituted on which there would be no Arcon representation. BuDocks concurred.

In June of 1951 CDR A. C. Morris relieved CDR George E. Fischer as manager of Radio, Coast Guard, and Petroleum Reserve Facilities Branch of BuDocks. He therefore assumed the BuDocks cognizance of the contract and became a member of the operating committee. In the same month R. G. Reese was replaced by C. L. Mohr as chief of exploration.

Fergus Hoffman of the Seattle Post Intelligencer went to Barrow by linehaul on 7 July. His visit was sponsored by the Navy. On 14 July CDR L. T. McQuiston went to Barrow to relieve the aviation technical advisor to the OICC, CDR G. K. Ebbe. CDR R. C. Jensen, Asst. DNPR, went to Barrow on 18 August. He returned on 25 August. On 21 August, R. E. Main, H. M. Tietel, and F. T. Kitze, of the Permafrost Division, Corps of Engineers, USA, went to Barrow on their way to Wainwright and Point Lay to study ground temperatures. W. W. Gifford was replaced in October by LT H. J. McGarr, USNR, as technical advisor to the OICC.

Early in October a new group that came to be called the executive operating committee met in Fairbanks to discuss a possible program for presentation to the November meeting of the operating committee. The executive operating committee was responsible to the OICC and was made up of the responsible heads of all the various operating segments of Pet 4.

On 5 November, the 15th regular meeting of the operating committee was convened in the offices of the DNPR in Denver. The meeting lasted through 8 November. Committee members present included the DNPR, L. W. MacNaughton, CDR A. C. Morris, Walter A. English, and John C. Reed (alternate for W. E. Wrather). About 35 others were present, and the group was made up of representatives from various parts of Pet 4 and special advisors and consultants. The Under Secretary of the Navy was represented by Walter M. Acree, Jr.

Captain Meade opened the meeting with a general statement that highlighted its special importance. He said:

> The purpose of this meeting is, of course, to review and evaluate the results of the exploration since our last opportunity to do so in June, and to make recommendations with respect to further exploration during the calendar years 1952 and 1953. The particular reason for so doing at this time is to enable me to make representation to the Congress for the necessary funds for those two years. I have just been to Washington for the past two weeks and I have consulted with the Under Secretary, with the financial people of the Navy, of the Secretary of Defense, and the Bureau of the Budget. I find no disposition for them to cut us off. In fact, the way has been cleared for a supplemental appropriation so far as they are concerned of approximately $6,100,000 for the completion of our calendar year 1952 work. I have tentatively advanced the lead for $8.5 million for the calendar year 1953. The Secretary and others that I mentioned are attaching considerable importance to the recommendations of this meeting. I am sure that they are prepared to accept the recommendations, but they're awaiting the action on the $8.5-million presentation until I go back with the formal recommendations of this meeting. So this becomes a very important meeting, and the Secretary, as I say, has indicated that he would take no action last week; but all his future actions would be guided by the advice which is formulated at this meeting.

After full discussion the operating committee—

1. Confirmed the presence of an oil field in the Umiat area with estimated recoverable reserves of 30 to 100 million barrels of oil within the presently known limits of the field.

2. Felt that natural gas finds, particularly in the Gubik area, indicate that gas reserves in NPR 4 may prove to be of commercial or military value. Natural gas reserves at Gubik have been estimated to be of the order of 900 billion cubic feet.

3. Found that many untested prospects exist, some similar in age to the Umiat and Gubik anticlines, and others of different age which should be tested before NPR 4 can be reasonably evaluated.

4. Recommended for 1952 the following program:

a. The drilling of 5 wells, each to be about 4,000 feet deep—Weasel Creek 1, Grandstand 1, Umiat 11, Wolf Creek 3, and the completion of Square Lake 1.

b. The operation of 3 seismic parties for 5 months each and an office interpretation crew for a full year.

c. The operation of a 6-man geologic party in the Colville-Chandler area, a 6-man party at Survey expense in the Sagavanirktok-Shaviovik area, and a 3-man party for selected locations of Lisburne group.

5. Concluded that a program for 1953 could be better determined at the April 1952 meeting but that such a program might include the drilling of such structural features as the Sentinel Hill, West Big Bend, Hawk, Awuna, and Carbon Creek anticlines. Seismograph work might include work not completed in 1952, areas of large anticlines in regard to which the surface geologic results need to be supplemented, and areas where previous seismic work shows folding that deserves more shooting. Tentative geologic work was not outlined.

6. Recommended that the exploration program continue until a reasonable evaluation of the oil-bearing potentialities of the area, including public land adjacent to the Reserve, has been determined.

7. Agreed and recommended that a 1953 program on the order of previous years would be practicable and that an appropriation for fiscal year 1953 of $8.5 million together with a supplemental appropriation for fiscal year 1952 of $6.1 million would provide for the orderly continuation of Pet 4.

Even before the November meeting of the operating committee, it was generally known that contract NOy–13360 would be closed out by BuDocks at the end of 1951. This required certain closeout procedures, such as the preparation of completion and technical reports, even though a new contract was to be negotiated with the same company, Arctic Contractors. The new contract, NOy–71333, was, in effect, a continuation of the old. It went into effect on 1 January 1952.

OPERATIONS

LAND TRANSPORTATION

The 1950–51 winter freighting was a bigger job than ever before. A total of 15,054 tons of freight was moved; the total miles traveled was 16,082, and the ton-miles, 1,860,194. The fall of 1950 in Pet 4 was extraordinarily mild; as late as 26 November, ice thickness on swamps and ponds near Barrow was as little as 4 inches. Therefore, the start of tractor-train freighting was somewhat delayed. All equipment—sleepers, galleys, shops, tractors, and weasels—had been put in excellent condition for the big job ahead. All freighting equipment used, except the weasels, was commercial equipment and had been modified only slightly to adapt it to arctic use. Similarly, all petroleum products used, with the exception of the fuel which was special, were of commercial grades.

The job to be done is set forth below to illustrate the size and complexity of such a freighting task.

1. Move geophysical party 144, consisting of rig, camp, equipment, and supplies, from 1950 season completion position near the head of the Ikpikpuk River; latitude 69°30′ N., longitude 154°30′ W., to Umiat for reconditioning and resupply, and thence to the mouth of the Chandler River for work required for location of proposed 5,000-foot well on the Gubik anticline.

2. Move four geophysical parties consisting of rigs, camps, equipment, and supplies as follows:

a. Party 45, from Kuk Inlet area; latitude 70°22′ N., longitude 159°50′ W., to Point Barrow.

b. Party 46 from Kaolak area, latitude 69°48′ N., longitude 160°29′ W., to Point Barrow.

c. Party 47, from Topagoruk area, latitude 70°31′ N., longitude 155°15′ W., to Point Barrow.

d. Party 249, camp wanigans only, from the Utokok area to Point Barrow.

3. Cache fuel, lubricating oil, powder, and miscellaneous supplies for party 44 in vicinities of Teshekpuk Lake, Square Lake, and Sentinel Hill.

4. Move National 50 Rig No. 1, including camp, equipment, and supplies from Meade River site to location at Kaolak test well 1. Transport fuel, additional equipment, and miscellaneous supplies to drill 6,000-foot well from Point Barrow to the Kaolak site.

5. Move National 50 Rig No. 2, including camp, equipment, and supplies from Fish Creek test well 1 to the Gubik site, to be picked after party 44 completes its geophysical work. Transport fuel, equipment, and supplies for a 6,000-foot well to same site.

6. Move Cardwell Portable Rig No. 1, including camp, equipment, and supplies from Simpson core test 28 to a site 16 miles east of Topagoruk. Transport additional fuel, equipment, and supplies for a 3,400-foot well from Point Barrow to that site.

7. Move Cardwell Portable Rig No. 2, including camp, equipment, fuel, and oil-field supplies for a 4,000-foot well, from Point Barrow to the Titaluk 1 location.

8. Return Wilson Super Titan rig, including camp, equipment, and supplies from East Oumalik test well 1 to Point Barrow.

9. Move fuel, camp structures, equipment and supplies from Point Barrow to the Maybe Creek area in order to:

a. Drill two 1,500-foot test wells with the Bucyrus spudder at Wolf Creek.

b. Drill four 1,500-foot test wells by Failing 1500 rig at Weasel Creek and Knifeblade.

10. Resupply National 125 rig at Topagoruk test well 1 with fuel, equipment, and supplies required to continue drilling until the end of 1951.

11. On completion of East Topagoruk test well 1 move Cardwell Portable Rig No. 1, including camp, equipment, and unexpended materials and supplies to Point Barrow.

12. Move 4,000 barrels of diesel fuel from Skull Cliff to Point Barrow.

13. Move materials for rig foundation, fuel, and oilfield supplies for a 4,000-foot well from Point Barrow to a site 7 miles west of Titaluk test well 1.

Because of the mild fall and early winter, initial trails had to be clear of water bodies. Trail scouting and staking were done by DC 3 and Norseman aircraft and by 2 LVT-weasel combinations. Initial trails were staked to the Meade, Topagoruk, and Kaolak areas over land. Ice-bridge locations were made at key crossings. Six men led by S. Harlan and D. Buck constituted the surface-scouting force. Each scouting party used a weasel and an LVT. The weasel had an extra large cab, gyroscopic compass, and radio receiver and transmitter. The LVT contained compass, tools, spare parts, cooking and sleeping gear, 800 gallons of gasoline, 60 man-days supply of food, and trail flags sufficient to stake 50–300 miles of trail. About 1,300 miles of trail was staked to the various field locations.

Four complete tractor train crews of nine men each were employed during the freighting season. Loading, unloading, and construction crews were maintained in the field at the Meade River, Kaolak, East Oumalik, East Topagoruk, Fish Creek, Titaluk, and Gubik locations. C. S. Lawson directed train loading at Barrow.

The first train departed Barrow on 15 December 1950, although everything was in readiness by 30 November. All trains were in operation by 30 December.

The following paragraphs are quoted directly from a report on the 1951 freighting operation as submitted to the DNPR by the OICC on 18 July 1951:

With the exception of the late freeze-up, few abnormal freighting conditions were encountered during the entire season. Snow depth throughout the reserve was considered to be somewhat less than average, causing the trails to be a trifle rougher than usual during the early part of the season and causing more time to be spent in building snow fills across entrenched crossings and steep banks on trails between East Oumalik and Titaluk and between the Simpson area and East Topagoruk. The last trips out of Umiat to Cache No. 34, and the Maybe Creek area completed by Train No. 1, were made over terrain that was 50 percent bare of snow.

A major segment of the overland Driftwood trail between Point Barrow, Skull Cliff, and Kaolak staked along the route traversed by Lawson and Buck, September 1949, and the cutoff from same, from a point sixteen miles east of Kuk crossing to Meade location, were the routes over which the National 50 Rig No. 1 was moved to Kaolak and supplied out of Point Barrow. U. G. C. (United Geophysical Co.) parties No. 45, No. 46 and No. 249 were returned to Barrow along this trail by trains freighting between Barrow and Kaolak.

The Oumalik trail, overland from Point Barrow to East Oumalik, was extended to Titaluk and from that point on to Umiat. Leaving East Oumalik, this trail bears southeasterly across an area comprising low rolling hills, traversed by several deeply incised left limit tributaries of the Ikpikpuk, some 35 miles to the Ikpikpuk River, which it follows southward about 15 miles to a point west of Titaluk No. 1. Leaving the river at this point, the trail proceeds along the ridge between Ikpikpuk and Maybe Creek drainage systems, into Titaluk, a distance of about 13 miles.

The Meade cut-off, leaving the Oumalik trail about 35 miles south of the Meade crossing, was used only in returning some National 50 rig equipment into Barrow for repair, and for moving "loading-tearing out crew" camp and equipment to the Meade site.

The Topagoruk cut-off, leaving the Oumalik trail at a point 16 miles south of the Meade crossing, bears about 16 miles in an easterly direction into Topagoruk. Traffic to Topagoruk, East Topagoruk, and Simpson areas was routed over this trail between 30 December and 7 March, at which time sufficient thickness of sea ice permitted travel to latter areas via Elson Lagoon and Admiralty Bay.

The Oumalik Trail and its branches was as in former years the main artery over which supplies were moved from Point Barrow to outlying facilities. Considerable time spent during the early part of the season in dragging and grading this route between Meade River and Point Barrow furnished a wide road bed that was maintained in good condition throughout the freighting season.

The trail between Umiat and Titaluk approximates the route taken by Party No. 44 between these places during their move of August 1950. Bearing easterly from Titaluk the trail follows a series of ridges and connecting saddles that form the watershed between Maybe Creek and Ikpikpuk drainages on the east, and Ikpikpuk and Colville River-Prince Creek drainages at its western end. The trail leaves the ridge country at Umiat range station—no streams are crossed en route and the terrain for the most part provides good traveling conditions, except where blown clear of snow by prevailing winds.

Branching from the Titaluk-Umiat trail are turnouts to East Titaluk, Wolf Creek, Weasel Creek and Knifeblade locations and Cache No. 33. These are less than 12 miles in length except in cases of Weasel Creek and Knifeblade which are 17 and 52 miles respectively from the main trail.

Over-ice freighting was started with a trip to Topagoruk 7 March, at which time minimum thickness of ice found on Elson Lagoon was 42 inches.

The Point Barrow-Umiat over-ice trail was staked via Elson Lagoon, Lake Minga, Teshekpuk Lake, Smith Bay, Harrison Bay and the Colville River. Portages of about 7 and 8 miles respectively were located between Lake Minga and Smith Bay, and between Smith Bay and Teshekpuk Lake.

Branching from this trail were the following cut-offs:

Christy Point to Topagoruk and East Topagoruk via Admiralty Bay, Teshekpuk Lake to Caches No. 30 and No. 31, Harrison Bay to National 50 Rig No. 2, Fish Creek.

Over-ice freighting conditions were excellent this season; the sea ice was usually smooth and pressure ridges were less extensive and smoother where crossed than in other years.

Occurrence of overflows on Colville River, chiefly between Sentinel Hill and Umiat was of normal incidence. There were no break-throughs of tractors or personnel on any river or on the sea ice.

AIR TRANSPORTATION

The airlift contract for Pet 4, including both the linehaul and bush service, that was entered into as of August 1950 by Transocean Airlines, as mentioned in the chapter for 1950, ran until 30 June 1951. An extension of the contract was negotiated for another 6 months through December 1951. Thus Transocean Airlines supplied the air service throughout all of the eighth year of Pet 4.

During the year an average of about 8 linehaul flights a week went from Fairbanks to Pet 4. The most flights per week were in the summer months. Those flights carried an average of about 6 passengers each. The same trips moved almost 3 million pounds of freight to Pet 4 or an average of about 56,000 pounds per week and 7,000 pounds per flight.

Because of the size of the freighting job to be done in the winter of 1950–51 and because of the lateness of the freezeup in the fall of 1950, it was decided to augment the tractor-train freighting with an airlift from Point Barrow to Umiat and elsewhere in the southern part of Pet 4. The freight consisted largely of oil-field supplies, drilling mud, chemicals, cement, and powder.

Tonnages hauled from Point Barrow and from Fairbanks to outlying camps primarily as a support to winter sled freighting were as follows: From Point Barrow to Topagoruk, 54.14 tons, to Kaolak, 3.96 tons, to Titaluk, 39.76 tons, to party 44, 0.75 tons, to Umiat, 2,338 tons, to Simpson, 2.87 tons; and from Fairbanks to Topagoruk, 98.33 tons, to Gubik, 19.75 tons, and to Umiat, 28.6 tons.

George Gryc, head of the Navy Oil Unit of the Geological Survey, reported at the November meeting of the operating committee that bush-plane support of the geologic parties in the summer of 1951 was especially good and was notable for the number and variety of aircraft available as required.

On 30 December 1951 one of Transocean's linehaul planes returning from Barrow to Fairbanks passed over Fairbanks and crashed on Chena Dome about 35 miles northeast of the city. On board were the pilot and first officer of Transocean and a pilot and mechanic of Wien Alaska Airlines as passengers. A search under the auspices of the 10th Rescue Squadron and including both air and land search, the latter by weasel and dog team, resulted in the locating of the wreckage on 3 January and in reaching it by helicopter on 5 January. There were no survivors. The only freight aboard was some mail that was recovered.

Linehaul operations during 1951 gradually fell behind on freighting from Fairbanks to Pet 4. At the end of the year there was a backlog in Fairbanks of approximately 300,000 pounds. The backlog was the result of some intervals of poor flying weather and a shortage of available aircraft during good weather.

SEA TRANSPORTATION

Barex '51 was, like the earlier expeditions, a most successful operation. It was not as large as some of the previous expeditions and, by 1951, a substantial background of experience had accumulated to aid in planning and effecting such an exercise.

Back in November 1950, the Chief of Naval Operations designated BuDocks to coordinate preliminary arrangements. On 10 January 1951 a CNO amendment indicated that, for planning purposes, Barex '51 would be the last Barex except as might be required to bring out salvageable materials. BuDocks on 13 December 1950 requested all Government agencies interested in shipping via Barex '51 to provide a list of their requirements by 12 January 1951.

CNO on 14 February directed that Commander in Chief, Pacific Fleet arrange with CINCAL (Commander in Chief, Alaska) as to Alaskan operations in regard to long-range ice reconnaissance and other assistance. Commander, Western Sea Frontier, would coordinate preparation, assembly, and loading of cargo. Chief, BuDocks would act as liaison to other Government agencies in regard to shipment via Barex. CINCPAC (Commander in Chief, Pacific) was assigned overall responsibility for the operation.

As has already been described, the doubt as to the continuation of Pet 4 in 1952 required the preparation of two plans for Barex—a minimum plan based on the assumption of closingout and a plan based on normal continuation. A preliminary conference was held in Coronado, Calif., at the Naval Amphibious Base on 25 and 26 April. Most of the interested groups were represented.

On 1 May the task organization was formed as follows: 1 AKA, U. S. S. *Seminole;* 1 AO, U. S. S. *Monongahela;* 1 AGB, U. S. S. *Burton Island;* LST's *1110*, *1126*, *1146* (and later *1138*); a Seabee detachment, an Underwater Demolition detachment, and an Ice Reconnaissance group. CAPT G. B. Helmick, USN, was detailed as COMBAREX (Commander, Barrow expedition).

All cargo was to be ready for loading at the Navy Fuel Depot, Point Molate, Calif., or at the Naval Advance Base Depot, Port Hueneme, Calif., by 15 June. By 1 July cargo to be loaded in Seattle, Wash., was to

be ready. It was not until 25 June that the larger Barex was authorized by Asst. SecNav John T. Koehler.

Barex '51 carried cargo for Pet 4 valued at almost $1,375,000 and comprising about 20,000 measurement tons.

The *Burton Island* left San Diego, Calif., on 9 July and, after several stops, arrived off Barrow on 22 July. LST's *1110* and *1146* departed Seattle, Wash., on 19 July and proceeded directly to Point Barrow which they reached on 30 July. LST's *1126* and *1138* left Seattle on 16 July. LST *1126* delivered fuel to the USC and GS ship *Pioneer* near St. Lawrence Island and later, at Cape Prince of Wales, unloaded cargo for the Naval Electronics Laboratory. Those two ships also reached Barrow on 30 July.

The U. S. S. *Monongahela* departed Long Beach on 25 July and sailed directly to Barrow and arrived on 4 August. The U. S. S. *Seminole* left Seattle on 28 July and reached Point Barrow on 5 August.

LST *1126* beached at beach 5 at 1200 on 30 July, and by 1000 on 31 July she was completed offloaded. After unloading over the side on 30 July, the *1138* made a dry-ramp landing on 31 July and finished unloading at 0400 on 1 August.

The LST's *1146* and *1110* were unloaded and departed at 1800 on 31 July for Pitt Point, Oliktok Point, and Barter Island. They were accompanied by the *Burton Island*. The LST's returned to Barrow on 5 August. LST's *1126* and *1110* departed Barrow for the States on 7 August, and *1138* and *1146* followed on 8 August. After completion of all unloading and backloading at Barrow on 8 August, the U. S. S. *Burton Island* was detached from duty with Barex, 1951 and resumed her normal organization.

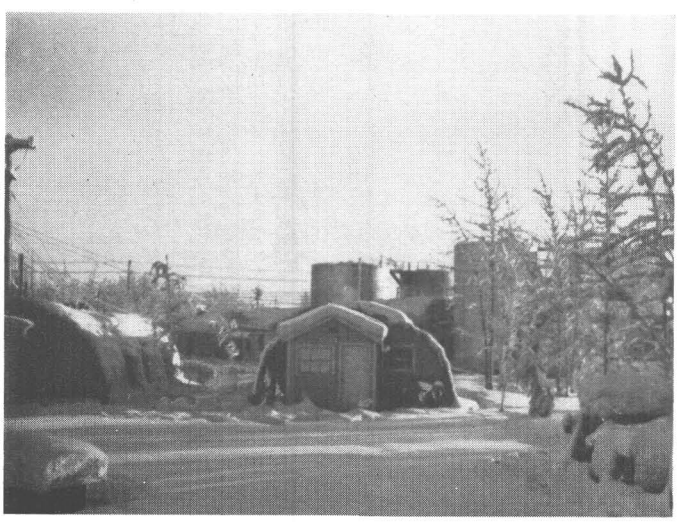

FIGURE 97.—Typical quonset-type living quarters in Fairbanks compound in winter, January 1951. Photograph by T. G. Roberts.

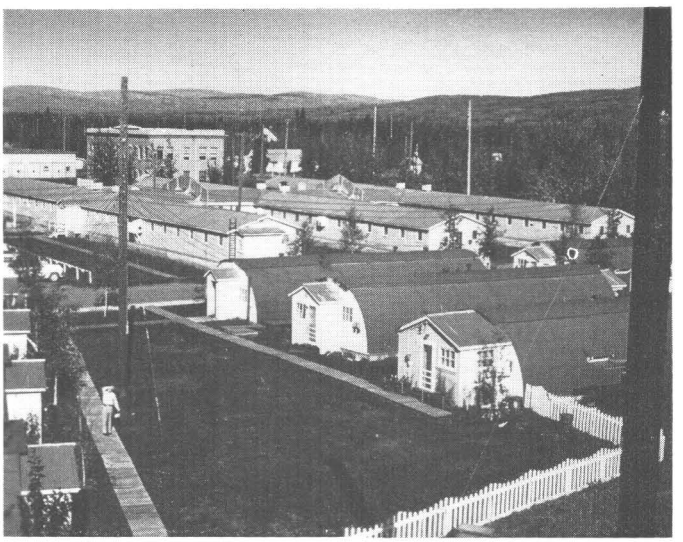

FIGURE 98.—General view of Fairbanks compound in early fall. Two-story building in background houses general offices of the U. S. Smelting, Refining, and Mining Co., Fairbanks Department. Photograph by Harlan Bergquist, September 1953.

The *Monongahela* was unloaded by 6 August and reported to Commander MSTS (Military Sea Transport Service) for operational control as she headed back toward Bering Strait. The *Seminole* left Barrow on 8 August bound for San Diego.

Offloading was handled with a smaller personnel and less equipment than in former years. The longer intervals between unit arrivals at Barrow allowed time to clear the beaches. The beach personnel included 2 beach foremen, 46 equipment operators, and 80 laborers.

Barex '51 was highly successful in spite of the difficulty of planning because of the late decision for a full expedition.

MAINTENANCE

Little new construction was required in 1951 as almost everything needed was on hand. There were, of course, an abundance of regular chores such as laying out new rig foundations, improvements such as the pouring of cement sidewalks around the Fairbanks headquarters (see figs. 97, 98), the design and installation of a new electrical distribution system at Umiat, inventory, and so on.

In addition to the more routine items, a second Cardwell rig was unitized for arctic movement, airport facilities at Barrow were expanded, and a new hangar floor was put in at Barrow.

A very substantial number of outside activities, either not related or only remotely related to Pet 4, were supported as in the past, and the list of them would be almost identical with that already given.

The gas used from South Barrow test well 4 totaled 131,513,000 cubic feet during the year. The lowest

consumption was 8,143,000 cubic feet in July and the highest 14,664,000 cubic feet in January.

Several fires occurred in Pet 4 during 1951. Most of these were serious. An incomplete list of the fires follows:

19 Jan	Explosion and fire in living-quarters hut 144.	Damage, considerable.
31 Jan	Insulation ignited in Arctic Test Station by blow torch being used in thawing frozen pipes.	Damage, minor.
30 Apr	Heat-pak wanigan at Umiat test well 5. Spread to mud wanigan and Failing 1500 drill rig.	Damage, total loss.
16 Aug	Jameway hut at Umiat. Probably caused by faulty oil heater.	Damage, hut and contents destroyed.
20 Sep	Righouse at Kaolak test well 1	Damage, not serious.
6 Dec	Gubik test well 2	Damage, very substantial.

Of the above the Gubik fire was the most spectacular and the most noteworthy as far as the overall program is concerned. The following extracts from a report of investigation made by the ROICC at Barrow, LCDR J. V. Jones; the technical advisor to the OICC, LT H. J. McGarr, Jr.; and the project manager of Arcon, E. L. Davis, appear to indicate reasonably well what actually happened:

* * * a cement plug had been set at about 2200 feet—about 2230, 5 December. When the midnight to noon tour came on, the rig was circulating mud. The driller's instructions were to continue circulating, then come out of the hole to pick up a drill collar and bit, then go back in and feel for the top of the plug, so that it could be reported by 0745, 6 December. The mud weight was checked by the derrickman (Blackwood) at 88.5 pounds, viscosity 55 seconds. No water-loss was taken. All personnel agree that there was no undue cement contamination of the mud; * * *. Sometime about 0100, they started coming out of the hole. After about the ninth stand, the hole was filled. The nineteenth or twentieth stand came out wet. * * * Then mud came up through the rotary table and two men were sent below to close the blow-out preventer. By this time the well was blowing gas and mud that blinded the driller, and the interior derrick lights failed. All personnel successfully scrambled for safety. Between five and ten minutes after the first blow, the gas caught fire, destroying the derrick in about three minutes. Apparently the rig settled and fractured the fill-up line, which caused a fire down below and destroyed the substructure. * * *.

It is the opinion of the Board that the column of drilling mud in the hole was in some manner lightened so that the pressure exerted by the column was less than that of the gas sand which blew out. * * *.

* * *. Because of the rapidity with which the gas blow came; the spray of mud inside of the derrick and the blacking out of the interior lights, there was no practical means available to the drill crew to shut off the flow of gas and mud through the drill pipe. It is believed that the crew did everything possible from this time on to minimize the loss of rig equipment.

GEOLOGY

On 15 December 1950, the DNPR wrote the Director, Geological Survey, requesting that the geologic work recommended at the 13th meeting of the operating committee be done by the Geological Survey according to the administrative agreement dated 1 July 1945 between the Departments of Navy and Interior. The work was planned as part of a closeout program and consequently was designed to obtain as much information as possible to fill the gaps in the geologic knowledge of Pet 4 in order to make possible a more complete final report. When it was decided at the 14th meeting of the operating committee in June 1951 to continue the Pet 4 exploration, it became necessary to reorient the geologic effort a little toward investigations that would be useful in selecting drill sites. This resulted in a slight slowing down of final report preparation.

The first proofs of Geological Survey Oil and Gas Map 126 appeared in 1951. Copies were distributed at the 15th meeting of the operating committee in November. The map contains much of the geologic information on northern Alaska that had been accumulated to that date.

FIELD PROJECTS

Four regular geologic field projects went on. (See pl. 3.) In addition, spot jobs of short duration were performed by small groups working out of Umiat. Such short jobs were done by back-packing or with boats, and with air support on the Toolik and upper Colville River and in the vicinity of Cape Thompson.

The regular projects went on in the Shaviovik-upper Sagavanirktok Rivers area, and the Driftwood-Noluk Lake area.

Party 1, with geologists A. S. Keller and R. L. Detterman, worked in the Shaviovik-Sagavanirktok Rivers area. The northeastern part of the area studied is believed to be more likely to contain oil accumulations than the southern part. The party traveled by weasels.

Party 2 traveled by weasel and small boats. The work was in the Brooks Range in the vicinities of the Okokmilaga and the John Rivers. The party was led by W. W. Patton and included geologists M. D. Mangus and W. P. Brosgé. Oil accumulations in the Brooks Range are believed unlikely, but the party accumulated much structural information valuable for interpretations in potential petroliferous areas farther north.

Party 3 was led by I. L. Tailleur. B. H. Kent and H. N. Reiser were also assigned to it. The party worked south from the Colville River to the south side of the DeLong Mountains. Most of the movement was by weasel but included also was a boat traverse down the Ipnavik River to its mouth in the Colville.

Party 4 worked in the general area of Driftwood Creek, the headwaters of the Colville River, and the Nuka River. Porosity and permeability of all the rocks seen are low. A major anticline on the Colville River may be the eastward extension of the Driftwood anticline. (See fig. 12.) The head of party 4 was

E. G. Sable, and he was assisted by J. T. Dutro, Jr., and R. H. Morris.

Parties 2, 3, and 4 reached or crossed the Brooks Range divide in weasels by four different routes. That was the first time that self-propelled land vehicles had reached the divide. Party 2 crossed the crest by way of the Okokmilaga River and the Hunt Fork of the John River. The weasels then returned to Umiat by way of the Anaktuvuk River. Party 3 crossed the crest of the range from the headwaters of the Kiligwa into the Noatak River drainage and returned by the same route. Party 4 reached the crest of the range at the head of the Utukok River.

SPECIAL STUDIES

Special studies in paleontology were continued with members of the regular Navy Oil Unit personnel and with the help of other Survey paleontologists in special fields and of paleontologists of the U. S. National Museum. Harlan Bergquist in Fairbanks and Helen Loeblich in Washington, D. C., continued to study and interpret the microfossils.

R. H. Morris continued the study of heavy minerals as an aid in geologic correlation, but that aspect of the work was somewhat slowed to allow Mr. Morris to participate in the fieldwork and thus gain firsthand experience with the rocks under study.

Sedimentation analysis, facies studies, and shoreline trends went on as part of the fieldwork. In addition, T. G. Payne continued as a consultant on sedimentation problems.

Under the guidance of W. A. Fischer, the study of the geology of northern Alaska through the use of aerial photographs increased during 1951, and techniques also improved greatly. By the end of the year the whole area of concern to Pet 4 was essentially covered photogeologically on a scale of 1:96,000. The compilations on a scale of 1:250,000 were more than half done and were to be completed by the spring of 1952.

Base maps for Pet 4 had been made over the years by the Geological Survey from aerial photographs. Adequate maps on a scale of 1:48,000 were completed for the whole area of concern by the end of 1951. Special maps had been made as required. Some photomosaics had been compiled by the Geological Survey and some by the Navy.

FAIRBANKS LABORATORY

The Survey's Fairbanks laboratory continued stratigraphic micropaleontologic studies under the guidance of T. G. Roberts.

GEOPHYSICS

Originally, the operating committee had recommended four seismic parties in 1951. However, only one was sent into the field in order to conserve funds so that the drilling program could be emphasized. The party worked about 6 months in the eastern and southeastern parts of the Reserve and in adjacent areas. (See pl. 3.) The party produced the following results:

1. Established east closure on the Gubik anticline. West closure had already been established both by surface geology and by geophysics.
2. Proved closure of the Square Lake anticline and surveyed it in detail by seismic shooting.
3. Searched unsuccessfully for closures west of Fish Creek test well 1.
4. Surveyed along the Sentinel Hill axis. West closure could not be found.

John R. Woolson, of the United Geophysical Co., in 1951 completed interpretive reports on a large part of the geophysical work that had been done as a part of Pet 4. These included papers on—

1. Regional interpretation of gravity results.
2. Regional and stratigraphic discussion of seismic results.
3. Correlation of Simpson test well 1 with Topagoruk test well 1.
4. Gravity-meter interpretation of the Barrow complex.

A well velocity survey of Topagoruk test well 1 was made on 17 September to determine—

1. The accurate velocity in order to correct the Topagoruk area cross sections.
2. The position of the seismic horizons in the geologic section.

The seismic studies in 1951 were summarized by W. H. Myers at the 15th meeting of the operating committee in November.

DRILLING

During 1951, 48,710 feet was drilled by Pet 4. This drilling was at 20 rig sites (see pl. 3). The total footage includes 979 feet of redrilling in 1 hole and 1,066 feet duplicated in 2 holes on which the rigs were skidded because of difficult jobs of recovering material dropped in the holes. Four of the holes were believed capable of producing oil and four (including one of the oil-bearing holes) of producing gas. Two of the gas wells indicated a major gas-bearing anticline.

Transportation problems were especially difficult at some of the locations in the foothills area, such as Wolf Creek, because there were no close lakes for float-plane landings and no nearby areas where an airstrip could be made for ski or wheel landings.

Less trouble was encountered with caving than previously because of more careful mud control. On two wells the bottom joint of casing broke off after cementing the string. Little difficulty was had with collapse

of surface casings. Oil and brine were used where available; and, in some instances where they were not used, the casings were cemented solidly to the surface.

At Umiat test wells 5 and 9 electric heating was tried by using the casing as the heating unit. That seemed to solve the icing problem in those holes.

Some difficulty was made by the formation of hydrates in the tubing at South Barrow test well 4 during the coldest weather, but gas production was continued through one annulus or the other while the tubing was left open to atmospheric pressure and triethylene glycol and alcohol were poured into the tubing and some forced into the annulus. That treatment cleared the hydrates, and the well thereafter was blown more frequently to keep the accumulation of bottom water to a minimum.

TOPAGORUK TEST WELL 1

In the report on the seventh year it was noted that Topagoruk test well 1 was spudded on 15 June 1950. At the end of 1950 the well had been drilled to 7,154 feet but had to be redrilled from 6,275 feet at the beginning of 1951. The hole was completed on 28 September 1951. It had accomplished its objective of yielding a large amount of useful geologic data from a critical location, but it did not not tap any substantial reservoir of gas or oil. The hole reached pre-Permian rocks, but no Lisburne group was found. The final depth was 10,503 feet.

The hole was left full of thinned drilling mud, and no casing was pulled. Thermistor cables were run into the hole to depths of 5,800, 2,200, 1,340, 980, and 325 feet.

EAST OUMALIK TEST WELL 1

At the end of 1950, East Oumalik test well 1 was being prepared for abandonment. The job was finished by 7 January 1951. The hole cut rocks containing some gas at several horizons, and some cores gave an oil cut; but, in general, porosity and permeability are low, and oil and gas showings were insignificant. An electric log was run of the hole, and five thermistor cables were installed before it was left.

SIMPSON CORE TEST 30

Simpson core test 30 was completed on 23 January. From the first of the year it was drilled from 630 to 693 feet, the final depth.

SIMPSON CORE TEST 30-A

Simpson core test 30–A is only 100 feet from 30. It was drilled because of the loss of 30 owing to a tool-recovery job. The hole was started on 23 January and completed on 6 February at a depth of 701 feet. Oil sands such as those found in No. 30 were also found in No. 30–A. At a depth of 350 feet the hole was bailed dry. Continued bailing for 24 hours yielded 5 barrels of oil. Gas was found at 423 feet but was not gaged. At the final depth the hole was bailed dry, but no oil or water entered. The hole made a little gas.

SIMPSON CORE TEST 27

Simpson core test 27 was drilled to investigate the cause of the seepages in the Cape Simpson area. It is 1,500 feet deep and was drilled between 8 February and 14 March. Several sand layers were found, and the sand cored from 324 to 371 feet was partly saturated with oil. At 380 feet the hole was bailed down, and subsequent bailing for 36 hours yielded oil at 3 barrels per day.

SIMPSON CORE TEST 31

On 21 March, Simpson core test 31 was spudded in. While coring at 355 feet the well started flowing oil. LT H. J. McGarr conducted tests that indicated a flow of about 125 barrels per day with some gas. The hole was abandoned on 2 April at 355 feet.

UMIAT TEST WELL 7

In the previous chapter it was pointed out that Umiat test well 7 was drilling ahead at 827 feet at the end of 1950. The well was completed on 12 April 1951 at a depth of 1,384 feet. In no. 7 the upper sand is water-bearing, whereas in No. 6 it is oil-bearing. No. 7 is 170 feet structurally lower than No. 6. The contact of the oil and water in the anticline is somewhere between 725 feet and 870 feet below sea level. Umiat test well 7 defines the extent of the oil reservoir on the south flank of the Umiat anticline. It does not preclude the possibility of oil in higher sands farther down the flank.

UMIAT TEST WELL 8

Umiat test well 8 was drilled with a Cardwell cable-tool spudder. Drilling began on 2 May, and the hole was completed on 28 August at a total depth of 1,327 feet. The test cut the upper sands from 860 to 930 feet and the lower sands from 1,230 to 1,327 feet. It is believed that about 200 feet of the lower sands was not penetrated.

At 1,080 feet a pumping test averaged 60 barrels per day. At total depth, and with tubing hung at 1,250 feet, after swabbing clean, the well flowed for 64 hours, starting at 2.5 barrels per hour and declining to 1 barrel per hour chiefly owing to the formation of ice in the tubing.

At total depth, with casing cemented at 1,231 feet, all fluid was removed, and a flow test for gas gave an estimated 5,858,700 cubic feet per day through a 1½-inch orifice. The shut-in pressure was 260 pounds.

UMIAT TEST WELL 9

On 25 June Umiat test well 9 was spudded in. A Failing 1500 rotary rig and oil-base drilling mud were used. The well was essentially completed by the end of the year, but certain testing went on until 15 January 1952. The total depth of the hole was 1,257 feet. The upper sands lie at 466 to 525 feet, and the lower sands, from 866 to 1,096 feet.

The hole was successively tested at various horizons as the drilling progressed. A swabbing test was made at 533 feet and resulted in the recovery of 2 barrels of mud. Another test was made from 866 feet to 901 feet; no fluid entered. A swabbing test from 959 to 1,017 feet yielded no oil.

At final depth of 1,257 feet and with tubing at 1,224 feet, oil started entering, and by the following day, the fluid level had risen to 280 feet. The well was put on a pump, and a 45-day test yielded oil at the pump capacity of around 200 to 250 barrels per day.

The hole was plugged back in stages to determine the horizons from which the oil was entering, but the results were inconclusive. Casing was set and perforated at the inferred correct horizons; no further oil entered.

UMIAT TEST WELL 10

Umiat test well 10 was drilled, with a Cardwell spudder, to test further a new productive area north of a fault that had been disclosed by Umiat test well 8. The well was spudded on 9 September, and operations were suspended on 10 January 1952 at a final depth of 1,573 feet. An oil-stained sand was found between 410 and 498 feet, but it yielded no oil, perhaps because of the slight pressure. A new oil sand was found between 650 and 740 feet. It yielded oil at the rate of 96 barrels per day. The upper sands are between 1,060 and 1,112 feet; the top of the lower sands is at 1,535 feet.

Bailing tests with the hole open to 1,120 feet indicated a potential of 200–250 barrels per day. With casing set at 1,339 feet and a depth of 1,573 feet, so much caving difficulty was met that drilling with the spudder was discontinued. The intention was to deepen the hole later with a small rotary.

EAST TOPAGORUK TEST WELL 1

East Topagoruk test well 1 was drilled to test the oil possibilities of sands found in Topagoruk test well 1 between 300 and 3,320 feet. Drilling was with the Cardwell No. 1 rotary. The hole was spudded on 18 February and completed on 17 April at a depth of 3,589 feet. No oil was found, and only one sand was found to contain a little gas. The sand seems to carry gas from 2,212 to 2,220 feet and water from 2,220 to 2,276 feet. Ten sands or more were listed as potential reservoirs, but the anticline probably has inadequate closure.

TITALUK TEST WELL 1

Between 22 April and 6 July, Titaluk test well 1 was drilled with the Cardwell No. 2 rotary to a depth of 4,020 feet—the rig's limit.

Between depths of 145 and 3,400 feet, the electric log showed 12 probable sand layers ranging in thickness from 20 feet to 93 feet. Most of the sands are too impermeable to have much merit as oil or gas reservoirs. A sand at 2,660 to 2,717 feet is permeable enough for production and yielded an odor and cut of oil. It was not tested for productivity. On a drill-stem test a similar sand at 2,958 to 3,032 feet yielded gas. A sand at 3,140 to 3,233 feet probably carries gas or oil but was not tested.

WOLF CREEK TEST WELL 1

Wolf Creek test well 1 was drilled with a Bucyrus-Armstrong cable-tool drill designed to drill to about 1,500 feet. Drilling went on between 29 April and 1 June, and the total depth reached was 1,500 feet. The objective of the well was to test the Wolf Creek anticline through the sands that are oil bearing at Umiat.

The Umiat sands were not found above the depth drilled, and further drilling was prevented by the loss of the tools in the hole. Nevertheless, a sand horizon at 863 feet yielded gas with a shut-in pressure of 70 pounds per square inch, and one from 1,491 to 1,500 feet tested 1,300 through a 1½-inch orifice.

WOLF CREEK TEST WELL 2

Wolf Creek test well 2 was spudded 7 June and completed on 3 July. It was drilled with the same rig as Wolf Creek test well 1. The hole was designed to test the possibilities of the north flank of the anticline, especially in sands that were gas bearing or impermeable at No. 1 on top of the anticline and in the Umiat sands that were believed to be lower in the section than was penetrated at No. 1. The section proved to be about 200 feet lower structurally at No. 2, and the hole reached only 1,618 feet; hence, even the better sands found in No. 1 were not quite reached. No oil showings were found, but a little gas appeared between 760 and 768 feet.

GUBIK TEST WELL 1

Gubik test well 1 was drilled near the top of the large Gubik anticline about 16 miles east of Umiat. It was planned to test the possibilities of the better sands that were also founded at Umiat. It was commenced on 20 May and completed on 11 August at a total depth of 6,000 feet. A National 50 rig was used.

A showing of gas was observed in the mud ditch at 1,205 feet. A drill-stem test showed gas between 1,438 and 1,495 feet. Slight fluorescence of cores was noted from 1,445 to 1,495 feet. A little oil and gas were seen at 3,443 to 3,445 feet. A cut of oil was obtained with ether from a sand core at 3,502 feet. Odors of gas were yielded by cores at 3,519 to 3,702 feet. Shale cores bled gas and oil from fractures at 4,261 to 4,543 feet and 5,209 to 5,646 feet.

Several drill-stem tests indicated gas producable in excess of 2 million cubic feet per day from sands of good thickness and porosity. The extent of the sands may be great, and the anticline is large.

GUBIK TEST WELL 2

Gubik test well 2 is approximately 4,000 feet southeast of Gubik 1. Its purpose was to find oil in sands that were gas bearing in Gubik 1, and it is spotted down the flank from No. 1 about 240 feet structurally lower. The well was spudded on 10 September. The well was 4,620 feet deep when it blew out, caught fire, and burned on 5 December. The site was abandoned on 14 December.

No oil was found in Gubik test well 2 except a few showings, such as finding a little oil in the core barrel and occasionally in mud recovered on drill-stem tests. Some of the sandstones seem oil saturated but have little permeability. Gas was found at several horizons, and the bulk of it that caused the blowout may have come from between 1,810 and 1,858 feet.

KAOLAK TEST WELL 1

Kaolak test well 1 (see figs. 99, 100) was drilled about 65 miles west of Meade test well 1. The objectives were to explore for reservoir rocks in the hitherto untested western part of Pet 4, to determine the oil and gas possibilities of the Kaolak anticline which had been found by seismic work, and to determine the fluid content of any reservoir rocks to a depth of 6,000 feet. When that depth was reached, the conditions were favorable enough, so that the decision was made to drill on to about 8,000 feet.

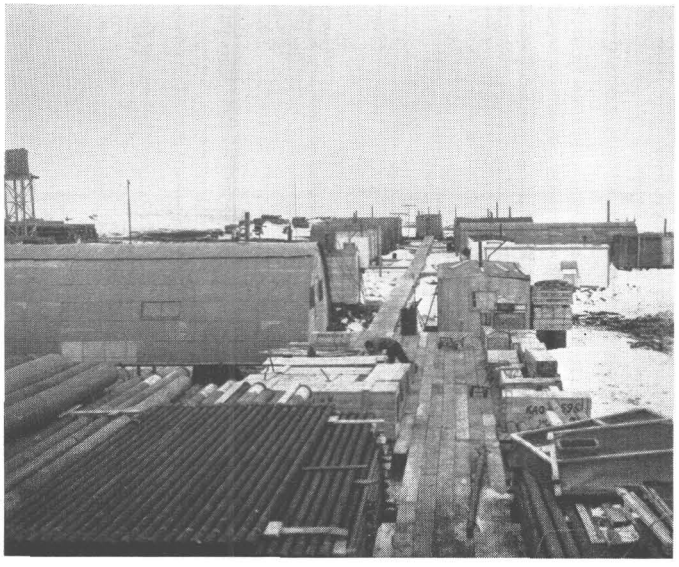

FIGURE 99.—Kaolak camp from derrick location. Photograph by U. S. Navy, 28 April 1951.

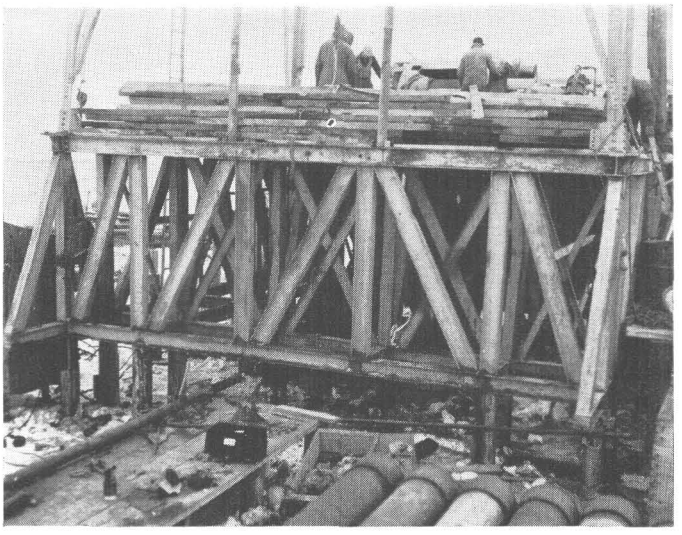

FIGURE 100.—Substructure of Kaolak drilling rig. Photograph by U. S. Navy, 28 April 1951.

The well was commenced on 21 July and abandoned on 12 November. A few sand layers were found and appeared to bear water. Using solvents cuts of oil were obtained from sandstone cores at 3,191, 4,805, 5,054, and 6,385 feet, but the saturation was slight, and the sandstones are thin and only slightly permeable.

The well was shut down at 6,952 feet to await favorable conditions to freight in 3½-inch drill pipe that was needed to go deeper. While shut down, the derrick blew over in a high wind and was destroyed. The project was abandoned.

KNIFEBLADE TEST WELL 2

Knifeblade test well 2 was spudded on 26 July and abandoned because of a drill recovery job at a depth of 373 feet on 5 August. The drill used was the Bucyrus-Armstrong spudder. On abandonment, two thermistor cables were installed in the hole.

KNIFEBLADE TEST WELL 2-A

After the loss of Knifeblade test well 2, the rig was skidded over 28 feet, and No. 2–A started on 6 August. It was completed at a depth of 1,805 feet on 7 October. The well revealed the presence of a sandstone zone with thickness, permeability, and porosity sufficient to constitute a good oil reservoir. The fact that the sands carried only water may be due to the well location being

too low on the anticline. Some of the sands were oil stained and yielded cuts.

KNIFEBLADE TEST WELL 1

On 13 October, Knifeblade test well 1 was spudded in about a mile north-northeast of Knifeblade 2. It was drilled with the same spudder and was completed on 22 December at a depth of 1,805 feet. Water-bearing sandstones were found at 884 to 910 feet and at 1,379 feet. There were no significant showings of oil or gas.

AVAK TEST WELL 1

The Cardwell rig No. 1 was used to drill Avak test well 1. The well was designed to test a gravity and seismic high in the Barrow vicinity. The well was spudded on 20 October, and by the end of the year was being drilled at 3,890 feet. Under the new contract, the well was completed at a depth of 4,020 feet on 14 January 1952. Some of the shales penetrated gave slight oil cuts.

A thermistor cable was installed to 200 feet in the well before it was left.

SUMMARY OF 1951

The eighth year, 1951, was the final year of contract NOy–13360. Pet 4 continued thereafter with the same contractor, Arcon, under contract NOy–71333. The year was one of decision as to whether or not Pet 4 would be closed out forthwith. The necessary delays in reaching the required decision had a marked effect on the programs, in some ways good and in others not.

In the early part of the year, it was felt that Pet 4 probably would be closed at the end of the year. Therefore, all efforts were made to carry out as large a drilling program as was possible in a final effort to prove or disprove as many anticlines as possible. This in turn made necessary a very heavy freighting schedule. It also resulted in a much smaller than normal geophysical program because it was felt that there was no need of searching for structural features that could not be drilled within the expected life of Pet 4 and because the funds were needed for the drilling. The geologic program was planned and started in order to fill in as many as possible of the gaps in the geologic knowledge of the region for the purpose of a well-rounded final report; but, when it was found that Pet 4 would continue, it was reoriented in part toward selection of future drilling possibilities. The effect of the delay in the decision relative to the continuation of Pet 4 was most critical in regard to Barex '51, for it involved procurement, the devising of two separate Barex plans, and proceeding on very short notice with by far the larger and more complex of the two plans.

The authorization for the full-scale Barex was not made until 25 June, and the first ship sailed from the States on 9 July. The final decision on the continuation of Pet 4 was made on 3 July after discussion with the Chairman of the House of Representatives Armed Services Committee.

The book cost against contract NOy–13360 for 1951 was about $8.2 million. This did not include transfers from Pet 4 funds to other Federal agencies to carry on Pet 4 work such as the Geological Survey and the CAA, nor did it include the cost of the airlift contract. Freighting over the tundra by sled train totaled 1,860,-194 ton-miles. Drilling at about 20 sites aggregated 47,710 feet. The employment peak of 536 was reached in August, and the low of 404 was in December. The average for the year was 496.

During the year, an oil field at Cape Simpson was proved, and sufficient data became available to appraise the field as being small and of little significance.

The Umiat field was better defined during 1951, and much more was learned about producing oil from such a structural feature. Neither the full extent nor the potential of the Umiat anticline is sufficiently known although at the end of 1951, on incomplete data, it was estimated as being capable of producing between 30 and 100 million barrels of oil. Gas in substantial amount was found in one hole on the Umiat anticline.

The large Gubik anticline during 1951 was proved to contain large quantities of gas, but much more information is needed to even roughly appraise the potential of the anticline.

All in all, 1951 was a year of accomplishment under difficult conditions brought about largely because of the doubt as to the future of Pet 4.

NINTH YEAR—1952

GENERAL PLANNING AND ADMINISTRATION

The assumption at the start of 1952 was that Pet 4 would continue until its defined objective of a reasonable appraisal of the oil possibilities of Naval Petroleum Reserve No. 4 and adjacent areas had been reached. This was a substantially different situation than had existed a year before at the start of the eighth year. Contract NOy–71333 had been negotiated with Arcon to replace contract NOy–13360.

Early in January Walter Fillipone replaced W. H. Myers as supervisor for NPR 4 work for the United Geophysical Co. LT H. J. McGarr, technical advisor to the OICC, was detached from duty in that capacity on 7 March and returned to the States. The position was not refilled until 5 May when A. J. Armell assumed the responsibility.

Because he did not expect to be present at the 16th meeting of the advisory committee in April, Walter A. English called on the DNPR in Denver on 25 and 26 February and went over the whole Pet 4 operation in substantial detail.

On 11 March and extending into 13 March, a meeting of the executive operating committee was held in Fairbanks to review progress since the 15th meeting of the operating committee in November 1951, to recommend any modifications in the 1952 program, and to formulate recommended programs for 1953 and 1954.

The key personnel of Arcon, BuDocks, Geological Survey, and United Geophysical Co. in Fairbanks were present as well as representatives from the States of the DNPR, DeGolyer and MacNaughton, Arcon, Geological Survey and the United Geophysical Co.

The progress of Pet 4 since November 1951 was carefully studied. Avak test well 1 was unsuccessful; the National 50 No. 2 rig at Gubik was destroyed by fire; the derrick of the National 50 No. 1 rig at Kaolak was damaged beyond repair in a windstorm. The program prepared for recommendation to the advisory committee (formerly the operating committee) included—

1. Continue drilling Square Lake test well 1.
2. Wolf Creek test well 3 to be drilled with the Cardwell rig No. 2 from Square Lake.
3. Grandstand test well 1 to be drilled.
4. Umiat test well 11 to be drilled with the Cardwell No. 3 rig.
5. Weasel Creek test well 1 to be drilled with the same rig as Umiat test well 11, after completion of the latter test.
6. Testing of Umiat test wells 9 and 10 to be deferred for economy reasons.
7. Continuation of Gubik test well 2 to remain tentative.

Recommendations for the geophysical and geological programs were essentially the same as had been recommended by the operating committee in November 1951.

Proposed drilling for 1953 included—

1. West Big Bend (western part of Big Bend anticline, see fig. 12) test well 1 to be drilled to 4,000 feet.
2. East Titaluk test well 1 to be drilled to 3,900 feet.
3. Umiat test well 10 to be deepened from 1,573 to 1,860 feet.
4. Gubik test well 3 to be drilled to 2,000 feet.
5. West Meade test well 1 to be drilled to 4,300 feet or Oumalik test well 2 to be drilled to 4,000 feet.
6. A conditional well, to be located after the 1952 seismic data are available, to be drilled to between 4,000 and 8,000 feet.

A tentative drilling program for 1954 included—

1. A pre-Cretaceous test to be drilled to between 9,000 and 12,000 feet.
2. One or more of the 2,000- to 4,000-foot tests not drilled in 1953.
3. Two or three 4,000- to 6,000-foot tests on structural features to be chosen.

In addition, the executive operating committee studied a progress report of a subcommittee of the advisory committee on geologic correlations in northern Alaska. The subcommittee was chaired by L. W. MacNaughton.

A subcommittee of the executive operating committee prepared a Pet 4 program policy statement that attempted to elaborate the general defined objective of Pet 4. That statement follows:

> Exploration for petroleum in NPR No. 4 will be based upon a long range program formulated for the purpose of evaluating the petroleum potentialities of the Reserve and adjacent areas. This evaluation will be based primarily upon data obtained from test wells which will penetrate the complete sedimentary section and will be drilled and tested to provide the maximum amount of geological, engineering, and production data. Locations for test wells will be determined on the basis of detailed studies using all geological, photogeological, geophysical and core drill information as may be applicable. Advance planning will attempt to take logistics into consideration to permit smooth field operations approximating the physical capacity of available facilities.

Another subcommittee appraised the accomplishments of Pet 4 to that date against the defined objective. The whole region was divided into five areas (see fig. 101) for appraisal purposes. It was concluded as follows:

> Area 1. (Coastal plain west of the Colville River) Requirements essentially complete.
>
> Area 2. (Coastal plain east of the Colville River) Additional surface geological studies contemplated. Geophysical and drilling operations will be required if evaluation is to be made.
>
> Area 3. (Northern foothills west of the Anaktuvuk River) Additional geological structure mapping and seismic detailing planned for several party seasons. Approximately five to ten shallow to medium tests contemplated for 1952 and 1953 seasons should provide the information required for an evaluation of this area.
>
> Area 4. (Northern foothills east of the Anaktuvuk River) Additional structural geological mapping planned. Seismic surveys recommended to begin this year. Test well drilling will depend on results of surface exploration.
>
> Area 5. (Southern foothills) Additional geological structural mapping recommended. Seismic surveys beginning this year and contemplated for future years. Test well drilling should start in 1954 or sooner dependent upon availability of suitable locations. Estimated that at least four years' drilling deep to medium wells required. Seven or eight wells required to obtain the data necessary.

The subcommittee summarized its analysis by concluding that "Based on the foregoing, a full scale exploration program with emphasis on drilling must be continued at least through 1957 to achieve the objectives set forth herein."

As of 30 March 1952 the Arcon personnel was 225 at Barrow, 212 at Umiat and elsewhere in the Reserve, 42 in Fairbanks, and 16 in Seattle.

On 4 April RADM Cruise, Commandant 17th Naval District and COMALSEAFRON (Commander, Alaska Sea Frontier) called on the OICC in Fairbanks and also made an official visit to Barrow.

Allotments for drill pipe and casing for 1952 were supplied by the PAD (Petroleum Administration for Defense). After the allotment was made, it was discovered that PAD had overallotted the market, and it was impossible to place orders for delivery of tubular goods in time to meet the Barex '52 sailing dates. With the help of PAD, orders were finally accepted, only to meet another delay owing to the general steel strike. Eventually an emergency priority was issued, and a part of the materials was withdrawn from emergency stocks in the Los Angeles area, Calif.

The 16th meeting of the advisory committee assembled in Denver on 14 April, and meetings were held on that day and the next. As a record of concerned persons at the time, the following listing of those present is given: From the advisory committee were CAPT R. H. Meade, DNPR; W. E. Wrather, Director, Geological Survey; L. W. MacNaughton, DeGolyer and MacNaughton; and CDR A. C. Morris, CEC USN. Others included James H. Tully, president, Exploration Contractors; A. A. Curtice and W. H. Myers, Exploration Contractors; Earle F. Taylor and J. W. Watson, DeGolyer and MacNaughton; E. C. Peterson, C. F. Lytle Co.; W. R. Fillipone and E. G. Schempf, United Geophysical Co.; CDR M. H. Aubey, OICC, contract NOy–71333; E. L. Davis and C. L. Mohr, Arctic Contractors; John C. Reed, George Gryc, and W. A. Fischer, Geological Survey; and CDR M. V. Carson, Jr., CDR R. C. Jensen, LCDR J. C. Bomke, R. G. Tracie, and R. L. Magnie, ONPR.

On 14 April C. L. Mohr, chief of exploration, Arcon, reviewed pertinent parts of the 1951 operations. He discussed drilling operations, the status of drilling rigs, seismograph operations, and geological data. George Gryc, chief, Navy Oil Unit, Geological Survey, reviewed geological work since November 1951 and gave a new tentative interpretation of the Umiat anticline. Earle F. Taylor of DeGolyer and MacNaughton reported for the committee on correlations in NPR 4. The committee was requested to continue and to report further at the next meeting.

Mr. Mohr presented the 1952 program along with revisions that were recommended by the executive operating committee that had held a meeting in Fairbanks in March. The proposed drilling program is set forth in the part of this report that records the meeting of the executive operating committee. One further change was recommended—that, because it had taken longer than anticipated to convert the Cardwell spudder to a rotary, the rig at Wolf Creek, after the completion of that test, be used at Weasel Creek instead of the Cardwell rig that was expected to be used after the completion of Umiat test well 11. The proposed drilling program was approved by the advisory committee.

The seismic program approved was essentially the same as that proposed at the 15th meeting of the advisory committee in November 1951. It provided for 3 seismic parties for 5 months each and an interpretation crew for the full year. Work was to include reflection surveys in the Castle Mountain area, a tie line from Castle Mountain to the Grandstand anticline, a detailed survey of the Schrader anticline, a tie line from the Schrader anticline to the work already done southeast of Umiat, a search for closure on the east end of the Umiat anticline as far east as the Kuparuk River, a line from the Kaolak area to Carbon Creek, a line from Carbon Creek to the Driftwood anticline, and detailed shooting at the Driftwood anticline. Refraction shooting was to be done east of the Chandler River opposite the Hawk anticline and at the Driftwood anticline.

Commander Aubey presented an analysis of the status of the exploration by the committee designated for that purpose. The work of the committee has previously been outlined under the record of the March meeting of the executive operating committee. E. L. Davis submitted the statement of exploration policy that was slightly modified from the one previously quoted in this report and that was prepared at the executive operating committee meeting in March.

George Gryc presented a proposed program of 1952 geological projects. The program would involve continuation of the Navy Oil Unit without significant modification in size. The advisory committee approved the program, which included a field headquarters unit at Umiat for special short geologic duties, a party in the Canning-Shaviovik area, a party in the Chandler River area, and a party in the Brooks Range to continue the study of rocks of Paleozoic age. One party would be supported with Geological Survey funds. The Fairbanks laboratory would be continued, and photogeologic and other special studies would proceed as required, much as in the past.

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Mr. Mohr presented in detail for discussion a proposed program for 1953, and Mr. Davis indicated that 4 tractors and 1 National 80 rig would be needed for the proposed 1953 program and would cost about $325,000. The whole program would cost a little more than $10 million. Five substitute programs were discussed that would be somewhat less expensive, but also less informative, than the recommended one.

It was agreed to start the executive operating committee meeting on 1 October in Fairbanks in order to precede the advisory committee meeting to be held in Denver starting 18 November.

A discussion was held in general terms of a possible program for 1954 to cost about $12 million.

A copy of the minutes of the 16th meeting of the advisory committee was sent on 6 May to the Munitions Board with a request that a staff study be made to determine whether or not the discoveries in Pet 4 had any military value. Such a study was made by the Office of Petroleum Programs of the Munitions Board and is dated 31 July. The study concluded that owing "to excessive costs and difficulties of development, operation and transportation, the Umiat oil field and Gubik gas field have no military value."

In June 1952 a Navy survey board investigated the concept of Naval Petroleum Reserves as such and all aspects of the operation of Naval Petroleum Reserves. This survey was conducted as ordered by the SecNav and according to instructions from the Under SecNav to the Inspector General. The board was made up of a group of distinguished officers and representatives of industry. The chairman was RADM J. B. Pearson, Jr.

The recommendations of the board included two relative to NPR 4 as follows:

> That NPR 4 is of questionable value, due to the difficulty and extreme vulnerability of any practical means of transportation, as a Navy or national defense petroleum reserve. It is therefore the least desirable of all existing reserves for use in emergencies, and should be transferred to another Government agency for administration at such time as feasible after the completion of the present exploratory program * * *.
>
> * * * * * * *
>
> That the Alaskan reserve exploration continue at its present level in order not to lose current extensive investment, but that it be considered only as an exploration of natural resources and not as a reserve.

On 20 May, LT John M. Daniels, CEC, USN, relieved LCDR J. V. Jones as ROICC in Barrow and on 5 May, A. J. Armell became technical advisor to the OICC in Fairbanks.

On 9 May, the OICC, CDR Aubey, reported to the DNPR that the Chamber of Commerce in Fairbanks was becoming interested in the possibility of the commercial development of gas from the Gubik field for use in the Alaska Railroad belt and specifically in the Fairbanks area. This apparently was the first publicly announced interest in the possibility of the use of the gas. Since then there has been increasing interest that culminated after Pet 4 was finished.

On 24 June, CDR M. H. Aubey, CEC, USN, was relieved as OICC, contract NOy–71333, by CDR Albert J. Seeboth. Thus ended a long tour of duty for Commander Aubey, who had guided the closing years of contract NOy–13360 and the opening months of contract NOy–71333. Commander Aubey had been the responsible officer for some of the most difficult parts of the contract intervals. Commander Seeboth immediately began to apply a much tightened policy in regard to contract supervision reflecting a continuing review of the situation by the DNPR and rapidly changing conditions of labor supply and operations, such as the greatly increased need for effecting all possible economies.

Glen Ruby, of the advisory committee, studied the progress of Pet 4 from 14 July to 22 July in Fairbanks. On 21 July, LCDR Fred S. Card, Jr., USN, relieved CDR L. T. McQuiston as aviation technical advisor to the OICC. On 14 August LCDR J. F. Beaver was detached from duty as Asst. OICC. He was relieved by LT H. T. Johnson, CEC, USN.

Two Eskimo employees of Arcon, while traveling to work in their own boat 12 August, overturned between the native village and the Arcon camp and lost their lives by drowning. The Navy was represented at the burial by the ROICC, Barrow. On 15 August an Alaska Airlines Super Cub bush plane crashed near Umiat, and Pilot Spernek sustained a badly fractured ankle. The only passenger, E. P. Erickson, Arcon assistant superintendent at Umiat was slightly injured. The injured men were evacuated to the hospital in Fairbanks in about 6 hours.

GEN Omar Bradley was briefed on the mission of Pet 4 at Ladd Air Force Base by the OICC on 19 August. On 28 August, A. J. Armell was assigned duties as safety engineer in addition to his regular responsibilities as technical advisor to the OICC.

On 14 June, E. L. Davis terminated his position as project manager of Arcon. His energy, experience, and general competence had contributed much to the progress of the contract work of both NOy–13360 and NOy–71333. The vacancy left by his leaving was ably filled by Ted C. Mathews, the former assistant project manager, as acting project manager until the position of project manager was filled by J. Ralph Coleman on 26 August. Mr. Coleman had previously been associated with Pet 4 in its earlier days. Mr. Coleman also

brought a high degree of competence and many years of oil-field experience to the project.

The OICC went to Ladd Air Force Base on 13 September and discussed Pet 4 with a subcommittee of the House Armed Services Committee. The subcommittee was especially interested in investigating construction costs. CDR R. C. Jensen, Asst. DNPR; John C. Reed, Director's Office, Geological Survey; and Earle Fennell, Topographic Division, Geological Survey, traveled to Barrow on 27 September to inspect operations and returned to Fairbanks on 30 September.

The fall preparatory meeting for the 17th meeting of the advisory committee was held in Fairbanks on 1 through 3 October. About 25 persons attended representing the Navy, the contractor, the United Geophysical Co., and the Geological Survey. Among those present were CDR Albert J. Seeboth, OICC and Chairman; CDR R. C. Jensen, Asst. DNPR; John C. Reed, Geological Survey; Earle Taylor and James Watson of DeGolyer and MacNaughton; James Tully and A. A. Curtice, Exploration Contractors, Inc., Ralph Coleman and C. L. Mohr, Arcon; and Walter Fillipone, United Geophysical Co.

In April the advisory committee had recommended a program for 1953 that was estimated to cost about $8.6 million. After a full discussion of the accomplishments during 1952 the prime consideration was an attempt to curtail the program in 1953 to fit the $4,003,000 that was estimated to be available for the work. Emphasis was placed on the best possible pre-Cretaceous test in the southern foothills belt.

The resultant proposed program for 1953 was the drilling of a 10,000-foot pre-Cretaceous test on the Shaviovik anticline and a 5,000-foot test of the Kemik anticline a little farther south. The wells would be completed in 1954. Nine party months of geophysical work was recommended for authorization for 1953. A geologic program involving three field parties and a few special service tasks was recommended. Several choices for the specific locations for geologic fieldwork were outlined.

A 1954 program was discussed in very general terms. It was to include a 7,000-foot test in the Brady anticline area.

The 17th meeting of the advisory committee was held in the ONPR (Office of Naval Petroleum Reserves) in Denver on 18 and 19 November. Approximately 50 persons representing organizations participating in Pet 4 were in attendance. The DNPR, CAPT R. H. Meade, was chairman. Organizations represented included the ONPR, the Geological Survey, DeGolyer and MacNaughton, BuDocks, the office of the Asst. SecNav, the office of CNO, the Munitions Board, the Office of the Director of Budgets and Reports of the Navy, the office of the OICC, NOy–71333; Arcon, Exploration Contractors, Inc., Union Oil Company of California, Office of the Comptroller, SecDef (Secretary of Defense); the United Geophysical Co., the Green Construction Co., the C. F. Lytle Co., and the Bureau of the Budget.

Voting members of the advisory committee present were the DNPR, the Director, U. S. Geological Survey, Earle F. Taylor, alternate for L. W. MacNaughton of DeGolyer and MacNaughton, CDR A. C. Morris of BuDocks, and Walter A. English, chief technical advisor to the DNPR. Also present was Herbert R. Askins, Asst. SecNav.

The committee confirmed, as the result of accomplishments since April, the existence of substantial reserves of gas in the Square Lake anticline, the presence of oil shows in sands of Cretaceous age at Wolf Creek, evidence of thrust faulting in the foothill belt of NPR 4, which indicates a similarity to Canadian thrust-belt oil fields.

After very careful consideration of the whole program to date and of the second report of the subcommittee appointed to evaluate results in terms of the objectives of Pet 4, it was the consensus of the committee that 6 to 10 additional wells, principally to test the deeper pre-Cretaceous rocks, would be required for a reasonable evaluation of the petroleum resources of NPR 4 and adjacent areas. (See fig. 101.)

The drilling program agreed on for 1953 would consist of 2 wells—1 on the Shaviovik anticline and 1 in the Brady area. It was expected that the Shaviovik test would not exceed 10,000 feet and the Brady, 7,000 feet.

One seismic crew was to operate for about 4½ months. It would do a limited amount of work on the Shaviovik and Brady anticlines prior to the drilling; run a seismic line from the Brady anticline to the East Carbon Creek anticline, and detail the latter anticline. If funds were available, a mobile crew would work on the Hawk and Aufeis anticlines.

Surface geologic work in 1953 would consist of 3 regular field parties—one to study the Brady area, the second to work in the Kuparuk-Aufeis area, and the third to investigate the Katakturuk area.

Photogeologic mapping was to be suspended on the North Grandstand and Big Bend anticlines. Previously authorized photogeologic mapping of the Killik, Big Bend, West Titaluk, and East Gregg anticlines would not be undertaken.

The Rex and Brady anticlines, the Kuparuk and Aufeis anticlines, and the Cape Lisburne area would be mapped photogeologically.

A possible program for 1954 was discussed in general terms. It was agreed that the previous estimate for funds for 1954 could not be reduced if the objective were to be attained. It was thought that, barring substantial discoveries, a program that would closeout in 1956 might permit the making of a reasonable evaluation of the petroleum potential.

CDR Albert J. Seeboth, CEC, USN, and OICC attended the 17th meeting of the advisory committee in Denver, Colo. To return to Fairbanks, he then boarded a MATS C124 on 22 November at McChord Air Force Base, Wash., but the aircraft did not arrive at Elmendorf AFB, Anchorage, and was later found to have crashed in the Chugach Range near Anchorage with all hands lost.

His place was taken by CDR R. C. Jensen, CEC, USN, who reported in Fairbanks on 16 December. Previously Commander Jensen was Assistant DNPR in charge of Pet 4; so he was intimately familiar with the operation.

On 14 November the CNO (Chief of Naval Operations), directed that all Naval activities provide Op 0303 (a new office of Polar Projects), with appropriate arctic information. On 26 November the DNPR sent a long memorandum to CNO, expressing satisfaction with the establishment of Op 0303, outlining Pet 4 and the type of arctic information that had resulted and stating his plan for supplying Op 0303 with appropriate data.

On 31 December the DNPR informed the CO, NPR 4 (Commanding Officer, Naval Petroleum Reserve No. 4) that discussions were planned in the near future with Congressional committees that might require the presentation of closeout alternatives. As of 31 December, however, there was no change in the budget for fiscal year 1954.

OPERATIONS

LAND TRANSPORTATION

The overland and overice tractor train freighting in the winter of 1951–52 was a normal operation that has been described for earlier years but was somewhat more effective than in the past because of increased general experience in the operation and the much greater individual experience of the crew members. The season started early—on 22 October 1951 and ended on 8 June 1952. As in the past few years, 4 regular sled trains were operated. In addition, 2 other trains made 1 trip each. In all 12,357 tons was hauled a total of 2,411,865 ton-miles. This was by far the greatest ton-mileage of any year of Pet 4 and was exceeded only during the following freighting season, 1952–53. The average direct cost for the whole freighting season was $0.29399 per ton-mile. There were 17 major hauling jobs ranging in mileage covered from 33 to 2,703 miles. Significantly, the range in direct ton-mile cost for all 17 projects ranged only between $0.29112 per ton-mile to $0.29484 per ton-mile.

Train 1 had no mechanical failures on any of its trips. It left Umiat on 22 October bound for East Titaluk, Square Lake, Titaluk No's. 1 and 2, and seismograph party 144 and returned to Umiat on 9 December. The train made another trip to Square Lake and returned to Umiat between 31 December and 13 January. It started for Barrow on 10 February and returned to Umiat on 19 February. It then serviced seismograph parties 144 and 145 until 19 March when it reached Barrow. The train then made two trips to Grandstand 1 and went to Umiat and cache 52 and returned to Barrow on 1 May. It made one more trip to Umiat and Topagoruk and back to Barrow and completed its season with a short trip to Skull Cliff and returned between 1 and 4 June.

Train 2 worked out of Barrow entirely. It went twice to Topagoruk, twice to Umiat, once each to seismograph party 145 and caches 50, 51, 53, 54, and 55, and twice to Grandstand 1. Its season started late on 27 January and ended at Barrow on 22 May. Train 2 had two mechanical failures—a broken water pump and a broken mainspring.

Train 3 operated from 2 February to 15 May between Barrow, Umiat, Grandstand, and some of the caches. It had no serious mechanical difficulties.

Train 4 began its season on 15 December 1951 and operated until 20 May. It operated out of Barrow to Kaolak and various caches. In mid-March it ran between Barrow and Topagoruk, to certain caches, to Umiat, and from Umiat to Wolf Creek and Square Lake. It ended its season at Umiat. Train 4 broke two tractor main springs and a tractor engine head.

Train 5 hauled between Barrow and East Oumalik from 24 April to 24 May. It broke down several times with a total of 8 days delay. Train 6 made one trip in May from Umiat to the mouth of the Etivluk River.

SEA TRANSPORTATION

This summary of Barex '52 is taken largely from the report on contract NOy–71333 dated 1 October 1952 by the OICC.

On the request of the DNPR to the CNO, the CNO on 20 December 1951 authorized Barex '52 and designated BuDocks to coordinate preliminary arrangements for the assembly and loading of cargo. BuDocks was required to determine cargo requirements by 1 February in order that ship requirements could be determined. BuDocks instructed all concerned agencies on 28 December 1951 to submit the necessary data.

By letter of 3 January, the CNO stated that the primary purpose of Barex '52 was the support of Pet 4 but that secondary purposes were the support of all U. S. Government activities in northern Alaska and the furthering of training in cold-weather operations. The CNO's letter assigned the planning and carrying out of Barex '52 to CINCPAC. CINCPAC was instructed to arrange with CINCAL for ice reconnaissance and other assistance; with COMWESTSEAFRON (Commander Western Sea Frontier) to coordinate preparation, assembly, and loading; and with BuDocks to continue liaison with other Government agencies in Washington, D. C., to ascertain final cargo requirements, including backhaul; to arrange details regarding packaging and shipment; and to keep appropriate commanders advised.

COMPHIBPAC on 21 January was designated by CINCPAC as his representative to conduct the expedition. COMPHIBPAC designated CAPT G. L. Heath, USN, as commander of Barex '52 to plan and carry out the operation.

On 6 February, the Chief, BuDocks reported that the total short tons to be shipped north was 23,936. The backload was estimated at 510 short tons. On 23 April representatives of all interested agencies convened at the Naval Amphibious Base at Coronado, Calif., to discuss the expedition. Among those present were representatives from BuDocks, the OICC, for contract NOy–71333, the ROICC, Seattle, the ROICC, Barrow, the Alaska Communications System, Port Directors from the ports concerned, the U. S. Signal Corps, and the U. S. Naval Advance Depot, Port Hueneme, Calif.

By that time BuDocks had issued instructions for packaging and marking of cargo and had designated the Naval Advance Base Depot, Port Hueneme, the Naval Supply Depot, Seattle, and the Naval Fuel Supply Depot, Point Molate, Calif., as loading ports. On 28 April COMWESTSEAFRON set the following deadlines: 15 May, submission of complete cargo lists; 15 June, placement of cargo ready for loading at Point Molate or Port Hueneme; 1 July, placement of cargo ready for loading at Seattle. Cargo not meeting the deadline dates would be accepted on a space-available basis.

Generally no special difficulty was encountered in procuring materials for Pet 4 by the deadlines set. A representative of Arcon had to be sent to Washington, D. C., in February to obtain a National Production Authority rating for the procurement of oil-field supplies. A steel strike prevented the delivery of casing before the sailing date of Barex '52. Some substitute casing was procured through efforts of the PAD (Petroleum Administration for Defense). Additional casing not meeting the specifications was located at Elk Hills; and, by rethreading 10,000 feet of casing, it was usable; nevertheless, it was necessary to ship it by truck from California to Seattle. Through contacts in industry, Arcon was also able to obtain some of the desired casing. Altogether, all but about 8,000 feet of the desired casing was shipped and even some of that deficit was made up by shipping some smaller casing that had been held in Seattle since Barex '51. Tractor spare parts were delivered too late to meet the deadlines. The parts were held at Seattle.

Materials were packaged so far as possible for easy handling at Barrow. Ammunition cans were used extensively for dry, loose, cargo. Cement was boxed at Port Hueneme. At Seattle, cargo was received by Arcon and packed and crated at the Naval Supply Depot.

The ships that made up the Barrow contingent included 1 icebreaker, AGB–1, the *Burton Island;* 4 LSM's, *175*, *268*, *419*, and *462;* 1 AL, the *Taluga;* 3 AKA's, the *Seminole* (flagship), the *Washburn*, and the *Andromeda;* 1 LST, the *1126*. The Barter Island contingent was made up of 2 LST's, the *1110* and the *1146*.

At Point Molate were loaded 15,001 short tons (16,950 measurement tons); at Port Hueneme 1,016 short tons (1,161 measurement tons); and at Seattle 4,963 short tons (6,809 measurement tons)—a total of 20,980 short tons (24,920 measurement tons).

The *Burton Island* was the first ship to arrive at Barrow, reaching there at 0730 on 26 July. Ice conditions were favorable before the arrival of the LSM's. They were off Barrow at 0130 on 3 August and left on 6 August. The LSM's made dry-ramp landings without difficulty. Limited headroom and lack of shipboard cranes made unloading difficult. Much cargo, such as railway ties, piling, and steel plates, were dragged off the ships with tractor towing winches.

The LST's reached Barrow with the LSM's. LST's *1110* and *1146* had to beach in order to load 373 tons of Marston matting for Barter Island. The LSM's and LST *1126* were completely unloaded by the time the AKA's arrived at Barrow. The *Taluga* arrived at 1200 on 3 August, and her diesel fuel, 46,623 barrels, was shuttled ashore by LST *1126* by 0600 on 6 August when the *Taluga* left.

The AKA's reached Barrow at 2100 on 4 August. All unloading was complete by 1400 on 6 August. To assist in the unloading operation, all available men were brought in from outlying camps bringing the camp complement during unloading up to 368 as compared with the 265 there before Barex arrived. About

450 tons of cargo was shipped from Barrow back to the States.

During Barex '52 the icepack remained 10 to 20 miles offshore, resulting in good ice conditions. The weather also was exceptionally fine, except for heavy fog at the start of the operation. During Barex '52 a PBY6A flew daily ice patrols. Before the PBY arrived, ice patrol was flown by two P2V's operating from Nome and Fairbanks. Short-range ice-reconnaissance flights were flown by two helicopters from the *Burton Island*.

The report of Barex '52 by the OICC for NOy 71333, contained several recommendations for future operations. Significant recommendations have been selected and are recorded below:

To permit greater flexibility in the movements of the advance contingent to meet changing ice conditions, it is recommended that a representative of Commander of Barex be ordered to Barrow in advance of the first ships' arrival and be authorized to direct ship movements into the area as local conditions warrant.

It is recommended that information on task group organization and movements be widely disseminated in advance of Expedition. This would enable ROICC, Point Barrow to intelligently schedule shifts in anticipation of ships' arrivals.

It is believed appropriate to revise the fundamental thinking behind the Barex operation. It appears that the primary mission of the expedition should be to supply the material to the Navy Camp, Barrow. This may be best accomplished by splitting up the expedition into several small groups which would depart from the States at widely spaced intervals. The entire project would permit unloading during regular camp work schedules with the personnel available and would avoid peak personnel loads with the attendant high costs.

It is recommended that load lists of individual vessels be forwarded to Point Barrow in advance of ships' arrival. This, too, would permit better distribution and utilization of unloading crews and equipment.

AIR TRANSPORTATION

As in the past, air support for Pet 4 in 1952 consisted of so-called linehaul flying of freight and passengers from Fairbanks to Barrow and Umiat and return and bush flying in and near the Reserve in support of all operations—supervision and administration, geological parties, geophysical parties, drilling, and other support operations. The linehaul flying was all with multiengine aircraft; and the bush flying, with both multiengine and single-engine aircraft, the multiengine accounting for somewhat more weight transported.

From 1 January through 30 June the air support was by Transocean Airlines under contract N406s–27086. From 1 July through the rest of the year, the flying was by Alaska Airlines under contract N406s–31650.

The following table indicates the extent of the total air support.

Amount of air freight transported during 1952

Month	Linehaul weight carried (pounds)	Multiengine bush plane (pounds)	Single-engine bush plane (pounds)	Total weight carried (pounds)
Transocean Airlines				
Jan	529,615	376,817	50,569	957,001
Feb	878,680	10,390	155,987	1,045,057
Mar	849,928		143,762	993,690
Apr	854,697		395,941	1,250,638
May	528,076	268,073	277,538	1,073,687
Jun	594,713	12,550	319,808	927,071
Alaska Airlines				
Jul	529,118	408,050	173,374	1,110,542
Aug	292,882	283,020	217,963	793,865
Sep	263,981	408,788	115,066	787,835
Oct	193,239	228,452	21,308	442,999
Nov	145,196	80,441	6,200	231,837
Dec	187,506	70,167	6,330	264,003
Total	5,846,631	2,146,748	1,884,846	9,878,225

The cost of the Transocean contract through June was $210,381 for linehaul flying and $150,851 for bush flying. The cost of the Alaska Airlines contract for the rest of the year was $203,915 for linehaul and $319,540 for bush flying.

CONSTRUCTION

It is evident by now that construction relative to Pet 4 was largely of semipermanent and temporary types. The semipermanent camps at Umiat and Barrow had facilities for housing, messing, recreation, manufacturing and overhaul equipment and buildings, bulk-fuel storage, heated storage, communications and power distribution, medical aid, sales store, outside warehousing yards, etc. Temporary construction in the field included everything required for oil exploration such as foundations, fabricated righouses, portable camps, and auxiliary portable structures for drilling and geophysical exploration.

By 1952 almost everything needed was at hand and available; so little new construction was required except that necessary to keep the program going. Existing facilities were ample to support all phases of Pet 4. Some expansion was required at the Umiat camp and was accomplished by new construction in 1952. A temporary canvas-covered shop was built in which sled-mounted drilling and geophysical equipment could be repaired. The shop was 32 by 90 feet and was supplemented by a lean-to 12 by 90 feet. The frame was wood, and the foundation of the main building was a gravel pad. A concrete slab was laid under the lean-to. The building was heated.

A canvas-covered oil-field warehouse was also built at Umiat. It was 40 feet wide and 100 feet long and was designed for the storage of muds, cements, and chemicals. Its foundation was a gravel pad, and the building was unheated. A smaller (20 by 48 feet)

parts warehouse of steel construction on timber sills was also built. It was heated.

Two airstrips were built in 1952 as adjuncts to the exploration activity. The Grandstand airfield was built in June on the gravel of the Chandler River near the Grandstand test site. It took 14 days to grade a 4,000-foot strip with one bulldozer and a scraper.

The Driftwood airfield was built in 6 days, also in June, with 2 D 9 tractors with hydraulic blades and one drag. It was 4,000 feet long and 120 feet wide and was on the gravel flood plain of the Utukok River at the mouth of Driftwood Creek. Both of the airfields were used by C46 planes.

MISCELLANEOUS SUPPORTING ACTIVITIES

During 1952 the various supporting activities for Pet 4 went on much as in earlier years. Communications were by the Alaska Communications System of the U. S. Army Signal Corps, the U. S. Air Force, Airways and Air Communications Service for Air Force use only, Civil Aeronautics Authority with funds made available by the Navy, and Arcon. The AACS also operated some navigational aids for Air Force use, and the CAA maintained airway facilities and navigational aids.

Arcon continued to supply food, housing, and special items of arctic clothing to the Pet 4 personnel. Dry cleaning and laundry facilities also were provided by Arcon. Recreational opportunities included a gymnasium, theater, and Armed Forces radio station.

Labor relations generally were good. There was no difficulty in 1952 in recruiting labor as required. The personnel obtained was satisfactory. The overall productivity of labor was estimated at about 60 percent of that in more temperate climates. The average number of employees during the year was 364, but the number at the end of March was 521; 1,178,550 man-hours was worked. Thirty-nine accidents resulted in the loss of 3,969 man-hours. The percentage of man-hours lost through accidents was 0.34.

The total cost of maintenance and operation of the Barrow camp in 1952 was $1,922,424. The following items are included:

Messing and billeting
Laundry and dry cleaning
Dispensary and first aid
Welfare and recreation
Camp transportation
Powerhouse operations
Boilerhouse operations
Electrical distribution
Camp heating
Camp water supply
Camp radio
Fabrication of pipe sleds and freighting sleds
Fabrication of miscellaneous appliances
Warehouses and outside storage areas
Fire protection
Maintenance and operation of gas system
Maintenance of camp buildings
Maintenance of roads and base area
Maintenance of airstrip
Airport operations
Repairs of nonmobile equipment
Rehabilitation of drill pipe
Dismantling of Gubik test 2
Dismantling of Topagoruk test 1
Dismantling of Oumalik test 1
Fabrication of wanigans
Depreciation of buildings
Depreciation of equipment
Overhead

On comparable bases, the operation of the Umiat camp cost $792,241 and of the Fairbanks headquarters, $105,180.

GEOLOGY

The principal geologic operations in 1952 were conducted by the Geological Survey. Arcon was called on to supply the necessary logistics support including transportation of the personnel, caching of supplies, maintenance of equipment for field parties, and essential base facilities.

A limited amount of field geology in special cases was done by the chief of exploration and assistant chief of exploration to expedite choice of drill sites and to obtain data for planning.

The following structural features were examined by Arcon in reconnaissance flights (see fig. 12): Umiat, Big Bend, Grandstand, Hawk, Shaviovik, Kemik, Kuparuk, West Big Bend, Kurupa, Rex, Brady, Meridian, Driftwood, Kokolik, Blizzard, West Carbon Creek, East Carbon Creek, Awuna, Knifeblade, Weasel Creek, and Wolf Creek. Reconnaissance checking on the ground was done at the Hawk, Grandstand, Driftwood, Blizzard, Brady, and Rex anticlines; and the Kokolik anticline was checked for closure by reconnaissance and by some detailed mapping.

A well geologist was assigned by Arcon continuously at each well, except Wolf Creek test well 3. Because Wolf Creek 3 was drilled near another test 1,500 feet deep, no geologist was stationed there until a depth of 1,400 feet was reached.

Office geologic work by Arcon was chiefly the preparation of reports and illustrations of the drilling results and the application of geological and geophysical data to the overall program. An important activity was the preparation of reports, maps, and proposed programs for the consideration of the executive operating committee and the advisory committee.

ORGANIZATION OF GEOLOGICAL SURVEY FOR PET 4

Geological Survey work for Pet 4 continued to be carried out through the Navy Oil Unit. The work was handled from a head office in Washington, D. C., and an office and laboratory in Fairbanks.

In the Washington, D. C., office, or operating from there in the field, were 19 full-time persons on Navy funds—16 geologists, 1 administrative assistant, and 2

clerks. The services of 5 additional geologists were used part time.

In the Fairbanks office were 3 full-time geologists, 3 disaggregators, 1 physical-science aide, and 1 clerk. One additional geologist was used part time. All Fairbanks personnel was supported by Navy funds.

WORK OF THE GEOLOGICAL SURVEY

The operations and plans of the Geological Survey were changed somewhat during the summer. Immediate exploration problems consumed more time than was anticipated and correspondingly less time was available for the compilation of final reports. Personnel changes and the change in emphasis from Cretaceous to pre-Cretaceous testing required some adjustment in the schedule of the Fairbanks laboratory.

The field program was completed about as planned. Airlift support and other logistic support were excellent. The late spring cut down the number of working days, but this was in part made up by good weather and good bush-plane support during the season. New weasels were used, and the need for parts, especially tracks, was greatly reduced. This in turn released plane time for other logistic support.

FIELD PROJECTS

The bulk of the field program consisted of three projects. Two of these were financed by the Navy, and one by the Geological Survey. They were in the Canning-Shaviovik area, the Chandler River area, and the eastern Brooks Range area.

In addition, spot jobs were completed in the Awuna River area, along the Utokok River in the vicinity of the Archimedes anticline, and near Wild Lake in the Brooks Range. Microfossil samples were collected in the Awuna and Utokok areas as part of the general problems of stratigraphic correlation and litholigic changes. Work in the Wild Lake area was part of the mapping project in the central Brooks Range that was begun in 1951.

CANNING-SHAVIOVIK PROJECT

Party 1 worked in the Canning-Shaviovik area. The party consisted of 6 men, including 2 geologists. It was led by A. Samuel Keller. The party moved with the use of 3 weasels, and the season was from 9 June to 22 August, when work was stopped by early snow. The party also worked an area a little farther south in the vicinity of Kemik Creek and including the Kemik anticline.

The primary objective of the project was to study the nature, extent, and petroleum possibilities of a structural high near the West Fork of the Shaviovik River and the Canning River. A secondary objective was to obtain information on the correlation of the rocks of upper Paleozoic and Mesozoic age between the West Fork of the Shaviovik and the area west of the Itkillik River.

The minimum closure on the Shaviovik anticline was estimated to be 900 feet. The depth to the Lisburne group of Mississippian age was calculated to be between 6,500 and 9,300 feet.

The Kemik anticline has a minimum closure of 500 feet in an area about 3½ miles long and ½ mile wide.

CHANDLER RIVER PROJECT

Approximately 2,500 square miles was studied geologically by party 2, which operated in an area from near the Chandler River eastward to the Anaktuvuk River. The area is in the northern foothills. Of the total area about 200 square miles was contoured structurally.

Party 2 led by R. L. Detterman and traveling in three weasels, included geologist R. S. Bickel and four other men. Work started on 9 June and continued until 27 August; 11 main camps and several additional camps were established.

The area includes the Hawk, Big Bend, and Grandstand anticlines, but only about 2 weeks at the end of the season were available for work on the Big Bend anticline. The main objective of the project was to test in the field the photogeologic structure-contour map prepared in the Washington, D. C., office by W. P. Brosgé and H. N. Reiser. The party was slowed somewhat by the unanticipated large amount of stratigraphic work required. The photogeologic maps were found to be accurate in areas uncomplicated by faulting and where there was good vertical control; they were less accurate in areas geologically more complicated.

The Hawk anticline has at least 1,000 feet of closure. The Grandstand anticline is complexly folded and faulted, and the maximum closure near the Chandler River is 300 feet. Grandstand test well 1 is on the north side of a thrust fault; the Big Bend anticline also is complex structurally. There appears to be a reversal of plunge on the Big Bend anticline east of the Chandler River resulting in a closure of between 200 and 500 feet.

EASTERN BROOKS RANGE PROJECT

Party 3, supported with Geological Survey funds, covered about 5,000 square miles in the eastern part of the Brooks Range from latitude 68°30′ N. to 69°20′ N. and between longitude 142° and 149° W. The party chief was W. P. Brosgé, assisted by Geologists J. T. Dutro, Jr., M. D. Mangus, and H. N. Reiser.

Base camps were on the upper Echooka River, Wahoo Lake, Porcupine Lake, Lakes Peters and Schrader, the

upper Sheenjek River, and Elusive Lake, all accessible by Norseman plane. All travel between field stations and camp was on foot.

On 11 June, four members of the party were landed on the ice at party 1's "Cache One Lake." Using party 1's weasel, the party moved on 13 June to the Echooka River, where it worked until late June. On 25 and 26 June, camp was moved by boat 6 miles downstream to a gravel bar large enough to accommodate a Norseman on wheels. On 27 and 28 June all of the personnel was returned to Umiat by plane.

On 2 July the party was flown by Norseman on floats to Wahoo Lake. On 12 July the party was shuttled to camp 3 at Porcupine Lake, where mapping was done and more sections measured.

Between 18 July and 4 August, work was done near Lake Schrader, where the party had been moved by float plane. Work extended to the south end of Lake Peters. On 5 August a move was made by float plane across the Brooks Range divide to Star Lake on the Sheenjek drainage where a connection was made to the work in the 1920's by the Geological Survey. On 9 August, Mangus and Dutro made a boat traverse down the Sheenjek about 17 miles to the mouth of Old Woman Creek. On 15 August some of the group were flown to camp 5A at a larger lake. By 21 August all members of the party had been returned to Umiat.

Party 3 was in the field 71 days; 31 were spent in actual fieldwork, and the rest were taken up by moving, bad weather, and waiting for planes.

SPECIAL STUDIES

The special studies program included the full-time efforts of several specialists and the part-time work of several others. The studies included both current exploration problems and background and interpretive investigations.

Paleontology.—Many of the specialists of the Survey's Branch of Paleontology and Stratigraphy worked on the numerous and difficult problems of the age and relations of the rocks of northern Alaska; some of them known only from deep drilling. In addition two full-time micropaleontologists—Harlan R. Bergquist and Helen T. Loeblich—worked on the Pet 4 program.

Photogeology.—By the end of 1952, compilation of photogeologic maps of northern Alaska on a scale of 1:250,000 was well advanced. The coastal-plain areas were not covered by these maps, but virtually all the foothills area was as far east as longitude 147° W. In addition, structure-contour maps had been made by photogeologic methods of many of the principal anticlines. In the latter part of the year, such structure-contour maps were nearly completed of the Awuna, Discovery, and Kurupa anticlines. For those maps the planimetric bases, with many elevations noted, were prepared by the Special Maps Branch of the Topographic Division of the Geological Survey. The photogeologic work was under the direction of William A. Fischer.

Stratigraphic zonation.—During the year George Gryc reviewed earlier geologic work and at the fall meeting of the advisory committee presented a report on Cretaceous stratigraphic zonation and correlation problems in Pet 4 and surrounding areas. He carefully traced the history of the studies that had led to the interpretation at the time of the meeting of the correlation of the Cretaceous sedimentary rocks over the Arctic slope and outlined some of the problems that still remained.

Fairbanks laboratory.—The Fairbanks laboratory continued throughout the year to process cores and cuttings from the drilling, as well as surface samples collected by the field geologists. A continuing important activity was the micropaleontologic studies that went on in the Fairbanks laboratory.

In June the chief of the laboratory, Thomas G. Roberts, transferred to an assignment in the States. From then until 6 October Harlan R. Bergquist acted as chief of the laboratory, and from 6 October until late in the year, Robert M. Chapman acted as chief. Near the end of 1952, Arthur L. Bowsher was placed in charge of the laboratory.

GEOPHYSICS

Three seismograph parties of the United Geophysical Co. operated in the field from approximately the first of March until the end of July (See pl. 3.) Thus 15 crew-months of work were done. The work was in charge of Walter R. Fillipone, geophysical supervisor, from whose report most of this section is condensed. The seismic work in 1952 was in areas somewhat more complex geologically than areas of previous seismic surveys. In general, the results were of the kind expected and were useful in making appraisals of petroleum possibilities. The principal accomplishment was the extension of the generalized subsurface picture southward from the latitude of Umiat to the north front of the Brooks Range.

In the Castle Mountain area and northward to Umiat are complex thrust faults overlain by shallow folds. Work was done in that area by party 144, led by E. J. Munns. The party completed several seismic profiles over the Ayiyak anticlinorium in the vicinity of the Ayiyak River in an attempt to determine its structure and as a test of the effectiveness of seismic surveys in such a complex area.

The work yielded insufficient data to explain the contrast between the gentle structural features north of

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Tuktu Bluff and the complex folding and faulting south of there. At the Schrader anticline 400 feet of east plunge was mapped on the east side of the Chandler River. High water prevented the crossing of the river to determine whether or not there is west plunge. From the Schrader anticline, a tie line was carried on northward to the survey line of party 145, coming southeast from Umiat. Party 144 also did some refraction shooting on a line east of the Chandler River opposite the Hawk anticline.

Party 145 was led by W. S. Howard. The party worked eastward from Umiat along the general Umiat structural trend. The tie to the Umiat anticline was not good because of the difficulty of drilling shotholes through the gravel deposits on extensive terraces southeast of the Colville River. Nevertheless, the survey east from Umiat established 2,000 feet of east plunge on the Umiat anticline.

About 40 miles east of Umiat was found a closure of 500–700 feet. This closure, from surface geology, seems to be separate from the Kuparuk anticline but on the same trend, and both are on the same trend as the Umiat anticline. The western part of the Kuparuk anticline was also surveyed by reflection seismology, and the anticline appeared fairly complex and somewhat faulted. In this eastern area no velocities were found to indicate pre-Cretaceous rocks at a depth less than 14,500 feet below sea level.

Party 146 was headed by G. C. Donahue. The party worked far to the west in the general longitude of the Utukok River. A seismic profile line was run from the Kaolak area to the Carbon Creek area, a line across the Carbon Creek anticline, a line from the Archimedes Ridge anticline to the Driftwood anticline, and several short detail lines on the Driftwood anticline.

Between Kaolak and Carbon Creek were found several important anticlines. One has 1,500 feet of reversal over a distance of 12 miles; another has approximately 1,100 feet of reversal. The Elusive Creek anticline as defined by surface geology is represented by a reversal of 300 feet. Over part of the distance from Kaolak to Carbon Creek, the data were poor and discordant.

Between Carbon Creek and Driftwood is a complex area of thrust faults. Surface anticlines are the result of the thrust faulting and do not persist in depth. The Driftwood anticline was surveyed in some detail revealing that the anticline is underlain by a large thrust fault corresponding to the surface axis. Attempts to determine the depths to high-velocity beds by refraction methods failed.

It was necessary to use all available information on the stratigraphic section to interpret the area from Carbon Creek to Driftwood. This was largely because of the impossibility of correlating seismically across the large thrust faults. More data are needed for a complete seismic interpretation.

DRILLING

During 1952 efforts were made to improve coring and testing techniques. Experience had shown that some of the sands lost some of their permeability on contact with water from the drilling fluid, presumably from the swelling of some of the clay minerals and by freezing of moisture in pore space in the permafrost zone.

A total of 15,142 feet of hole was drilled in 1952 at 5 rig sites. (See pl. 3.) The Avak test well 1 on the so-called Barrow high was described in the section on Drilling for 1951. The hole was started in October 1951 and was abandoned on 14 January 1952. Umiat test well 9 was also described in the section on 1951 although testing of the well was going on at the start of 1952. Testing continued until 13 January 1952 when orders were received to abandon. It was still undetermined why production shut off by casing the well could not be restored by perforating the casing. Similarly Umiat test well 10 was drilled to completion depth of 1,573 feet in 1951. The first week of 1952 was spent in cleaning out the hole, which caved continually, to a depth of 1,520 feet. The intention was to deepen the hole later with a Failing rig, but orders were received on 8 January to abandon the hole immediately.

The remaining holes described below were all started in 1952.

SQUARE LAKE TEST WELL 1

Square Lake test well 1 is approximately at latitude 69°34′, longitude 153°18′ on the Square Lake anticline. The well was drilled with the Cardwell No. 2 rig. The objectives were to test at all horizons to approximately 4,000 feet from the surface. The well was started on 26 January 1952 and was completed on 18 April at a total depth of 3,987 feet.

Gas was found between 1,640 and 1,675 feet. A short test of this zone indicated a gas yield of 112,000 cubic feet a day. The electric log showed the top of the sand to be at 1,660 feet and the base, at 1,692 feet, with the contact of gas and water at 1,675 feet. According to the seismograph map, 1,600 acres has 32 feet of sand in the gas zone, and 900 acres has an average of 24 feet of sand in the gas zone. The volume of recoverable gas is estimated at 12.8 to 21.4 billion cubic feet.

Another gas-bearing zone was found a little below 1,800 feet. The electric log indicated the sand to lie

between 1,835 and 1,880 feet and the contact of the gas and water to be at about 1,860 feet. The shut-in pressure was 800 pounds per square inch. A drill-stem test revealed a strong flow of gas estimated to be at the rate of 1 to 3 million cubic feet per day. From the seismograph map, about 1,600 acres has 45 feet of sand in the gas zone and 900 acres an average of 33 feet of sand in the gas zone. Recoverable gas is estimated at 22.2 to 37.0 billion cubic feet.

Before the hole was abandoned, a thermistor cable was set at from 200 to 540 feet.

GRANDSTAND TEST WELL 1

Grandstand test well 1 was started on 1 May about 31 miles south of Umiat on the west bank of the Chandler River where it crosses the axis of the Grandstand anticline. The hole was completed on 8 August at a depth of 3,939 feet. The well was drilled with the Cardwell No. 1 rig.

The five principal objectives of the hole were—

1. To discover oil and gas in sands in the lower part of the Nanushuk group.
2. To determine the reservoir characteristics of the sands and the presence of shale layers that would constitute cap rocks over any such sands.
3. To gain information on the lateral extent of sands found at Umiat and in outcrops in order to evaluate better the possibilities of other structural features in the vicinity.
4. To determine more definitely the thickness of the lower part of the Nanushuk group and the relation of the thickness to drilling depths on other structural features.
5. To obtain additional paleontological data for use in correlations.

No permeable sand was detected in the hole, and the base of the Nanushuk group was not reached. High-pressure gas in small volume was noted repeatedly from the surface to the bottom, especially in fractured shale at about 3,900 feet.

The objectives of the test were only partly realized:

1. No oil or gas was discovered. The sandy section as known from outcrops to the south is dominantly shaly at Grandstand.
2. The reservoir characteristics of the few sands found were very poor; permeability was very low.
3. Stratigraphic relations were clarified.
4. The drilling did not establish the thickness of the Nanushuk group.
5. Useful paleontological data were obtained.
6. The estimated depth of 2,000 feet to the top of a thick shale sequence was found to be far too little. Actually it was proved that the depth is in excess of 4,000 feet.

The lack of permeable sand to the depth drilled at Grandstand reduced the attractiveness of the Big Bend and West Big Bed anticlines to the north and northwest, but did not affect the possibilities of the Hawk anticline to the southwest. Unusually steep dips, up to 35°, found in the lower part of the hole indicated the possibility that the drill went through a fault at somewhere below 3,500 feet.

UMIAT TEST WELL 11

Umiat test well 11 was designed to determine whether or not production was obtained from the Umiat anticline from the north side of the axial fault, to test the possibilities of sands younger than the producible sands on the south flank, and to yield information on the size of any producible area north of the fault. The test was on the north flank not far from Umiat test well 8. The test was drilled with the Cardwell rotary rig No. 3. It was spudded in on 3 June and completed and abandoned at 3,303 feet on 29 August.

At 804 feet, free oil appeared in the ditch, but a drill-stem test failed to recover any oil. A slight showing of gas was observed in the ditch at 2,081 feet and in a sand core from 2,069 to 2,077 feet. A 3-inch core section at 2,128 feet bled a little oil, and the section from 2,128 to 2,131 feet fluoresced. A sand core from 2,444 to 2,448 feet had an odor of oil and gave a cut with solvents, and the same was true of a core from 2,833 to 2,837 feet. None of the tests indicated any possibility of oil or gas production.

WOLF CREEK TEST WELL 3

Wolf Creek test well 3 was drilled with the Cardwell rotary rig No. 2. The hole was spudded in on 20 August and completed at a depth of 3,760 feet on 3 November. The location is 485 feet west of Wolf Creek test well 1. The objectives of Wolf Creek test well 3 were to test the oil and gas possibilities of any sands below the 1,500-foot gas sand of Wolf Creek test well 1, to throw further light on facies changes as they might influence petroleum possibilities of adjacent areas, and to correlate the stratigraphy with that in neighboring areas.

Using solvents some cuts were obtained from sand cores at several depths. Cores from 2,585; 2,602; 2,645; and 2,660 feet bled a little oil, but permeabilities were too low for production. Small volumes of gas were found at intervals.

Six sandy zones were penetrated in the upper 600 feet of the test well. Wolf Creek test well 3 provided a good set of samples and a good electric log.

SUPPORTED ACTIVITIES

In 1952 Pet 4 continued to provide various forms of support to a wide variety of outside activities, some of which were related to Pet 4 in one way or another, such as those for the CAA and the Coast and Geodetic Survey, and others that had no relation to Pet 4 except to use the facilities there.

Taken together, such partly related and unrelated activities included the following: The Alaska Communications System, U. S. Army; the Airways and Air Communications Service, U. S. Air Force; the Arctic Research Laboratory, Office of Naval Research; the Civil Aeronautics Administration; the National Bureau of Standards; the Geological Survey; Transocean and Alaska Airlines; the U. S. Coast and Geodetic Survey; the U. S. Weather Bureau; the 1150th Field Detachment, U. S. Air Force; the Arctic Test Station, Bureau of Yards and Docks, U. S. Navy; the Optical Research Laboratory, U. S. Air Force; and Project Lincoln operated under contract with the Navy by the Massachusetts Institute of Technology.

The types of facilities afforded by Arcon to such activities included one or more, in some instances all of the following:

1. Messing and billeting.
2. Laundry and dry cleaning.
3. The provision and maintenance of equipment and vehicles at Barrow and Umiat and in the field.
4. The handling and storage of cargo shipped to and from Pet 4 by airlift and Barex.
5. Sales store participation.
6. Winter freighting.
7. Provision, operation, and maintenance of portable camp facilities.
8. The provision of equipment, parts, and maintenance personnel for field parties.

The principal support load imposed by these outside activities was in the summer. In total, the number of persons supported ranged from about 80 in the winter to as many as 190 in July.

The activities related to the exploration effort made a wide range of important contributions to Pet 4. Others, although important to the Government, were a hindrance to the effective prosecution of the oil exploration program and increased the operational and overhead expense greatly beyond the requirements of Pet 4 itself.

Typical of expressions of appreciation and also of some of the responsibilities occasioned by assistance to such activities is illustrated by the following memorandum to the DNPR from the Navy Representative of Project Lincoln, dated 5 December:

1. Project Lincoln is a joint Army-Navy-Air Force research and development project operated under a contract by Massachusetts Institute of Technology for the purpose of improving the air defense of continental United States. One of the numerous phases included in this program is the development and engineering of a network of warning sites in far northern latitudes.

2. Mr. M. M. Hubbard, Assistant Director, recently returned from one of his trips to Alaska and sent us Enclosure (1) which we wish to forward to you for your information. In planning establishment of sites in the far North we feel that the extensive experience your organization has had would be most helpful to us. At present, we would like information on the following questions:

a. The annual operating cost of Pet 4 for Fairbanks, Umiat, Point Barrow and others.

b. The number of survey and drill parties that can be supported by Point Barrow; i. e., the total men in the field.

c. Total annual tonnage of Barex.

d. Any available construction capacity that we might use from the Arctic Contractors, Inc.

3. We appreciate the cooperation the Naval Petroleum Research organization has given Project Lincoln.

A copy of Enclosure (1) follows:

During my recent trip for Lincoln Laboratory to Fairbanks and Point Barrow I received very material assistance from Naval Personnel and contractors connected with Naval Petroleum Reserve No. 4 (Pet 4). Lt. Johnson, acting OICC at Fairbanks was most cooperative and helpful as indeed were Lt. Daniels, ROICC (Resident Officer in Charge of Construction) at Point Barrow, and Mr. Larson, the superintendent for Arctic Contractors. I might say that the capability of this establishment was very impressive. I should also like to point out that Dr. Wiggins' staff of the Arctic Research Laboratory and his assitant, Mr. Johnson, were most helpful and rendered much assistance, making a great difference in the success of our operations.

I have singled out a few individuals who were my principal contact. I would like to say, however, that all the personnel connected with Pet 4, ARCON, and ARL were most friendly and sympathetic in giving our group much more than perfunctory assistance. I feel that the whole organization is a very capable and useful one.

The services rendered to Mr. Hubbard won for the Naval staff and Arcon the official commendation of the DNPR.

SUMMARY OF 1952

Contract NOy–13360 was terminated on 31 December 1951 and was immediately resumed under contract NOy–71333 on 1 January 1952. The operating plan for 1952 was confirmed by the advisory committee in November 1951 and was carried out with some minor and one major change. The plan visualized the drilling of 5 wells, 15 crew months of seismic fieldwork, and the use of 3 geological field parties. The major deviation from the plan was that only 4 wells were drilled instead of 5. The reduction in drilling was to conserve fuel for the drilling of 2 deep tests planned for 1953.

In 1952 the high point of employment was 534 in April, and the low was 251 in November. Only 0.34 percent of the man-hours was lost because of accidents.

One fatality occurred when a workman fell from a moving truck.

A successful Barex reached Pet 4 in 11 ships. In all, 20,980 tons was unloaded on the Barrow beach, and an additional 827 tons was loaded at Barrow for delivery elsewhere. Winter freighting aggregated 2,411,865 ton-miles at a cost of $709,000—not including overhead or a direct cost per ton-mile of a little more than $0.29. A total of 15,142 feet of hole was drilled.

A large number of outside operations were supported in a variety of ways as in earlier years. The air-support contract was changed at the end of June from Transocean Airlines to Alaska Airlines. The total weight lifted by air, including both linehaul from Fairbanks to Umiat and Barrow, and bush flying, was 9,878,225 pounds, including passenger weights.

It was decided that in 1953 emphasis would be placed on pre-Cretaceous tests at localities that generally are much more remote and farther south and east than in the past.

THE LAST YEAR—1953

ADMINISTRATION

Pet 4 moved into 1953 with expectation that the project would continue for several years until its full objective had been accomplished. It had been long recognized that a change in policy might result in the sudden cessation of Pet 4 and substantial preparation for such a situation had been made. An example of the recognition of the possibility of a more or less abrupt closeout order was a request by the DNPR for closeout estimates that was made on 31 December 1952. On 29 January 1953 rather detailed closeout estimates on several postulated bases were made by Arcon and submitted to the DNPR by CDR Jensen, the commanding officer for Pet 4 in Fairbanks.

Nevertheless, the year started with plans, preparations, procurement, and financing for a full year of activity.

On 6 March a hearing was held before the Committee on Armed Services of the House of Representatives, and one of the items considered was Pet 4. At that hearing the SecNav suggested the closure of Pet 4 in an expeditious but orderly manner. This was concurred in by the committee. The committee had considered testimony and opinions of informed experts. Captain Meade, the DNPR, gave a brief but comprehensive summary of Pet 4 and submitted a statement on his own behalf and another prepared by Dr. W. E. Wrather, the Director of the Geological Survey.

On 6 March the closeout was announced. The Chief of BuDocks and the commanding officer, NPR No. 4, were informed by the following memorandum of that date from the DNPR:

1. At a hearing before the House Committee on Armed Services today the Secretary of the Navy stated his intention to cease the exploration program in Naval Petroleum Reserve No. 4. This intention was concurred in by the Committee.

2. You are therefore requested to conserve expenditures in connection with that project to the minimum consistant with a cessation of the program and to avoid obligation of any funds for the purpose of continued exploration.

3. There is a definite commitment not to drill any more wells. However, the close-out is to proceed in an orderly manner, and an informal meeting of the Advisory Committee is to be convened in the immediate future to formulate a course of action in that regard. Included in that course will be a determination as to what geophysical and geological work should be performed with funds already available. There will be no funds requested for the program in the fiscal year 1954 budget. In addition, it is expected that a substantial amount of the money already made available by prior appropriations can be returned to the treasury.

As the year started and as agreed at the advisory committee meeting in November 1952, the program in 1953 was to include—

1. The drilling of Shaviovik test well 1 to 10,000 feet.

2. The drilling of Brady test well 1 to 7,000 feet.

3. Four and one-half party-months of seismic work with the possibility of doubling the amount of seismic work if more funds became available.

4. Geologic work to the total of 12 party months' work by 3 field parties in the Brady, Aufeis, East Kuparuk, and Katakturuk areas.

At the first of the year there were 200 Arcon employees at Barrow, 30 at Umiat, and 11 at various places in the field. Other than the Arcon personnel, there were 64 persons at Barrow including 7 dependents, 6 at Umiat, and 2 in the field.

On 13 January a fire broke out in the large warehouse and garage in the Navy compound at Fairbanks. The fire was put out, and the loss was trivial. A more serious fire occurred on 8 February when the heavy-duty-equipment shop at Umiat was completely destroyed. In addition to the loss of the shop facilities, 4 tractors, 1 cherrypicker, and 2 weasels were destroyed. The commanding officer of Pet 4 immediately appointed an investigation board to study the circumstances that resulted in the fire. The total estimated loss was approximately $40,000.

On 28 January A. J. Armell, technical advisor to the OICC, terminated his employment.

On the receipt of the closeout order, the whole aspect of Pet 4 changed rapidly. On 9 March the OICC formally notified Arcon of the closeout order. The contractor was directed to cease all work preparatory to drilling and to cancel all subcontracts and rental agreements relative to drilling. Arcon was also

directed to review the personnel with a view to making reductions consistent with an orderly closeout.

On 10 March the DNPR requested the SecNav to notify the National Security Council of the decision to suspend Pet 4, and on 16 March the SecNav requested the SecDef to notify the National Security Council. On 11 March the DNPR met with representatives of the advisory committee in Washington, D. C. In attendance were the DNPR; CDR M. V. Carson, the Deputy DNPR; CDR M. H. Aubey of BuDocks; John C. Reed and George Gryc, of the Geological Survey; and J. W. Watson, of DeGolyer and MacNaughton. At that meeting it was agreed that—

1. A drilling rig, pipe, casing, cement, mud, and machine-shop items necessary to support a deep test would be placed in storage at Barrow for use in the event that the Navy might at some future time wish to drill such a test.

2. Other items, subject to a conference to be held on 16 March with interested Federal agencies, that could be economically salvaged would be returned to the States on Barex '53. A tentative limit of 60,000 tons was set for such material. Any items desired by any Federal agency would be left at Barrow or elsewhere in Pet 4.

3. A mobile geological field party would be used in the summer of 1953 to check several structural features to obtain information necessary for the final report.

4. Two and one-half years would be needed for the Geological Survey to complete its reports, as estimated by Mr. Gryc.

5. The Fairbanks laboratory of the Survey would close sometime in July 1953.

6. Cores and cuttings would be classified and stored at Fairbanks for future reference.

7. The seismic party at Shaviovik would continue until a satisfactory interpretation of the anticline was obtained, but in any event the party would discontinue in time to return with its equipment and vehicles before terrain and weather conditions forced abandonment in the field.

8. The funds required by the Geological Survey by transfer from the Navy would total $575,000 and the work would extend through calendar year 1955.

9. Necessary instructions would be given by BuDocks to the OICC, contract NOy–71333 and that Mr. Reed would inform the Geological Survey of the foregoing.

One day earlier, on 9 March, the OICC met in Fairbanks with the project manager of Arcon; the AOICC; the Navy auditor; the ROICC, Barrow; and Arcon's general superintendent. The following is briefed from the record of that meeting:

A. After general discussion of procedures to be followed in effecting an orderly closeout, the following determinations were made as to specific actions to be placed in immediate effect:
   1. Tractor train to be routed to Brady location for purpose of moving material to safe location on site and to pick up for return to Barrow items of equipment and selected materials. Such materials as lumber, drilling, mud, chemicals, cement, and fuel will remain at location.
   2. Mr. Dalton, general superintendent, charged with responsibility of reviewing tractor-train load lists with view of selecting materials and equipment to be returned to Barrow.
   3. Decision to route tractor trains to Shaviovik for purpose of returning selected materials and equipment in same manner as from Brady.
   4. Inventory of materials at Topagoruk to be reviewed with view of selecting items for return to Barrow.
   5. Any materials or equipment at Grandstand, Wolf Creek, or other drilling camp locations to be abandoned.
   6. With regard to the Umiat camp:
      a. Complete inventory to be made.
      b. All oil-field material (other than mud, chemicals, and cement) and equipment with exception of those items used in connection with cable-tool rigs to be returned to Barrow.
   7. General superintendent and ROICC to furnish estimate of date of completion of freighting program not later than 13 March.
   8. Imperative that complete and accurate inventories be prepared of all materials and equipment abandoned at field locations.
   9. Every effort in Barrow to be pointed toward early completion of work. Estimated date of completion of all fieldwork is 1 October. The estimated date should be shaded if at all possible. Materials returned from field to be returned to inventory stocks; warehouses to be prepared for physical inventory. All inventories to be reviewed with view of recommending materials to be returned to the United States.

B. The OICC indicated the possible desire of BuDocks to complete winter freighting to Shaviovik with view of establishing complete cache with thought that drilling might be started at some future date. OICC recommended against this procedure and suggested that materials and equipment be stored at Barrow. BuDocks concurred with OICC recommendation.

C. Subject to approval of ROICC, Arcon was charged with routing of freight trains to complete expeditiously remaining program. Total scope of remaining freighting would probably include 2 trains from Brady, 2 trains from Shaviovik, and possibly 1 train from Umiat.

D. Considerable discussion ensued regarding relative merits of returning oil-field equipment and materials to the States as against leaving in Barrow. Project manager pointed out that if drilling is not resumed within 5 years all equipment would be obsolete and therefore more economical to return at this time. Decision must await further instructions from BuDocks.

E. The OICC advised that the Air Force had been contacted about taking over of all equipment in the field and facilities. General Smith, of Ladd AFB (Air Force Base), had advised OICC of Air Force interest and lists of equipment have been furnished to Air Force for review. Complete equipment lists are being assembled for transmittal to Com 17 for information.

F. It was the consensus that equipment and tools would be valuable in the United States for defense work. OICC recommended that minimum shop facilities be left in Barrow if the facility is transferred to the Air Force or other Government activity.

G. The OICC charged Arcon with proper packing of items to be returned to the United States.

H. The ROICC indicated the required changes in type of complement in Barrow camp. Some shops will be closed, others will operate on a reduced scale, but increases will be needed in certain classes of personnel, especially carpenters and typists. Arcon advised that an immediate reduction would be made in the machine and welding shops to about two men and that there would be a reduction in the heavy-duty-equipment shop.

I. Arcon is to submit a new cost estimate in order that financial statements may be prepared for OICC and DNPR.

On 13 March the DNPR, who was in Washington, D. C., at the time, notified his Denver office of the likelihood that substantial assistance under contract NOy-71333 would be required by the Air Force. He stated that any extra cost would of necessity be borne by the Air Force.

A meeting was called by the DNPR in Washington, D. C., on 16 March to discuss the requirements of Federal agencies for supplies, materials, and equipment that would be available because of the closeout of Pet 4. At the meeting were representatives of the ONPR, the CNO, the USAF, Army Signal Corps, BuDocks, Arcon, Coast and Geodetic Survey, Geological Survey, Weather Bureau, CAA, Bureau of Indian Affairs, Bureau of Standards, ONR, and Navy Office of Budget and Reports. Only a little interest was indicated in some of the materials to be available.

In the early spring, negotiations were started for the transfer of the whole Umiat facility to the Air Force. After considerable correspondence this transfer was effected on a temporary basis as is indicated by memorandum dated 6 July from the commanding officer, NPR No. 4, to the commander, 11th Air Division (Defense), Ladd Air Force Base, as follows:

> 1. In accordance with authority granted * * *, permission is hereby granted for the U. S. Air Force to enter, occupy and operate certain facilities and improvements comprising a Navy-owned camp located at Umiat, Alaska in Naval Petroleum Reserve No. 4.
>
> 2. This right of entry is issued on a temporary basis pending a formal permit of occupancy and transfer of facilities, which will be issued by the Bureau of Yards and Docks, Navy Department when all arrangements have been made firm.

A long series of negotiations between the Department of the Interior and the Navy Department culminated on 5 January for the turning over to the Geological Survey of the Fairbanks housing, offices, warehouse, and appurtenant facilities as they were vacated by the Navy and Arcon. This arrangement was cleared with the Alaska Railroad because that agency controls the land on which the facility is established. The Navy withheld a small part of the facility for the continuing use of the new inspector for NPR 4. The transfer was finally completed on 31 December.

Authority was received from the Office of Naval Material to transfer materials, supplies, and equipment to Federal agencies, giving priority to the military establishments, without the necessity of formal screening of such supplies as outlined in Navy Property Redistribution and Disposal Regulation No. 1. On 30 March the OICC promulgated a multiple addressee letter advising activities of the availability of NPR 4 inventories for transfer without exchange of funds. Upon receipt of requests for transfers of the inventories, the OICC on 7 May established a priority list which governed the allocation of supplies to requesting activities. Arcon, upon receipt of specific instructions from the ROICC at Barrow, proceeded with the transfer of inventories.

On 19 March Tony Schwamm, Director of the Alaska Department of Aviation, and Dick Webb, of Wien Alaska Airlines, called on the OICC about the construction of an airstrip at Barrow village. On the same day R. B. Merridity and J. E. Hamilton, of Drake-Puget Sound Co., and V. B. Bagnall, of the Western Electric Co., discussed with the OICC the possibility of using

Navy equipment and personnel in support of their Air Force project in Arctic Alaska.

The ROICC at Barrow sent a memorandum on 2 April to AACS, the ARL, the CAA, the Ionosphere Detachment of the ACS, the Bureau of Standards, and the Coast and Geodetic Survey, all at Barrow, to the effect that support of tenant activities at Barrow would be continued only until 15 September and giving specific instructions about the relation of the closeout of Pet 4 to such activities.

On 13 May an Arcon letter of 29 April, and enclosures, setting forth closeout recommendations in great detail, was approved with a few modifications by the OICC.

LCDR Donald G. Storey, CEC, USN, reported to the OICC in Fairbanks on 19 April to relieve LT John M. Daniels, ROICC, Barrow. Lieutenant Daniels, however, was not relieved until 7 May. LCDR N. M. Jackson, CEC, USN, was detached as ROICC, Seattle, on 1 May.

On 1 June the SecNav instructed the DNPR to make tentative arrangements for an inspection party to visit Barrow and Pet 4 at his invitation to review closeout plans. A memorandum to the SecNav from the DNPR dated 11 June informed the Secretary that tentative plans had been made. Plans developed rapidly for the inspection that was to be led by LT GEN E. O. Thompson of the Texas Railroad Commission. Other members of the inspection party were W. E. Wrather, Director, Geological Survey; J. S. Abercrombie, Robert Abercrombie, William A. Smith, Wesley West, George R. Brown, RADM John R. Perry, and the DNPR. Gordon Edwards and Julius Gordon accompanied the party, and the group was guided from Fairbanks through Pet 4 and back to Fairbanks by the OICC.

A special Navy plane left Washington, D. C., with members of the party on 30 June and proceeded to Austin, Tex., where other members boarded. On 1 July the party proceeded to Denver and there was fully briefed on Pet 4 and the inspection. On 2 July the flight was made to Fairbanks. The party was at Barrow on 3 and 4 July and made a thorough investigation. The plane reached Austin on the return trip on 5 July.

Lieutenant General Thompson's report to the SecNav was dated 8 July. The inspection party concurred fully in the decision to recess the exploration.

In view of the recessing of Pet 4, the ONR was faced with a decision as to whether or not to close the ARL. At the request of the CNR another inspection party was sent to the ARL to review its work and plans and to advise on the above decision. The party consisted of John Field (chairman) University of California at Los Angeles; RADM E. H. Smith, USCG (retired), director, Woods Hole Oceanographic Institution; John C. Reed, Geological Survey; J. Glenn Dyer, U. S. Weather Bureau; Earl G. Droessler, Department of Defense; COL A. E. Krieger, Jr., USAF; LT COL A. I. Karstens, USAF; LT COL G. P. Jones, USAF; CAPT Roy Hanson, USAF; James E. Gillis, Jr., SIPRE; Keith Boyd, SIPRE; Evelyn L. Pruitt, ONR; F. H. Quimby, ONR; George Sprugel, ONR; Norman A. Maier, ONR; W. B. Girkin, ONR; and LT J. St. M. Bates, USN, ONR.

Some of the party left Washington, D. C., in a special Navy plane on 29 June. Additional members of the inspection group were picked up in Seattle, and on 30 June the plane reached Fairbanks. The next day was spent in Fairbanks; on 2 July the party went to Barrow. Thus, parts of the 2 inspection groups were in Barrow at the same time. The ONR party strongly recommended to the CNR that the ARL be continued because of the need for arctic research in spite of anticipated higher operating costs. This recommendation was accepted, and the ARL was continued after the end of Pet 4.

On 15 July C. L. Mohr, Arcon chief of exploration, terminated his appointment as part of Pet 4. James W. Dalton, Arcon general superintendent at Barrow remained until 7 October; and Ralph Coleman, project manager, until 31 October.

A small caretaker staff was employed to carry on custodial functions at Barrow after the close of Pet 4. The camp at Barrow was closed on 1 October, but the ARL and necessary appurtenant facilities had been turned over to the ONR. The airfield was relinquished to the CAA which thereafter continued its operation by a contract with Wien Alaska Airlines. Office work in connection with completion of reports continued until 12 December. On that date the last Arcon employee was terminated. The final completion report was submitted to BuDocks on 10 December and was accepted on 23 December. On 26 October CDR R. C. Jensen, the last OICC was detached. Subsequently the Navy office for Pet 4 in Fairbanks was under an inspector for NPR 4 who was CDR D. G. Storey, previously the ROICC at Barrow.

The average number of Arcon employees from January to October was 166. During that time 738 man-hours was lost through accidents from a total of 457,590 man-hours worked. At the close of Pet 4 the efficiency of the labor used was judged satisfactory. Contract NOy–71333 was staffed with a large carryover force from contract NOy–13360, and many of the less desirable workers had already been weeded out. The OICC reported that relations with Arcon had been satisfactory.

Transfer of inventories to other Federal agencies totaled $5,311,732, of which $4,007,932 worth was transferred to the Air Force. Residual inventories valued at $7,020,097 were transferred to the inspector NPR No. 4.

On 25 September an inspection was made of South Barrow No. 4 gas well by A. A. Curtice, J. W. Dalton, Hugh Saltsman, and J. R. Coleman. The well was found to be in good order. All control valves had been closed and all handles removed. The Christmas tree and landing head had been cleaned and painted. Everything was secured for the winter. On the departure from the well, the building was locked, and the keys were turned over to Mr. Saltsman, the caretaker who was to remain at Barrow.

OPERATIONS

Because the closeout order came before any drilling was started in 1953, there was no drilling in that year. General operations consisted largely of the normal maintenance of Umiat, until it was turned over to the Air Force, and Barrow, and of field facilities in support of closeout activities. During the early part of the year, before the recessing of Pet 4 was known, there was considerable preparation of what was expected to be a more or less normal year. Even after the closeout order some of these operations had to continue at almost the same scale, but, of course, with a closeout objective. For example, the overland freighting was converted to an operation to return materials and equipment to Barrow or Umiat, or other points, rather than to disperse them according to the plans for new work.

After the closeout order, there was a greatly increased workload in inventorying, packaging for return to the States, warehousing, storing, and preparation for transfer of materials to other Federal agencies.

All equipment stored with Pet 4 was given minimum protection against the elements. Most equipment was placed in covered storage in shops or warehouses. Priority was given to the inside storage of the draw works of the National 125 rig. Machine tools were removed from their foundations and placed on timber sleepers to prevent damage from settling or heaving of foundations. Priority for storage inside was given to items which would be most likely to be pilfered or would be damaged by long outside storage.

An inventory and location map was made of all equipment and materials cached in field locations. The same was done at Barrow after transfer of materials to other agencies. To reduce danger to persons, all explosives in field caches were destroyed.

LAND TRANSPORTATION

The 1953 sled freighting season started on 15 October 1952. Before the close of the season on 14 May, a total of 2,508,822 net ton-miles had been hauled. With the closeout order in early March, the character of the freighting changed markedly to a strong emphasis on returning equipment and materials to selected centers, principally Barrow. The freighting was done principally by 4 sled trains and by 3 field crews. In addition, a special train hauled geophysical party 144 to Shaviovik.

Field crew 1 worked mostly in and near the southeastern part of Pet 4. It made a trip from Grandstand to Umiat in October 1952. In the latter part of October 1952 and until 11 November, it made three trips to the Chandler River from Umiat. In the rest of November three short hauls were made to Umiat test well 11. In the latter part of February, the crew made a trip from Barrow to Skull Cliff; and in early April, from Umiat to a point called Colville Junction. A final trip was made in the first half of March from Barrow to Topagoruk. Two tractors broke down on one of the Chandler River trips in October and November, and there was trouble with an injector and fuel pump of a tractor in April. Field crew 1 hauled a total of 50,187 ton-miles.

Field crew 2 made 1 haul from Barrow to Skull Cliff from 28 November to 5 December 1952 with a total of 1,564 ton-miles. Field crew 3 freighted 9,750 ton-miles from Shaviovik to Bullen Point between 8 and 10 April 1953.

Train 1 operated out of Barrow. From 13 December 1952 to 14 March 1953, it made 1 trip to Brady, 2 to Brady and Kaolak, and a fourth from Barrow to Umiat with Coast and Geodetic Survey caches. From 19 March to 12 April, a haul was made from Barrow to Barter Island. The last trip was from Barrow to Umiat from 29 April to 12 May. In spite of a number of mechanical difficulties, the train accumulated a total of 711,043 net ton-miles hauled.

Train 2 made a trip from Barrow to Brady from 14 December to 7 January, 2 trips from Barrow to Brady and Kaolak from 9 January to 2 February, 3 from Barrow to Brady and East Oumalik from 21 February to 13 March, 3 from Barrow to Brady from 14 March to 1 April; 1 trip from Barrow to Barter Island from 5 to 21 April, 1 from Barter Island to Barrow from 26 April to 6 May, and a final trip from Barrow to Umiat from 8 to 14 May. The ton-mile total of train 2 was 678,239.

The record of train 3 is tabulated on page 166 below as it appears in the project history for 1953.

Record of train 3

Number of trips	Trip From—	Trip To—	Departed—	Returned—	Mechanical failures	Net ton miles
1	Umiat	Brady	23 Dec	11 Jan	Two tractor generators	76, 341
1	Umiat	Caches 51, 52	12 Jan	20 Jan	Trouble with one tractor valve	9, 592
1	Barrow	Shaviovik	11 Feb	2 Mar	Two tractor generators	173, 042
2	Barrow	Umiat Brady	4 Mar	28 Mar	Four broken winch lines, 4 tractor generators, 1 cylinder head.	286, 801
1	Barrow	Project 22	2 Apr	2 May	One tractor head, 3 winch lines, 1 main spring	201, 066
2	Barrow	Umiat	5 May	11 May	None	107, 046
	Total					853, 888

Train 4 worked out of Umiat until near the end of February. It made 1 trip from Umiat to Weasel Creek and Wolf Creek No. 4, starting on 23 November; 3 trips from Umiat to Grandstand; 1 trip from Umiat to cache 55, Shaviovik, and Gubik; and 3 trips from Umiat to Shaviovik and Barrow, reaching there on 28 February. It then freighted from Barrow to Shaviovik (canceled en route) and from Barrow to Topagoruk. It also made a haul from Barrow to Bagnall Beach (on the Arctic coast in Canada) and Barter Island and from Barter Island to Bagnall Beach, returning to Barter Island at the end of the season on 21 April. Its total was 441,374 net ton-miles.

The special trip from Umiat to Shaviovik left Umiat on 6 January and reached Shaviovik on 11 January, having hauled 23,714 ton-miles.

The freighting experience was normal except for more mechanical difficulties because of older equipment and less attention to equipment condition owing to the impending close of Pet 4.

AIR TRANSPORTATION

During 1953 the air support for contract NOy–71333 continued to be supplied by Alaska Airlines. This included both linehaul flights and bush plane service. The service was operated much as in previous years. The last linehaul flight was made on 30 September, and the last bush flight on 28 August. Cost figures for air support are available for the period 1 July 1952 to 31 May 1953. In that 11 months, linehaul flying cost $203,915; and bush flying $319,540.

Some air-support data for typical weeks are set forth below as samples of the flying service required.

Week ending 8 Mar:
- Linehaul:
  - Northbound: 2 flights from Fairbanks to Umiat to Barrow and 4 flights from Umiat to Barrow. — 15 passengers, 13,299 lb of cargo, 12 hr 37 min flight time.
  - Southbound: 2 flights from Barrow to Umiat to Fairbanks and 4 flights from Barrow to Umiat. — 26 passengers, 37,764 lb of cargo, 14 hr 19 min flight time.
- Bush flying: 20 flights — 26 passengers, 33,222 lb of cargo, 24 hr 11 min flying time.

Week ending 5 Apr:
- Linehaul:
  - Northbound: 2 flights from Fairbanks to Umiat to Barrow and 6 flights from Umiat to Barrow. — 26 passengers, 9,791 lb of cargo, 15 hr 59 min flying time.
  - Southbound: 2 flights from Barrow to Umiat to Fairbanks and 6 flights from Barrow to Umiat. — 55 passengers, 43,128 lb of cargo, 14 hr 39 min flight time.
- Bush flying: 31 flights — 67 passengers, 45,056 lb of cargo, 38 hr 49 min flying time.

Week ending 31 May:
- Linehaul:
  - Northbound: 3 flights from Fairbanks to Umiat to Barrow and 3 flights from Umiat to Barrow. — 23 passengers, 8,439 lb of cargo, 9 hr 50 min flying time.
  - Southbound: 2 flights from Barrow to Umiat to Fairbanks and 3 flights from Barrow to Umiat. — 16 passengers, 40,973 lb of cargo, 10 hr 17 min flight time.
- Bush flying: 15 flights — 13 passengers, 25,777 lb of cargo, 20 hr 48 min flying time.

There follows a summary of the 1953 air operations as recorded in the project history of Pet 4 for 1953 as prepared by the OICC:

Summary of air operations, 1953

Month	Linehaul flights—weight lifted (in pounds)	Bush flights—Weight lifted (in pounds) by— Multiengine aircraft	Bush flights—Weight lifted (in pounds) by— Single-engine aircraft	Total weight lifted (in pounds)
Jan	189, 356	332, 991	24, 655	547, 002
Feb	144, 611	218, 329	19, 612	382, 552
Mar	136, 908	195, 759	21, 524	354, 191
Apr	124, 551	115, 201	16, 046	256, 198
May	100, 051	75, 089	15, 170	190, 310
Jun	165, 686	9, 323	16, 460	191, 469
Jul	77, 517		19, 875	97, 392
Aug	86, 980			86, 980
Sep	132, 258			132, 258
Total	1, 158, 318	946, 692	133, 342	2, 238, 352

One inconsistency appears in the record in that it is reported that the last bush flight was on 28 August, whereas the table above, from the project history, shows no weight lifted in bush flying after July. The inconsistency probably is not significant.

SEA TRANSPORTATION

In 1953 there was no Barex as such. The ship expedition that year was organized differently and was designed primarily for returning material from Barrow, not for northbound shipping. It was therefore called Barchange Expedition for Barrow exchange. There was no procurement for contract NOy–71333 because of the recessing of Pet 4.

The backhaul from Barrow consisted of 3,731 tons of miscellaneous equipment and parts for various Government agencies and 70 tons for Barter Island. Packing and crating of spare parts, equipment, and miscellaneous material was performed by Arcon personnel.

Pet 4 personnel in 1953 did not attend the initial planning conference for Barchange, and therefore the expedition did not have the advantage of Pet 4 experience. Such participation in the planning probably would have resulted in a more effective and successful operation.

Air reconnaissance for Barchange was conducted by 1 Navy and 1 Coast Guard PBY. The ice patrol covered an area southwest from Barrow as far as Icy Cape and eastward to Barter and Herschel Islands. The Navy PBY under command of Lieutenant Henning, USN, arrived at Point Barrow on 2 July and flew ice patrol until 25 July when the crew was relieved by a crew headed by Lieutenant Hessey, USN. The Coast Guard PBY was commanded by Ensign Fraser. It arrived at Barrow on 13 July and flew patrol until 31 July when a new crew under Lieutenant Huxtable took over. No short-range ice reconnaissance was performed by helicopters. Another Navy PBY arrived on 1 July for the purpose of aerial photography of ice patrol and photo reconnaissance. That flying boat departed 8 July.

The commanding officer of Barchange was RADM F. S. Withington, USN. CDR J. Backlund and Mr. Swanson were ice pilots. The ships included the U. S. S. *Estes* (flagship), the U. S. S. *Skagit* and *Electra* (AKA's), LST's *1146*, *1110*, *975*, and *914*. *Belle Grove* (LSD), and *Grapple* (ARS).

The LST's, the *Grapple*, and the *Belle Grove* arrived off Barrow on 28 July. Because of ice off the camp, the ships, with the exception of the *Belle Grove*, went to emergency landings off beaches east of Point Barrow. The *Belle Grove* remained at emergency anchorage off Point Barrow. The *Electra*, the *Skagit*, and the *Estes* arrived off Barrow on 2 August. At 1300 a conference was called aboard the *Estes* by Admiral Withington. All key personnel, both shore and ship, attended.

Ice and wind made loading extremely difficult. Loading operations from beach to LCM's and LST's were conducted by Arcon personnel. The normal beaches were closed by ice floes, and the cargo for the first 2 days was loaded from the lagoon. Later the LCM's and barges were able to load from the beaches, but the AKA's remained about 5 miles offshore northeast of Point Barrow. Freight had to be boated to the ships; and a round trip, not including loading and unloading, took 2 hours.

After the loading of the LST's, they continued eastward to Barter Island in support of Counterchange, the designation of the support trip to that island. The *Electra*, *Skagit*, and *Estes* had anchored 7 miles east of Point Barrow to await favorable ice conditions, which never materialized; and the loading of the AKA's took place at that anchorage.

Unloading of supplies for various agencies at Barrow was accomplished without difficulty with the exception of the long haul to reach shore. A total of 184 tons was offloaded as follows: For the Weather Bureau, 164 long tons; the Bureau of Standards, 17 tons; the CAA, 3 tons; and the ARL, 331 pounds.

The LST's that had returned from Barter Island left for the south first. On 14 August the *Estes*, *Belle Grove*, *Electra*, and *Skagit* departed.

Barchange encountered poor weather and ice conditions throughout. Not a single day showed completely open water. A few days after the ships had left, the ice moved 30 miles offshore, and the ocean at the point was completely clear of ice.

Communications from ship to shore were very poor. Navy-type restricted messages received at the camp could not be deciphered because no code was held by the ACS or AACS. There was considerable pilferage of cargo, including clothing designated for the Alaska Native Service.

On one day, 3 August, the boat crews, officers and 80 men were stranded, and their were boats caught in the lagoon by ice. About 10 officers and men of UDT's were unable to pay messing and billeting charges because they had no pay accounts as their destination was Barter Island.

The AGB U. S. S. *Northwind*, an icebreaker, not connected with Barchange arrived off Barrow on 20 July. Hydrographers, physicists, and various technicians, 12 in all, were taken to the *Northwind* by the ARL boat. The ship returned westward the same day and came back again on 2 August. The *Northwind* finally went southward with the other ships on 14 August.

A small custodial force was organized to remain at Barrow. Large stocks of supplies and equipment were transferred to the Western Electric Co. for use by it and its subcontractor, the Drake-Puget Sound Co. on an Air Force contract. Much of this material was freighted to Barter Island. Original closeout plans assumed that

all of the oil-field equipment and most of the construction and transportation equipment and supplies would remain stored at Barrow. As soon as the requirements of other Government agencies were known, it was apparent that most of the construction equipment, spare parts, and supplies at Barrow would be required for use on other Government projects; the bulk of them were needed by the Air Force.

In about 14 days in January and February, an airstrip was constructed in the Shaviovik area by grading a large bar on the Shaviovik River near Finn Creek. The strip was 4,000 feet long and about 100 feet wide.

SEISMIC SURVEYS

Party 144 of the United Geophysical Co. started a seismic survey in the Shaviovik area on 1 January. (See pl. 3.) It was decided to complete that work in a somewhat limited fashion. The surveys were completed on 8 April for a total of 3¼ party-months.

The objective of the survey was to attempt to check the relation between the subsurface structure and the Shaviovik anticline as mapped on the surface. The reflection data were much better than those from the Castle Mountain and Driftwood areas. The work showed that the anticline as it shows on the surface apparently does not have a similar deep counterpart. Only a limited number of data were obtained from the first 7,000 feet of section. The reflections showed a complex of thrust faults between 7,000 and 10,000 feet. A deeper reflection at about 13,000 feet shows a north-dipping monocline. Insufficient work was done to indicate the regional dip.

GEOLOGIC SURVEYS

In order to bring the geologic surveys to a logical stopping place and to collect sufficient information for the final report, several Geological Survey parties collected data on specific geologic problems. The parties were in the field from early June to early September and worked on a variety of problems as indicated below. (See pl. 3.) All of the work was staged from Umiat. The Navy financed projects 1 through 6, and the Survey financed projects 7 and 8. Arcon supplied some or all logistic support for all of the projects.

Project 1 was a traverse by weasel in the vicinity of the Kiligwa and Nuka Rivers. The work completed the geologic mapping of the area and yielded further data on the trend of the Brady anticline. Two geologists with one field assistant spent approximately 5 weeks on the project.

Two geologists assigned to project 2 spent 6 weeks in the area of the Killik and Colville Rivers. The party moved by boat. The area was selected for restudy in an attempt to solve several problems pertaining to the dating and correlation of Cretaceous rock units. Several sections were resampled for microfossils. Additional spot examinations were made on selected outcrops along Maybe Creek and the Anaktuvuk, Nanushuk, and Etivluk Rivers. A small plane on floats was used to reach the outcrops.

Project 3 was a resampling of Cretaceous sections in the vicinity of Carbon Creek and the Utokok River. The project personnel included 1 geologist and 1 field assistant. The Torok formation and Nanushuk group sections were resampled. The project took 4 days, and bush planes were used for transportation.

One geologist and one assistant studied the structure and stratigraphy of the Carter Creek anticline. This was project 4. Transportation was by bush plane, weasel, and foot. Office studies of aerial photographs previously had indicated folding of Pliocene strata near the axis. In the 5 days allotted to the work, the folding was confirmed, but the amount of closure could not be determined.

Project 5 involved structural and stratigraphic mapping in the Corwin-Cape Lisburne area. The study added greatly to the knowledge of the late Paleozoic and Mesozoic rocks of that little-known area. Two geologists spent about 6 weeks on the project; and, in addition, 1 geologist worked 3 days near Cape Lisburne.

A geologist, whose work was designated as project 6, spent 5 weeks along parts of the Kongakut and Firth Rivers. Most of the travel was by boat. The project was of a reconnaissance nature and was cooperative with a project of the Arctic Research Laboratory and the National Park Service.

Project 7 was a resampling by two geologists and a restudy of selected Paleozoic and Triassic sections in the central Brooks Range. The sections are on the Kiruktagiak River, Tiglukpuk Creek, and Kevik Lake. The project occupied about 1 month.

The two geologists assigned to project 8 were flown to Wild Lake to start a boat traverse down the Wild River to the Koyukuk River. The Wild River proved too low to permit the use of a boat; so the men were moved to Wiseman and from there traversed the Koyukuk River to the mouth of the Hogatza River. Structural and stratigraphic mapping were done.

SUPPORTED ACTIVITIES

Outside activities only partly related or completely unrelated to Pet 4 were supported in 1953 in a manner comparable to earlier years up to the time Pet 4 was finally recessed in the fall. This support, while supplied gladly, had continued to grow in size and complexity; and, although work unrelated to Pet 4 was generally paid for, the total effort for such activities

became a substantial drain on time, space, and personnel of Pet 4. In the winter of 1952–53 support was supplied to about 80 persons not connected with Pet 4.

The project history for 1953 prepared by the OICC contains the following list of supported activities with a note that some may have been inadvertently omitted:

a. Supported by change order to the contract:
   1. Arctic Test Station
   2. Arctic Research Laboratory
   3. 1930th Det–5 AACS
   4. Optical Research Laboratory (Keys project)
   5. National Bureau of Standards
   6. Air Force Barter Island project
   7. Air Force Umiat and General Project

b. Supported other than by change order to contract:
   1. Alaska Communication System, U. S. Army
   2. Airway and Air Communications Service, USAF
   3. Civil Aeronautics Administration
   4. National Bureau of Standards
   5. Air support contractor
   6. Geological Survey
   7. Coast and Geodetic Survey (Coastal)
   8. Coast and Geodetic Survey (Magnetic)
   9. Weather Bureau
   10. 1150th Field Detachment, USAF
   11. Office of Naval Research
   12. ARL (Boston University) USN
   13. Alaska Native Service
   14. Fish and Wildlife Service
   15. Army Signal Corps
   16. Alaska National Guard
   17. USAF
   18. Department of Aviation, Territory of Alaska
   19. Coast Guard
   20. Naval Station, Kodiak
   21. Commandant, 17th Naval District, Kodiak
   22. National Park Service
   23. Fairbanks Civil Defense
   24. DirPacAlDocks, San Francisco, Calif.

SUMMARY OF 1953

The outstanding feature of 1953 was the decision to recess Pet 4. This resulted from a series of studies and decisions that required, starting in March, a rapid cessation of exploration activities and a program designed to effect an efficient closeout before late fall. Much time and effort went into moving selected equipment and material to central points, its inventorying, storing or packing for return shipment, and the transfer of many supplies, much material, and equipment to other Federal agencies, mostly to the Air Force. No drilling was done, but some geology and geophysical work were continued to logical stopping places designed to result in reasonably complete information for use in the final report.

The cessation was accomplished in an effective manner and one that reflects credit on all concerned. Generally satisfactory provision was made for closing out most supported activities and for the continuation of those that were destined to go on. The fact that the Air Force was just getting well into a major Arctic project was fortunate in that that Department required a large part of the equipment and supplies that would no longer be needed.

SUMMARY AND CONCLUSIONS OF EXPLORATION

For 10 years a program had been carried on that was unique for the American Arctic in size, complexity, and accomplishment. What did it mean to the American in the street that some of his tax dollars over all those years had gone to support such an ambitious venture in a vast region unknown and of virtually no interest to most of the people? It is probably too soon to answer this question in anything like an adequate fashion, but the question can be taken apart and answered in part in terms of certain specific accomplishments, of trends, and of a variety of groups, individuals, and organizations. For example, what did Pet 4 mean to the Eskimos, to the oil industry, to the Navy, to the Territory of Alaska, to modern concepts of national defense, and so on? It is the purpose of this final section of this historical report to explore some of those questions and to attempt some sort of qualitative appraisal.

The answers are satisfying ones to anyone who participated extensively in Pet 4 over the long, hard years and who shared in the difficulties, discouragements, and disappointments that were faced continuously and for the most part were overcome. The record is one of hard work and accomplishment of which the Navy can be proud indeed. Commendation is due the key Naval officers throughout the undertaking. Sharing in the "well done" are Arcon and numerous other organizations, both Federal and private, including the United Geophysical Company, the United States Geological Survey, the United States Coast and Geodetic Survey, Wien Alaska Airlines, Alaska Airlines, Transocean Airlines, and many others. Special mention is due the operating committee (later the advisory committee) that advised the Navy on policies, operations, and all other phases of a complex but closely integrated operating organization. The outstanding men of that committee, chaired by the DNPR, gave freely of their time and advice, studied the countless problems from their diverse backgrounds and specialized aptitudes, and developed counsel and advice that resulted in an effective operation in spite of staggering problems of organization, administration, budget justifications, and many others.

Perhaps the best way to appraise Pet 4 in terms of results is first to review some of the accomplishments in terms of the defined objective—to appraise the pe-

troleum possibilities of Naval Petroleum Reserve No. 4 and adjacent areas. In all, 36 test wells (135,677 feet) and 44 core tests (33,873 feet) were drilled. The total footage drilled was 169,250. The 44 core tests ranged in depth from 115 feet in Simpson core test 1 to 2,505 feet in Simpson core test 28. Test wells ranged in depth from 373 feet in Knifeblade test well 2 to 11,872 feet in Oumalik test well 1. Two wells exceeded 10,000 feet in depth, and eight were drilled to depths between 5,000 and 10,000 feet. The distinction between holes classified as core tests and test wells depended not on depth reached but on the type of rig used in drilling.

Oil or gas, or both, were discovered in several geologic structural features, and the drilling in some was sufficient to yield data adequate for at least general appraisals of the producible oil or gas. The data on some of the more important of these structural features are summarized and generalized below.

UMIAT FIELD

The most extensive oil field discovered was the Umiat field in the southeastern part of Pet 4. Eleven holes were drilled in that field, and there is substantial information on the reserves it contains. Nevertheless, the various estimates made by a half dozen authorities range widely. In general, the reserves appear to be disappointingly small north of a fault that passes through the Umiat anticline about parallel to the axis. In part, the wide divergence in reserve estimates is because of differing opinions as to the amount of oil that could be produced from the permafrost zone that includes a substantial part of the field.

Four sandy zones have been shown to contain producible oil. Keeping in mind the fact that reserve estimates range widely, the most generally accepted estimate at the close of Pet 4 was about 70 million barrels of recoverable oil.

Significant gas was discovered in one of the wells. The size of the gas reserve is not known, but the gas apparently is confined to a fault block in the anticline and is not present in most places. It is not under high pressure and presumably would not provide appreciable gas drive for oil production.

SIMPSON FIELD

At the Simpson field, drilling discovered paraffin-base oil of 19° API gravity. It has a high pour point and cannot be readily handled at low temperatures. The seismograph work in the area revealed virtually no departures from the regional east dip. The Geological Survey postulated an interpretation of oil accumulation under an unconformity that was the result of submarine erosion of unconsolidated sediments.

The field was tested by 35 wells, 33 of which were core tests near the Simpson seepages. The core tests ranged in depth from 115 feet to 2,505 feet. Simpson test well 1 was drilled to 7,002 feet; and North Simpson test well 1, to 3,774 feet.

Reserves were difficult to estimate and highly speculative. Near the end of May 1951, the assistant chief of exploration estimated the field to contain around 12 million barrels of recoverable oil.

Only a little gas was found at Simpson. Core test 16, when bailed down, flowed enough gas to prevent the filling of the hole with water to stop the flow. It is known that this flow continued for at least a year. The pressure was relatively low, and the volume is believed to have been small.

FISH CREEK FIELD

The regional dip of the strata in the Fish Creek area is east at about 500 feet per mile. The Fish Creek well seems to be on a structural terrace. The oil seems to have accumulated in a stratigraphic or an unconformity trap. Because of the absence of a definable structural feature, the extent of the accumulation cannot be estimated.

Only one well was drilled at Fish Creek, not sufficient to explore the field adequately. The well was drilled to 7,020 feet, and oil was found near 3,000 feet. A pumping test yielded only 12 barrels per day, and that soon decreased to 8 barrels per day with a little water and gas.

BARROW FIELD

The Barrow gas field was discovered in 1949, and the camp was subsequently gradually converted to the use of gas instead of fuel oil. The gas lies at about 2,500 feet below the surface. The pressure has continued for years at about 1,010 pounds per square inch. The field since discovery has continually produced between one-fourth to one-half million cubic feet of gas per day. Because the pressure has not fallen off, it is assumed that the field has a water drive. Available data indicate that the field contains between 5 and 7 billion cubic feet of gas.

GUBIK FIELD

The Gubik gas field is of major size. It was tested by two wells, and production tests were made on 3 sands in Gubik test well 1. At least 10 other sands of similar characteristics were not tested. Gas from one sand blew out in Gubik test well 2 with a flow estimated at near 50 million cubic feet of gas per day. Only one sand tested in Gubik test well 2 had gas in commercial quantities. Arcon has estimated a reserve of 22 billion cubic feet of recoverable gas in tested sands and a possible

295 billion cubic feet if untested sands of similar characteristics are included.

WOLF CREEK FIELD

The Wolf Creek gas field is relatively small. Five sands were tested, and the maximum flow from any sand was 881,000 cubic feet per day. The field would be valuable apparently for local use only.

OUMALIK FIELD

Gas under high pressure is present in the Oumalik anticline, but the sands were not located accurately or tested. Apparently the gas sands are above 2,762 feet. At one point during drilling, high-pressure gas threatened to blow out the well. Well-head pressure at one time built up to 1,350 pounds per square inch. No estimates of reserves were made, but presumably the volume is not large enough for commercial production.

MEADE FIELD

Substantial gas is present in the Meade anticline in several sandy zones. No satisfactory tests were made, and there are insufficient data for a reliable estimate of reserves. On the basis of a few data and many assumptions, a possible reserve of 10 billion cubic feet of gas was estimated.

SQUARE LAKE FIELD

Gas was found at 2 levels in the 1 well drilled on the Square Lake anticline. Data are insufficient for quantitative estimates, but the volume and pressure from the lower level at about 1,850 feet indicate that the possibilities of the field may be substantial.

OTHER EXPLORATION ACTIVITIES

In brief summary, exploration activities, other than drilling that has already been discussed, included overall the following:

1. The coverage of about 67,000 square miles by seismic shooting, mostly reflection shooting.
2. The geologic mapping of 21,000 square miles by reconnaissance, semidetailed, and detailed methods, plus many related studies.
3. Trimetrogon photography of all of Pet 4, about 37,000 square miles. Vertical aerial photography of about 70,000 square miles.
4. Coverage of about 75,000 square miles with the airborne magnetometer.
5. Gravity-meter coverage of about 26,000 square miles.

STATUS OF EXPLORATION

Near the close of the program, a subcommittee of the advisory committee carefully appraised the status of the program as briefed above in terms of the defined objective. This appraisal is a systematic review of just what Pet 4 has meant as an oil-exploration project. In short, it is a thumbnail sketch of what the taxpayer received for his money.

The subcommittee reported twice; the second time was in November 1952. After that the subcommittee revised its report slightly and turned in a final report in January 1953 after almost all exploration activity had ceased. A little geologic and seismic work was done in 1953 after the report was submitted.

The subcommittee considered the program in terms of 5 areas and then studied the status of Pet 4 for each of those areas.

Area 1 (see fig. 101) included the coastal plain within the boundaries of NPR 4. Coverage by surface geology was considered as 100 percent because there are virtually no outcrops, and little could be done. Seismic coverage was estimated at about 30 percent, and no further work of that type was considered necessary. Coverage by airborne magnetometer and by gravity meter was 100 percent. Drilling in area 1 included 10 test wells and 35 core tests. The subcommittee agreed that the likelihood of usable petroleum deposits in the area are poor but that it does contain usable gas accumulations. The subcommittee felt that the objective of Pet 4 for area 1 had been attained.

Area 2 was the coastal plain east of the Reserve. Bedrock exposures are rare and about 90 percent of what could be done by surface geology had been accomplished. Only about 5 percent of what could be done by seismic methods had been done and no gravity-meter coverage had been made. Airborne magnetometer coverage was 100 percent. The petroleum potentialities are unknown; no drilling had been done, but the area is known to contain anticlines similar to those in area 3. A little geologic work, substantial detailed seismic coverage, and 1 or 2 wells at least would be needed to test the Tertiary and the Cretaceous rocks.

Area 3 was defined as the northern foothills within NPR 4 and the northern foothills eastward to the Anaktuvuk River to include the Gubik anticline. Surface geology was considered as about 95 percent complete. This included 90 percent coverage by reconnaissance mapping and some detailing of selected geologic structures. Seismic work embraced only about 5 percent of the area. The area was about 60 percent covered by gravity surveys and entirely by the airborne magnetometer. Twenty-five test wells and five core tests had been drilled in area 3. The area is known to contain small- to medium-sized oil and gas fields. Some more seismic work and more drilling,

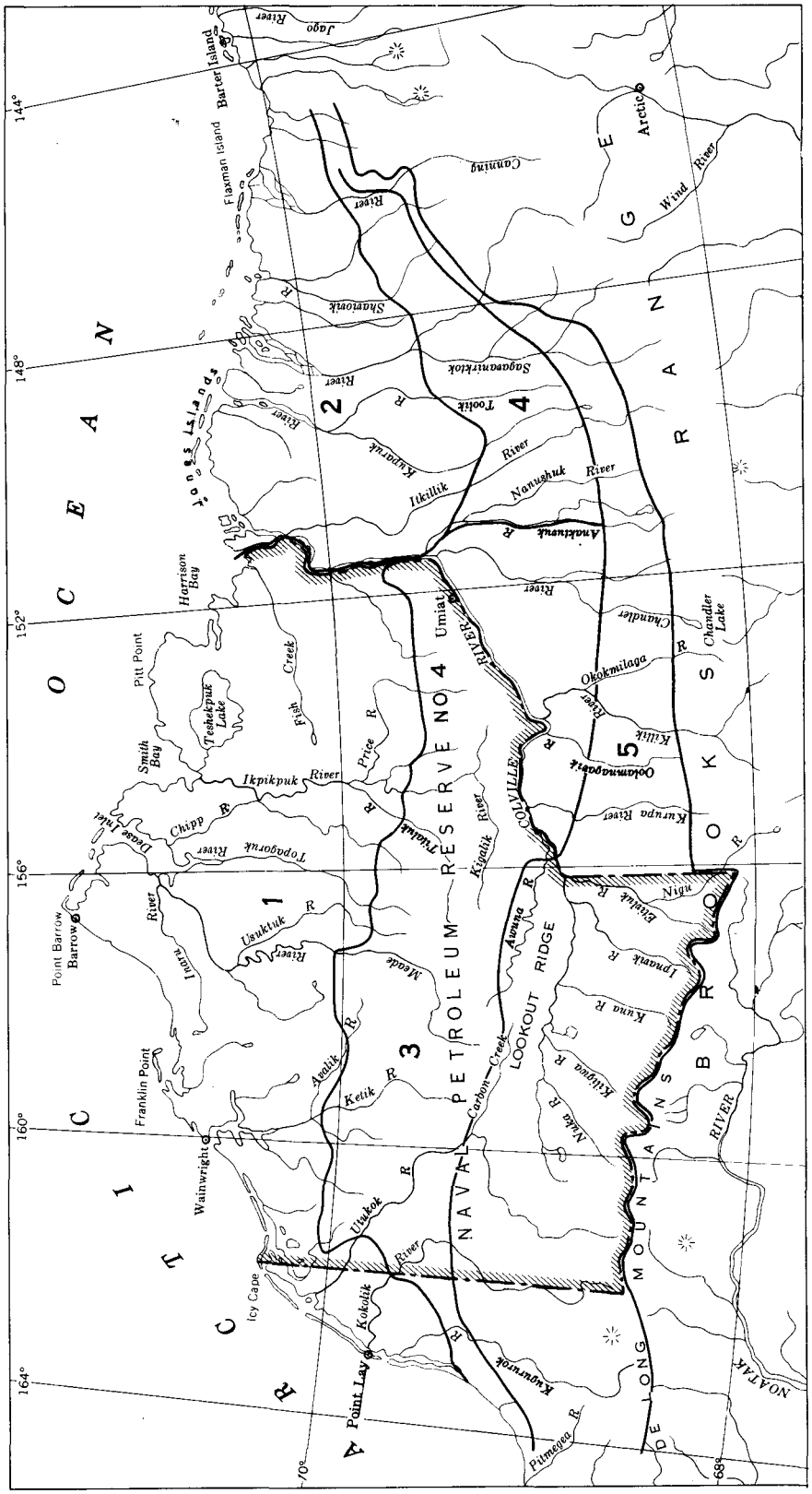

FIGURE 101.—Index map of northern Alaska showing areas used as basis for appraisal of status of exploration.

Area 1, coastal plain west of the Colville River.
Area 2, coastal plain east of the Colville River.
Area 3, northern foothills west of the Anaktuvuk River.
Area 4, northern foothills east of the Anaktuvuk River.
Area 5, southern foothills.

especially into the pre-Cretaceous rocks, would be needed to attain the objective in area 3.

Area 4 was the northern foothills east of area 3. Geologic work was considered as 70 percent complete. Airborne magnetometer surveys had covered about 90 percent of the area. There had been no seismic work, but some was done after the report was submitted. There had been no drilling. The possibilities of the area were considered unknown, but there was thought to be a fair possibility that the Lisburne group might be petroliferous in favorable structural features such as the Shaviovik anticline. More geologic mapping, more seismic surveys, and at least three test wells would be needed to reach the objective in area 4.

Area 5 was defined as the southern foothills all along the north front of the Brooks Range. About 75 percent of the surface geology had been mapped. Several structural features had been mapped in detail. Only a little of the area had been covered by the seismograph or by the airborne magnetometer, and there had been no gravity surveys. No test wells had been drilled. The possibilities of area 5 are unknown. Geologic surveys, seismic coverage, and at least two tests of the pre-Cretaceous rocks would be needed.

In summary, it was estimated that 6–10 test wells and preliminary geologic and seismic surveys would be necessary for a reasonable appraisal of the oil possibilities. Arcon estimated that the work visualized would require 3 to 5 additional years.

FISCAL SUMMARY

A subject of proper concern to the citizen interested in Pet 4 is what did it all cost. This is somewhat difficult to answer because certain costs were not charged directly to the project. For example, the cost of sending Barex to the Reserve each summer was carried as an operational cost by BuShips and not as a direct cost to be paid from funds appropriated or made available otherwise specifically for Pet 4. It is not within the scope of this history to record the details of cost, but a few salient cost figures are indicative of the directly charged cost of Pet 4.

The recorded cost from the start of Pet 4 to the end of May 1953 is summarized below.

Drilling 36 test wells, 44 core holes	$11,233,098
Geophysical exploration	8,874,965
Geological exploration	2,176,646
Maintenance and operation of camps	15,786,000
Miscellaneous supporting expenses (Bureau procurement, spare parts, consultants, travel, etc.)	5,261,605
Airway facilities	813,723
Airlift, bush and linehaul	3,469,218
Total	47,615,255

As of 30 June 1953, the value of the Barrow camp, including structures, utilities equipment, shop equipment, and other installed equipment was estimated as $896,999. The Fairbanks installation was worth $99,000. An inventory of noninstalled equipment on the same date was reported as—

Oil-field equipment:	
Rigs, cementing equipment, blow-out preventers, boilers, logging units, etc	$1,013,000
Oil-field consumable supplies:	
Drill pipe, casing, tubing, linepipe, fittings, bits, mud, cement, etc	2,576,000
General construction equipment:	
Bulldozers, draglines, trucks, materials, handling equipment, shovels, Athey wagons, sleds, diesel electric generators, etc	2,882,000
General stores and food	5,473,000
Total	11,944,000

A KEY TO ARCTIC OPERATIONS

In addition to the direct results of Pet 4 as related to its defined objective, much information and experience and much in terms of operating techniques came out of Pet 4.

Pet 4 was one of the largest, longest, and most difficult Arctic operations of all time, anywhere—it certainly was by far the greatest development and most complex activity ever undertaken in the Alaskan Arctic. It yielded a rich harvest indeed of byproduct data and experience on all manner of operations and environmental facts about the 70,000 square miles, more or less, that lie between the drainage divide of the Brooks Range and the polar sea. In this section of the history of Pet 4 is set down an analysis of the kinds of information that may be useful for many purposes both military and civilian.

The northern part of Alaska is important to the defense of the United States. It is the only United States segment of the perimeter of the Arctic Ocean; it is relatively close to the great Alaskan Air Force bases such as Elmendorf, Ladd, and Eielson; it faces across the Chukchi Sea directly at the easternmost part of the USSR; it is crossed by many potential great-circle air routes between major population centers in the northern hemisphere; it contains natural resources of coal, gas, and petroleum, but the full extent of those resources is not known; and it is the area in which for 10 years was played out a great saga of the Arctic, Pet 4.

Many informed persons feel that the experience and knowledge gained were worth the total investment from the standpoint of defense and Alaskan development—entirely aside from the primary objective of Pet 4 itself, namely a reasonable interpretation of the oil possibilities of NPR 4. This was the first United States ex-

perience in a truly arctic operation involving large numbers of men, up to more than 500 at times, engaged in all sorts of construction, including the building and use of airfields, many types of structures, and drilling deep test wells down to a depth of about 12,000 feet; all kinds of transportation over long distances and carrying heavy loads, summer and winter, by land, sea, and air; all sorts of arctic living conditions at all seasons with the attendant problems of human relations, medicine, food, water supply, shelter, and morale; close relations with the native Eskimos and their maximum use in the project; and the close coordination and operation of a master plan with its infinite aspects of contractual relations, programming, and supply and logistics; as well as many other problems.

Excellent and detailed records were kept throughout the entire operation. Many volumes would be required to record in systematic fashion all the data that were accumulated, and that is far beyond the scope of this paper, which presumes only to indicate some of the salient types of information that should be digested and used in military thinking about northern Alaska specifically and about the Arctic generally.

PLANNING, ADMINISTRATION, AND DIRECTION

The planning, administration, and direction of an operation such as Pet 4 is complex. The pattern of these aspects of Pet 4 contains much of value in considering future Arctic projects. Several Navy offices were involved, as were several civilian Federal agencies and a basic contractor, with an additional group of subcontractors.

The appropriation items for the project were made available to the Office of Naval Petroleum Reserves, which was then an arm of the office of an Assistant Secretary of the Navy but is now under the office of the Under SecNav. The Director of Naval Petroleum Reserves, therefore, was primarily responsible for Pet 4; and he, with assistants generally selected by him, prepared the justifications and defended the proposals before the Bureau of the Budget and the congressional appropriation subcommittees. In addition, the Director of Naval Petroleum Reserves continually kept the Armed Services Committees of the House and Senate fully informed about Pet 4.

Pet 4 started before the close of the war, and for a little more than a year, until early in 1946, the operation was carried out by a Seabee detachment. The first ship expedition to Point Barrow in the fall of 1944 was during that interval. The Seabees built the nucleus of the very substantial permanent camp that followed, constructed the airstrip on the beach, drilled the first major test hole on the Umiat anticline, and gained the first experience in Arctic oil-field operations. By early 1946 a basic contract had been negotiated by BuDocks with Arctic Contractors, a company formed for the purpose. In the first year also, a transportation office for air transport to Pet 4 was established in Fairbanks, roughly 500 miles to the south in the heart of Alaska and on the railroad and highway to the Pacific coast and also on the Alaska Highway to the States.

It was soon recognized that the most practicable air support would be by contract, and appropriate contracts were made successively with several airlines including Wien Alaska Airlines, Transocean Airlines, and Alaska Airlines. Arctic Contractors entered into several subcontracts for certain aspects of the total job. The most important of these was with the United Geophysical Co. for the geophysical exploration that was contemplated.

Early in Pet 4 an arrangement was made by the Director of Naval Petroleum Reserves with the U. S. Geological Survey for the geological aspects of the operation. Similar arrangements were made with the U. S. Coast and Geodetic Survey for hydrographic work and geodetic control and with the Civil Aeronautics Administration for flight control.

The funds were received by the Office of Naval Petroleum Reserves. Transfers, advances, and repayments were made from that office to other Federal agencies. The remaining funds were transferred to BuDocks for the payment of costs of the basic contract and subcontracts and to BuAir for the cost of air support.

The Director of Naval Petroleum Reserves established an operating committee under his own chairmanship to advise on the scale, scope, and accomplishment of Pet 4 toward its basic objective that had been defined by the Congress in the language of the appropriation item. This group consisted of the Director of Naval Petroleum Reserves and his alternate the Deputy Director of Naval Petroleum Reserves; a member of the oil-exploration and operation firm of DeGolyer and MacNaughton, which at that time was advisor on petroleum matters to the Secretary of the Navy; a member of the oil-exploration firm of Hoover, Curtice, and Ruby (later reorganized to form Exploration Contractors, Inc.); the Director of the Geological Survey; a technical advisor to the Director of Naval Petroleum Reserves; and a representative of the Bureau of Yards and Docks. The constitution of the committee changed slightly from time to time and in the later years of Pet 4 was renamed the advisory committee.

The operating committee determined policies, blocked out the program to be carried out, critically observed the course of Pet 4, and measured progress from time to time toward the defined objective. Its real responsi-

bility was advisory only, and its recommendations in order to be validated required and received the approval of the Secretary of the Navy or the appropriate Assistant Secretary of the Navy.

When Arcon (Arctic Contractors) took over, a headquarters and operating office was constituted in Fairbanks; another office was opened at the main operating base at Point Barrow; and a smaller office was opened in Seattle to expedite such things as hiring and shipping. The officer in charge of construction from the Bureau of Yards and Docks with an appropriate staff was established in the same building with Arcon in Fairbanks. A resident officer in charge was placed at Barrow and another in Seattle.

As Pet 4 progressed, a need for on-the-spot coordination of plans and operations became apparent and a technical operating committee was formed in Fairbanks for that purpose. It consisted of the project manager for Arcon, the chief of exploration (an Arcon employee), the Fairbanks head of the Navy Oil Unit (a unit formed within the Alaskan Geology Branch of the Geological Survey for the Pet 4 work), the officer in charge of construction, and the Fairbanks representative of the United Geophysical Co.

Other advisors and special consultants were called in at all levels many times on many topics, as required.

Both the Geological Survey and the United Geophysical Co. had offices and laboratories as required in Fairbanks; the Geological Survey facility included a small but complete petroleum laboratory.

Administration and direction of such a complex team as had to be organized for the Pet 4 job is a difficult matter. The pattern that evolved was found to be satisfactory and workable. The problems in general were not unlike those to be expected in any large technical operation. The special problems that arose because Pet 4 was an Arctic operation were not especially unusual. Planning and programming, however, were different and much more difficult matters. The Arctic location of the job made a great difference. So did the fact that the whole region was virtually unknown except in a very general and fragmentary fashion. These aspects require a little discussion even in such a summary as this.

The Arctic slope of Alaska has a truly Arctic environment—only tundra vegetation, perpetually frozen ground, an ice-bound ocean for most of the year, long, dark winters and continual summer daylight, clouds of mosquitoes in the summer, no access by usual means, no local supply points, and great extremes of temperature. All these and many other factors had to be encountered and operational solutions found. Planning had to done precisely and a long time in advance. Consider, for example, the drilling of a 5,000-foot test well perhaps 200 miles from Point Barrow, and many such were drilled during Pet 4. First the decision had to be made to drill the hole at a specified location. Because of the scarcity of information on the area both a geological and a geophysical survey were commonly required. These operations in themselves posed operational and logistic problems. Finally, sufficient data were judged to be in hand. The proposal would be debated by the operating committee perhaps in November, after the summer field season was over and the field investigations had been made, and the decision to drill the hole would be made. Any equipment and supplies needed and not on hand would have to be listed and procured during the winter and gotten to a shipping point, either Port Hueneme, Calif., or Seattle, Wash., to get on the ship expedition the following July. In August the material would be landed on the beach at Point Barrow. It would then have to be organized, perhaps winterized or otherwise modified and prepared for shipment. It would move by tractor train, perhaps in February when the tundra surface is hard enough to bear heavy loads and would be delivered at the drill site; there it would remain until April when it could be assembled and the well started. Note that a year and half had passed between the decision to drill the hole and the date on which it was spudded in.

CONSTRUCTION AND MAINTENANCE

Everything that was used in Pet 4 had to be taken there from the States or elsewhere. There was essentially no local source of supply of labor, materials, machinery, or anything else useful in such an operation. The two exceptions to the above were the presence in the area of a thousand or so Eskimos, a few tens of whom were used in Pet 4 in capacities where they could be used, or for which they could be trained, and the bringing in of a small gas field a few miles from the camp at Barrow that was used part way through Pet 4 as a gas source for power generation and space heating at a very substantial saving.

Environmental factors had a profound effect on all construction and maintenance during Pet 4. Arcon had had a considerable previous experience with foundation problems, excavation, and use of piling in permafrost areas. Generally no design data were available for construction of facilities of the kinds needed. Most buildings were of the quonset type. Frequently it was necessary to work out new designs based on general knowledge of environment. Structures based on these new designs and structures built on designs for lower latitudes were modified as required. Most construction was of a temporary nature as the length of the project was not definitely known

and the locations of specific activities were continually changing. This resulted in high maintenance costs. Some basic research was performed for structures involving large investments; an example of this was the research performed in a small soil-test laboratory to determine the mechanical properties of piling frozen into permafrost. This was preliminary to the foundation plan for a deep-hole rig (Oumalik test well 1) that was expected to be in place for 2 years and which would have warm drilling mud coming up the hole being drilled for long periods. The conductor pipe was arranged so that it could be refrigerated, and the pilings also were designed to be refrigerated when temperatures approached the melting point of water.

Because projects to be undertaken in a given year usually were not definite until the winter of the previous year, it was necessary to maintain an unusually large inventory of materials that would be available for almost any project that might come up. This was expensive but less expensive than the delivery by air of large quantities of materials that might not be at hand when needed.

The facility at Fairbanks requires only brief mention here. It included an office and laboratory building about 13,000 square feet in area, a warehouse and shop, a car-storage shed, a laundry, large fireproof storage vault, a building to accommodate around 17 transients, and 17 quarters for families.

Barrow was the largest and best developed camp. In all there were about 80 buildings, including 53 quonsets for dormitories and a few family living quarters, a hangar, an administration and office building, a theater, a gymnasium, warehouses, shops, powerhouse, laundry, galley and messing quarters, the Arctic Research Laboratory buildings, and others. The Barrow camp was built on the coarse-sand beach of the Arctic Ocean, but the rear of the camp area overlapped the tundra a little.

The main subsidiary camp was Umiat on the Colville River about 180 miles southeast of Barrow. The whole camp was built on a thick pad of river-bar gravel. It included several warehouses, 18 quonsets 20 by 48 feet, a galley and messhall, shops, a CAA building, a powerhouse, and a few other buildings.

Arcon built another substantial camp for the Air Force at Barter Island about 300 miles east of Barrow on the Arctic coast. Other camps at various drill sites were more temporary although their construction and operation also presented many problems and resulted in much information.

Buildings for long use were placed on pilings frozen into permafrost. Most of the quonset huts were on beach gravel where possible or on gravel pads placed on frozen silt. Difficulty was encountered with heated buildings with concrete floors. One of the large buildings of the Arctic Research Laboratory gave much trouble through differential settling. No difficulty was had with the hangar building at Barrow for 4 years—then the building was heated, and the floor sank 4 feet in the central part. The Barter Island buildings were on gravel mats. Those with concrete floors settled badly, and piling foundations had to be installed. It was discovered that much of the trouble was due to a clay layer under the silt that was plastic at temperatures as low as −6°C but was firm at −12°C.

When practicable construction schedules were established to take full advantage of the seasons. Excavating can be best done in late summer. Frames, roofs, and closing of exteriors should be completed before the cold weather. For example, roofing paper is too brittle to use at temperatures below 10°F. Snow readily slides off roofs with a pitch of 1 to 3. Quonsets used for living quarters had 8-foot additions built for storm entrances. Doubledeck bunks were not used because it was found that inside temperature gradients in winter resulted in the lower decks being too cold for comfort and the upper decks too hot.

Four 10,000-barrel fuel-storage tanks were constructed at Barrow on a 4-foot gravel pad on frozen silt. One such tank was put on a piling foundation for comparative data. No settling occurred of any of the tanks.

Drilling-rig foundations were studied with special care. The Oumalik test well 1 foundation has already been mentioned. Foundation designs varied with the estimated load, the length of time the hole was expected to be drilling, and the season during which drilling would go on. With experience it became possible to provide simpler, cheaper, and better foundations. For rigs to be set up on gravel flood plains, it was found that timber sills were sufficient and no concrete pedestals were needed. Rigs on silt were usually placed on piles frozen into the silt. Sills that could be refrigerated were used in some foundations and were satisfactory but required a larger personnel to operate the refrigerating system during the summer.

A special problem was the foundation of a 625-foot Loran tower that was built by Arcon for the Air Force at Skull Cliff, about 30 miles southwest of Barrow. No settlement could be tolerated, and the foundation not only had to support the tower but also to act as an anchor to prevent overturning during high winds. Excavations were drilled rather than thawed to minimize the heating of surrounding permafrost. Each

tower leg rested in a massive concrete block that extended 15 feet below the surface. Under each of these piers was a gravel pad. Steel piles 10 inches in diameter were placed beneath the piers and extended into the concrete blocks where they were tied into the reinforcing steel. Water had to be kept out of the foundation holes by pumping for 4 months. There has been no settling.

The airstrip at Barrow was constructed by the Seabees. Pierced steel plank was laid on leveled coarse sand of a strip of the beach. Into the sand to partially stabilize it was mixed peat and silt. Later the strip was lengthened by Arcon. The runway has been satisfactory and has taken repeated landings by C14 and C54 aircraft. Each year sand had to be sifted through the pierced plank in low places to maintain grade. Heavy aircraft landings were limited as much as possible during the summer.

Runways on river bars were constructed in ordinary fashion, but any silt areas had to be first excavated to a depth of at least 8 feet.

The arctic climate preserves structures naturally. The low temperatures inhibit corrosion and rot, but wind damage required some maintenance work. The heating systems required much maintenance. Water was hauled from a lake near the Barrow camp that was deep enough that it did not freeze to the bottom in winter. This required much manpower, and the quality of the water was not good. Its naturally high chlorine content caused much corrosion of boilers, pipes, and other fixtures.

The experience of Pet 4 has resulted in the recognition of several "do's" and "don'ts" of arctic operations that have to do with construction and maintenance. Only a few of these are selected for listing below:

Do's

1. For foundations on frozen silt use pilings rather than concrete footings.
2. Use slow-burning powders for effective blasting of frozen fine-grained materials.
3. Use higher velocity dynamites for shattering frozen gravel with high moisture content.
4. Remove frozen silt by hydraulicking whenever possible.
5. Make maximum use of favorable seasons.
6. Remove silt from beneath concrete foundations and floors.
7. Heat nails before use in extremely cold weather.
8. Use quick-setting cements for most concrete work.
9. Design buildings with insulation above ceiling joists and roof space open to air to prevent icing of eaves.
10. Break up temperature stratification in buildings by small circulating fans.
11. Provide space for air circulation under buildings wherever possible.

Don'ts

1. Backfill with frozen material.
2. Grade roads or runways without removing sufficient frozen silt.
3. Pour concrete against frozen gravel.
4. Allow moisture to accumulate under footings.
5. Use wet lumber at below-freezing temperatures.
6. Use vermiculite or similar types of insulation in walls as it becomes soggy with moisture.
7. Use fan-exhausts in buildings because it pulls cold air through moisture-laden insulation chilling it.
8. Allow runoff water from roofs to accumulate around buildings.

CAMP OPERATIONS

At Barrow water was hauled from the lake by means of a tractor-drawn Athey wagon on which enclosed tanks were built. The water was filtered and chlorinated and then piped to the messhall and hauled as drinking water to the quonset huts. Wash bowls were placed in each hut and connected to a hot-water tank above the space heater. This water was not chlorinated. A sewage line was run from the messhall to the beach to carry wash water, and another such line served the Arctic Research Laboratory. The lines were kept free by steam pipes laid with the waste lines. Sewage was disposed of in 50-gallon drums from latrines. The drums were emptied directly on the ocean ice.

Mess was in a central hall with 4 wings—2 for workmen's mess, 1 for hot lunches for Eskimo employees, 1 for the supervisory and military personnel, and 1 for married couples. Complete laundry and dry cleaning services were provided, and barracksmen cleaned the huts daily.

Large inventories were maintained of all kinds of material. Separate warehouses, each under a head storekeeper, were used for various classes of materials. A running inventory was maintained, and cost accounting followed issue of each item. A sales store was available where the personnel could purchase personal needs such as nonissue clothing and toilet articles.

Complete shop facilities were established at Barrow. These included a well-equipped machine shop. Overhead cranes were provided throughout the shop. A light-duty-equipment shop was used for overhauling and rebuilding weasels, jeeps, LVT's, and trucks. A heavy-duty-equipment shop overhauled cranes, tractors, Athey wagons, and cherrypickers. There was a carpenter shop, a sled shop, a rig shop, a sheet-metal shop, a plumbing shop, and an electrical shop. Much attention was given to fire protection with extinguishers and water tanks located in heated buildings at strategic locations. Fire protection was under a fire marshal, and a 24-hour fire watch was maintained. An LVT was modified as a fire engine.

TRANSPORTATION

Transportation is almost certain to be one of the most critical aspects of any large Arctic operation. This is likely to be true whether the operation requires transportation by land, sea, or air or any combination thereof. Arctic transportation is a large and complex subject and only a few of its aspects relative to Pet 4 can be touched on in this summary. Access to Pet 4 was by ship during the short open season in August and September and by air, generally from Fairbanks. Transportation within the area of operation of Pet 4 was by land, by means of several types of vehicles; by air, by means of aircraft on wheels, skis, or pontoons; and by water, by various craft along the coast and on the rivers. This discussion focuses on some of the transportation problems and the information resulting from Pet 4, but in so doing some information is included on certain kinds of vehicles and equipment.

SEA TRANSPORTATION

Each year of Pet 4 a ship expedition proceeded from the States to Barrow and a few other points on the Arctic coast bringing all types of supplies, equipment, and material.

The Arctic Ocean in the Barrow vicinity is generally reasonably ice free in August and September. There is a considerable variation in the length of the open season from year to year, and the ice pack may move in at any point along the coast at any time. Thus an ice patrol by air, usually by PBY and helicopter, was generally used. It was also found that it was most desirable for Barex to be accompanied by an ice breaker.

The ships were loaded in stateside ports in a manner to exepedite unloading. The beach at Barrow was marked out carefully for the handling of various types of cargo in certain sections with a view to reducing later movement as much as possible.

The standard LCM's have been used for some transport along the Arctic coast. The cost was low but the risk from ice was great, and such operations are possible only during a small part of the year.

AIR TRANSPORTATION

Air operations consisted of two distinct types of support: transportation of workers and materials to and from Pet 4, the so-called linehaul, and bush flying in northern Alaska.

The linehaul planes at various times during Pet 4 used both the Ladd Air Force Base and the commercial fields at Fairbanks as the Fairbanks end of the linehaul. The principal landing points for this service in Pet 4 were at Barrow and Umiat. The bush flying was usually from Barrow or Umiat to a few temporary subsidiary strips and to many spots in and south and east of the Reserve.

An attempt was made throughout Pet 4 to encourage careful planning and long-range ordering to keep the plane cost as low as possible. Where large tonnages had to be moved by air, the use of the largest possible aircraft was the most economical. Landing strips for the planes used had to be about 5,000 feet long, well marked, and lighted. Winter strips were available in any size desired by simply clearing the snow from a nearby lake. March and April were found to be the best months for using such strips because of the greater ice thickness by then and the better visibility. Efficient maintenance and unloading crews must be provided to effect the quick return trip desirable for such operations because of the low temperatures.

Satisfactory operation of large aircraft in the Arctic requires hangars. Operation is possible, but very difficult, with the use of simple nose hangars and portable heaters. Planes parked to the windward of runways cause serious drifting on the runways. Blowing snow is likely to fill parts of parked aircraft with tightly packed snow that is removed with difficulty. There is also danger of such packed snow fouling controls.

DC 4's (C54's) were the best planes regularly used in Pet 4 for carrying heavy loads over long distances. Some hauling was done with C124's by the Air Force for Pet 4. Its large capacity and ability to use a 5,000-foot strip are very desirable. The C46 was efficient for flights up to about 1½ hours. The C47 (DC 3) was an excellent large bush plane, especially when equipped with skis for winter operation. Norseman bush planes were effectively used on wheels, skis, and pontoons, and there was a variety of uses for even smaller aircraft, such as the Stinson, Cessna, and Super Cub, for scouting, geologic work, delivery of mail, transport of supervisory personnel, and others.

Helicopters were used to some extent during Pet 4 and were very suitable for a certain few jobs such as gravity-meter surveys that require many landings close to specified points but with light instruments. They were not as satisfactory, as was anticipated, for support of geologic parties because of the difficult maintenance problem at any but short distances from repair and maintenance facilities.

The CAA supplied Pet 4 with personnels, on a reimbursable basis, for the operation of control towers, navigational aids, and weather observations at Bettles, Umiat, and Barrow. The CAA also furnished technical personnel to assist in the installation of electronic equipment for navigational aids.

LAND TRANSPORTATION

The heavy freighting of Pet 4 was performed by sled trains pulled by tractors. The experience gained in these sled train operations will have many applications in future Arctic operations. Generally, the tractor trains moved from December through May. Land transportation is most difficult during the freezeup period of September and October when the newly frozen surface is too thin to support equipment and the layer thawed the previous summer has not yet frozen down to the permafrost.

Routes to be followed by the trains followed trails previously flagged by scout weasels. After the Arctic Ocean was frozen to sufficient depth its surface was found to provide the best sled-train conditions and was used as much as possible. The trains were self-supporting and usually were outfitted with a 2-week supply of food, fuel, spare parts, and other items. The trains included a mess wanigan, a sleeping wanigan, and a shop wanigan with light plant, electric welder, gas welder, Herman-Nelson heater, and other items. Radio contact with Barrow was established generally twice a day. Any emergency items were delivered to the train by bush plane.

The tractors carried ice cleats, special cab with escape hatch, winter hoods, and where necessary snow plows. The lead tractor towed the mess, sleeping, and shop wanigans, and cleared the trail. The following tractors, sometimes up to five, pulled the payload of up to about 80 tons per tractor. Maximum daily distances covered were about 80 miles.

From the whole freighting experience, the following are a few of the principles that were developed:

1. Use proper fuels and lubricants for subzero operations.
2. Make every effort to keep engines, transmissions, and gear boxes operating at recommended temperatures.
3. Preheat engines prior to starting in subzero temperatures. Herman-Nelson heaters are recommended.
4. Use qualified and experienced personnel.
5. Be prepared with adequate maintenance by competent mechanics.

HEAVY EQUIPMENT

Many large and small items of equipment were used in Pet 4. A large proportion required some sort of alteration or modified operational practices for effective use in the Arctic. Attention is given here to a few of the larger items that were widely and effectively used. The ones discussed are selected because it is believed that they are pertinent to the consideration of any Arctic project. Specialized items such as oil-field equipment are omitted.

The crawler or track-type tractor was the most useful single item of mechanized equipment required by Pet 4. It proved a most versatile prime mover and was used for such jobs as airfield construction and maintenance; hauling water, fuel, and supplies; the motive power of sled trains; and moving self-contained geophysical parties. As required, tractors were equipped with a hydraulic bulldozer blade, a cable bulldozer blade, a towing winch, and a snow plow.

Cabs were fabricated of hardwood with angle-iron framing. Shatterproof glass and plexiglass were used in windows. Cabs had sliding doors, a heater using engine heat, and an escape hatch for use in the event the tractor broke through ice. In winter the top track-carrier rollers, which freeze solid in very cold weather and do not turn, were replaced with hardwood blocks. These cannot be used in summer because of the abrasive action of loose sand and gravel. Snow tracks were used in winter. These had ice cleats and holes cut in the pads to prevent buildup of snow on the track pins and sprockets.

In winter some difficulty was experienced in keeping the oil warm enough to lubricate properly. In such weather the oil coolers were removed. Plywood panels bolted to frame and belly pan enclosed the crankcase. The engine air intake was placed inside the winter hood. Radiators were covered with canvas. The standard coolant was 50–50 Prestone and water.

Cranes were modified for subzero weather by installing cabs, using Prestone in radiators, adding radiator covers, enclosing crankcases, and installing heavy-duty batteries. The Northwest Model 25 cranes used came from Navy surplus. Cranes that could be boomed up or down while traveling and swinging would have been more useful as would a somewhat greater lifting capacity for very heavy oil-field equipment. Hystaway dragline cranes Model HW on a D 6 Caterpillar were satisfactory on hard ground but not in loose sand and mud. Smaller tractor cranes were useful around base camps and rig sites. A tractor crane with high clearance is needed around rig sites in summer because of the deep mud.

Of special use were fork lifts for loading and unloading aircraft and for warehousing. The units used were Hughes Keenan Fork Lifts mounted on TD9 tractors.

The LVT (landing vehicle, tracked) was designed for assault landing but was appropriate for certain jobs in the Arctic. They were useful when thawed ground inhibited sled train transport and lack of airfields in-

Activities supported by Pet 4

Directly or indirectly related to Pet 4:
- U. S. Army:
  - Signal Corps
  - Snow, Ice, and Permafrost Research Establishment
- U. S. Navy: Arctic Test Station (BuDocks)
- U. S. Coast and Geodetic Survey
- U. S. Geological Survey
- U. S. Weather Bureau
- Civil Aeronautics Administration

Not related to Pet 4:
- U. S. Air Force:
  - Airways and Air Service Communications
  - Beetle projects
  - Project Keys
- National Bureau of Standards
- U. S. Bureau of Indian Affairs (Alaska Native Service)
- U. S. Army
  - Alaska National Guard
  - Ionosphere project
- U. S. Fish and Wildlife Service
- U. S. Navy:
  - Arctic Research Laboratory
  - Project Lincoln
  - Operation Ski Jump

The participation in Pet 4 of the units listed above as related to Pet 4 have all been mentioned previously, except the Arctic Test Station of the Bureau of Yards and Docks. That unit made development studies of Arctic housing, strength of foundations, snow compaction tests, airfield construction on sea ice, performance and modification of certain equipment, and other studies, many of which were applicable to improvements in Pet 4 techniques. In addition to geodetic control and hydrographic surveys, the Coast and Geodetic Survey made studies of magnetic properties of the earth in the Barrow area.

Under those listed as not related to Pet 4, the Beetle projects had to do with the construction of the Barter Island camp and runway and with the construction of certain Loran elements such as the tower at Skull Cliff. The Bureau of Standards made upper atmosphere and radio propagation studies.

Operation Ski Jump of the Office of Naval Research was an Arctic oceanographic project that used Barrow as a staging point. One of the very important supported activities was the well-equipped Arctic Research Laboratory of the Office of Naval Research in which went on many research projects related to the arctic environment. Much of interest and value came out of those research efforts that will be useful in the future. The ARL is continuing under its own support.

The kinds of support furnished outside activities by Pet 4 included, but was not limited to the following, although not all of the services listed were supplied to every activity:

1. Messing and billeting.
2. Laundry and dry cleaning facilities.
3. Provision and maintenance of equipment and vehicles.
4. Handling and storing of cargo shipped to and from Barrow by air and by Barex.
5. Sales store participation.
6. Winter freighting.
7. Provision, operation, and maintenance of portable camp facilities.

The personnel attached to outside activities reached at one time a total of 190 persons. Some of the activities were supported at the cost of substantial effort and expense. Additional inconvenience resulted from the unpredictability of the amount and kind of support to be required. In any future comparable situation, more advance notice should be given to the main project.

ENVIRONMENTAL ASPECTS AND MILITARY IMPLICATIONS

The foregoing discussion indicates some of the aspects of some of the segments of Pet 4 that have far-reaching applicability to military thinking. It is apparent that the arctic environment was the source of most of the problems that arose in the course of Pet 4. The environment will also give rise to many of the problems of military operations in Arctic Alaska or elsewhere in similar arctic areas. The lessons to be learned from Pet 4 can contribute significantly to the United States' appraisal of arctic difficulties and of arctic possibilities. It has shown that normal men can live, work, and accomplish all sorts of objectives in the Arctic. The importance of advance planning and special administrative effort have been stressed. Construction and maintenance problems were met and surmounted and can be again. Transportation and communications have been emphasized and a few indications were given of the kinds of equipment problems that arise and of the kinds of solutions that can be found. Personnel problems were found to be less than anticipated. They yielded readily to knowledge and experience. The Eskimos' intelligence and native talents due to environment proved to be of great use in the Pet 4 activities that were beyond the capabilities of stateside workers. Activities supported by Pet 4 have made great contributions to the general store of arctic knowledge.

Pet 4 also cast light on other environmental aspects that are of direct benefit to military concepts, and some of these are mentioned in this section.

Pet 4 required aerial photographs and maps far superior to anything that was available when the project started. The photographs were taken, mostly by the Navy, and the maps were compiled by the Geological Survey. These are now available for most of the Arctic slope. To be sure, the maps are not up to

the standards applied in other, better known areas; but they are, and long will continue to be, very useful.

A large store of knowledge has been accumulated about the oil and gas resources of the region. Incidental data were collected on other resources that have military significance if operations in the area are ever required. One such resource is coal, which is present in vast quantities, although of generally low quality, over much of the Arctic slope. Another is construction materials of many types.

The geologic surveys, both surface and subsurface, have resulted in a reasonably adequate knowledge of the rocks of northern Alaska and the thickness and types of surface cover. Similarly the geophysical surveys yielded much information on subsurface conditions as well as some facts about permafrost including its distribution, thickness, and variations from place to place under different conditions. The geophysical surveys included seismic surveys, airborne magnetometer surveys, and gravity surveys—all covered large areas.

The geologic and geophysical parties in particular learned and reported much terrain information including topography, relief and drainage, geomorphology, vegetal cover, formation of pingoes (frost mounds) and other premafrost features, kinds and distribution of animals, and many other data. Knowledge of the terrain and its hazards and helps to surface travel under winter conditions was collected abundantly during winter freighting operations.

Meteorological data were collected by almost all operating units and in total constitute a considerable store of knowledge of weather conditions. A work feasibility chart was developed by Pet 4 and summarizes some of the information in various categories.

A GLIMPSE OF THE FUTURE

Pet 4 was closed out toward the end of 1953. Already some of its experience and some of its facilities are being used for military and other purposes. The Arctic Research Laboratory is continuing, and good use is being made of some of the old buildings, the gas well, one of the smaller power plants, and equipment such as weasels and tractors. Also, supplies and fuel left at Barrow are being used. The CAA has taken over the airstrip, and it is being operated under CAA contract by Wien Alaska Airlines, which now provides commercial air service to and from Barrow from Fairbanks at least twice a week. The Fairbanks facility has been taken over by the Geological Survey. There is (end of 1954) also a watchman for Naval Petroleum Reserves at Barrow with a few Eskimo assistants.

The Air Force is embarking on a large project in northern Alaska (winter of 1954) and is taking over many of the facilities. It has taken over the Umiat camp and airstrip completely. The Air Force project is said to require a ship expedition, as it did in the fall of 1953, and the experience of Barex will be most helpful. Additional drafts on the Pet 4 background will be made through the individual experience of members of the Arcon personnel who have been employed by the Air Force project.

In Fairbanks, and to an undetermined extent in the oil industry, a keen interest has been stimulated in the possibility of the commercial development of the oil and gas possibilities of Arctic Alaska, especially the gas possibilities. A large gas field, the Gubik anticline, was found in the course of Pet 4 but was of no interest to the Navy. It lies just outside NPR 4 not far from Umiat. The idea would be to pipe the gas south through the low Anaktuvuk Pass through the Brooks Range and across interior Alaska to Fairbanks.

It would seem that every bit of pertinent information that came to light through Pet 4 should be organized, set down in useful fashion, and used in military thinking. An appraisal of the data available would reveal certain gaps in available knowledge and certain deficiencies in data that should be corrected through additional research, development, and testing. Most of these gaps are in the knowledge about the environment and how to deal with it. If the Arctic is important because of its geographic location or for other reasons, the military should insure itself against deficiencies in environmental knowledge and operational capability. More knowledge is required about the ocean, the land, and the air.

The remaining few paragraphs deal in speculations about some of the problems that might arise in any military activity in or over the Alaskan Arctic and the type of information that would result in greater operating ability and might save lives.

There would surely be survival problems for those unfortunate enough to become isolated from supplies and transportatoin. First might come the problem of location to occupants of a downed aircraft. Still better maps would be useful. How can one best travel on foot across the tundra of the foothills or coastal plain? The simple knowledge that many of the lakes are oriented 15° or so west of north might help. What arctic plants are edible and capable of yielding nourishment to humans? What animals and birds can be caught, and how? Where and how does one find nests, and at what season do they contain eggs? Is it better to follow this old beach line with its better footing or to strike out across the summer swamps of the coastal

plain? How can one improvise protection against clouds of vicious mosquitoes? Which way does the wind generally blow, and what are the weather signs? How reliable is a hand compass? Should a rifle be kept and carried, or should it be left behind as a useless weight? How does one cross streams?

In planning operations, both more meteorological data and more terrain information are needed—here again is the requirement for maps. What are the local variations in climate, and how can they be used? How reliable are the meteorological records from the few stations where records have been obtained? What is the habit of the sea fog that appears to lie near the edge of the ice pack? Why does it so frequently blanket the coast, blotting out airfields but also providing concealment? Why does the snow leave the interior before it melts from coastal areas? What does this mean in terms of transportation?

How difficult is it to build airstrips on sea ice? What is the best season for such a job? How long will it take? What equipment is needed? How long will it last? Which way will it move? Are airfields best located on the open tundra, ocean beaches, old beach lines inland, glacial outwash from the Brooks Range, or river bars? What will floods and ice do to river-bar landing areas?

What are the shore processes, and what is their relation to beach landings for assault, or for the unloading of supplies and freight? Can shore deposits be stabilized for foundations and for transportation? Can a dock be made that will stay in place, if so how? How rapidly will it silt up? How long will a dredged channel from the ocean into the protection of lagoons behind low-lying bar islands remain open? What are the acoustics of the solidly frozen sea and of the pack ice, and what may ice noises mean to underwater navigation of submarines? What can be learned about coastal and river navigation, and what equipment can be used or developed?

An obvious requirement is the improvement of vehicles for both summer and winter use. Especially needed is a freight or towing vehicle capable of travel over the tundra during the freezeup and breakup period. How feasible is road construction; how should roads be built? Is an east-trending road along the north front of the Brooks Range possible using the glacial outwash both as a location for the road and as road metal for construction?

Further attention should be given to improved arctic clothing. Native-type clothing is impracticable for large numbers of men because of insufficient supply of skins and difficulty of manufacture. Lightness, improved body and especially hand and foot movement, and better provision for seeing and hearing should be stressed. How can the personnel be indoctrinated against the traditional fear of the Arctic?

The Arctic holds many camouflage problems. Vehicle tracks are likely to remain easily visible for years because of the slow recovery of tundra vegetation. Even winter tracks may long be visible because the compacted snow affects the following summer's growth.

Water supply, especially in winter, is a difficult arctic problem. Must reliance be placed on melted snow or ice? How prevalent are places in streams or lakes that are deep enough to inhibit freezing to the bottom? Can year-round water supplies be had from unfrozen zones beneath present or past deep lakes or from alluvial deposits? What is the quality of underground water? Pet 4 data indicate that it frequently may be of very poor quality. What can be done about sewage disposal? Burning is likely to be difficult because of insufficient fuel.

Much more needs to be learned about permafrost. It affects transportation, construction, water supply, waste disposal, and almost every military activity in one way or another. What are the possibilities of using permafrost zones for underground cold storage, for various types of openings such as ammunition storage, living quarters, gun emplacements, mine fields, etc.?

What can be done to improve radio propagation and reception?

The implications of the above questions are many, and they represent the brief speculation of but one man. Many other questions could be asked, and the answers could be of large military application. Pet 4 has provided a considerable foundation. Its experience should be utilized and used as a springboard to more knowledge of possible military value.

Thus ends the story of Pet 4—truly an arctic epic. All material contained in this history, and much more, can be found in the files of the Office of Naval Petroleum Reserves, the Bureau of Yards and Docks, and the Geological Survey. Many technical and scientific details and interpretations will follow in published form as other reports in the series of which this is one.

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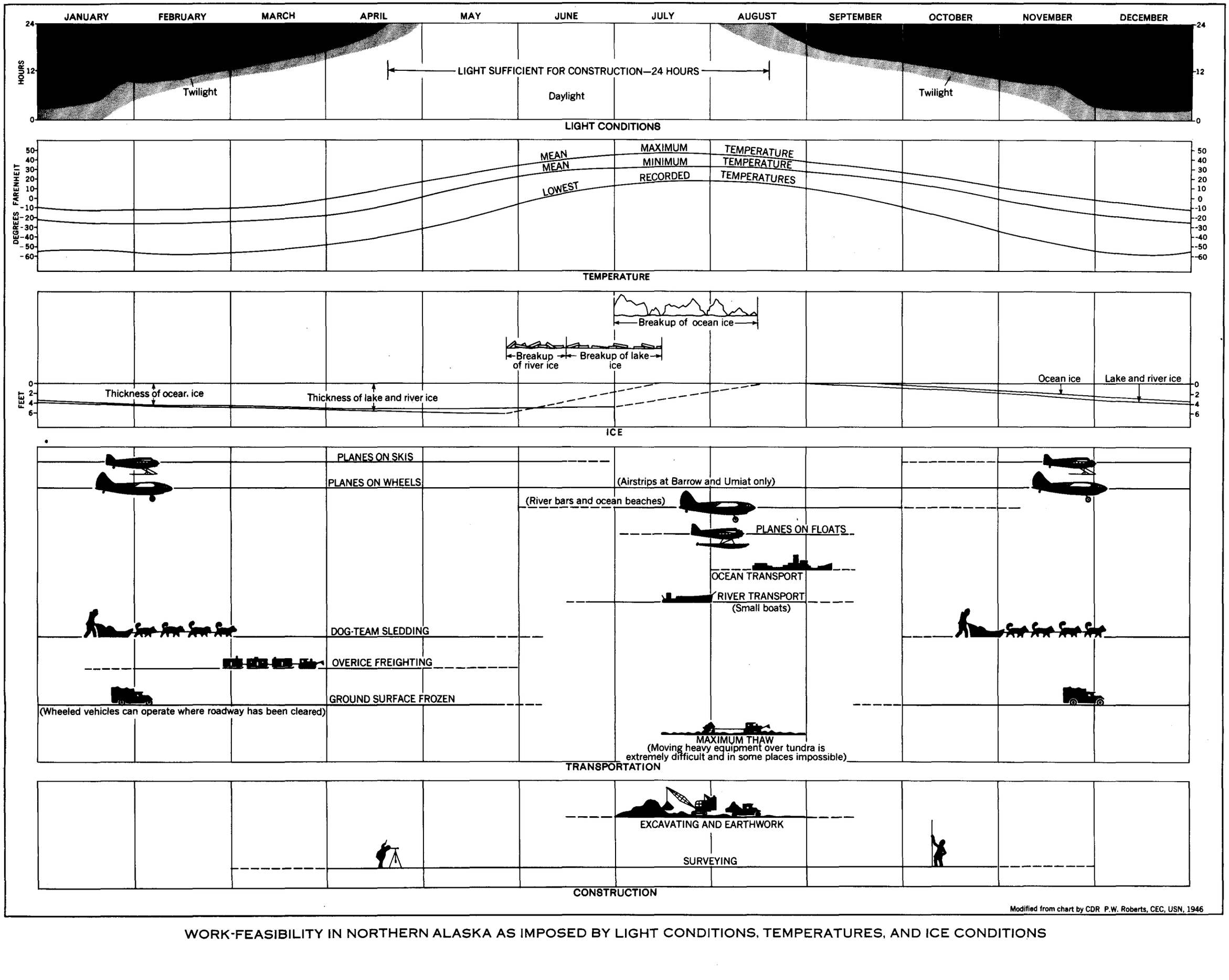

Modified from chart by CDR P.W. Roberts, CEC, USN, 1946

WORK-FEASIBILITY IN NORTHERN ALASKA AS IMPOSED BY LIGHT CONDITIONS, TEMPERATURES, AND ICE CONDITIONS

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