STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

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January 1976

Alaska Open File Report 93

A STRATIGRAPHIC STUDY OF THE GULF OF ALASKA TERTIARY PROVINCE, NORTHERN GULF OF ALASKA AREA

By: State Division of Geological and Geophysical Surveys and U.S. Geological Survey, Conservation Division

TABLE OF CONTENTS

FIGURES

ILLUSTRATIONS

APPENDICES

PARTICIPATING PERSONNEL

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ABSTRACT

Thick widespread sandstone beds, with an aggregate thickness up to 500 feet, crop out near the coast of the Gulf of Alaska, adjacent to state-owned acreage within the three-mile limit. These sandstones are in the basal Yakataga Formation of Miocene age. Sandstone and conglomerate units were deposited by channel cutting and filling, by longshore current action, and by wave action.

The sandstones have generally fair porosity and permeability, but good reservoir characteristics were found in the middle and upper parts of the formation in outcrops on the south flank of the Sullivan anticline. Porosity values greater than 20 percent along with good permeability were found in moderately thick sandstone beds deposited in shoreface or shallow marine, strandline depositional environments. The channel sandstones generally have less porosity and permeability than the marine shoreface deposits.

INTRODUCTION

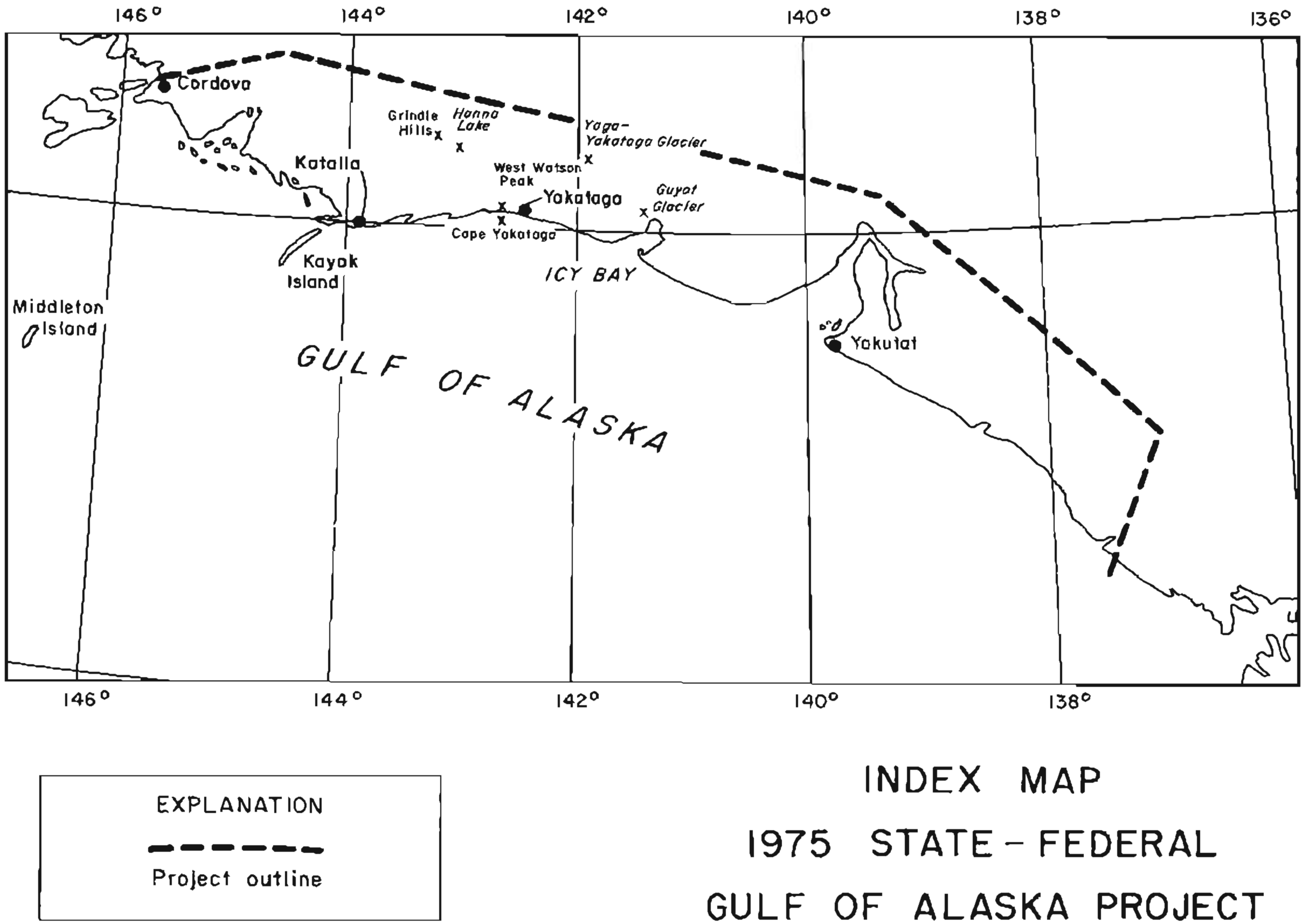
A stratigraphic field project was conducted in the Gulf of Alaska Tertiary Province (fig. 1) during a 30-day period in June and July of 1975 by the Alaska Division of Geological and Geophysical Surveys and the Conservation Division of the U.S. Geological Survey. The USGS Geologic Division in Menlo Park, Calif., was represented for 1 week.

Eight stratigraphic sections totaling 14,490 feet were measured and sampled. Five sandstone traverses were measured and sampled; they totaled 26,990 feet. Samples were obtained for porosity and permeability, microfossil and macrofossil paleontological age determinations, hydrocarbon source-rock determinations, stream-sediment geochemistry, and seep-oil analyses. Samples were also obtained for selected special analyses such as the petrography of the clasts on conglomeratic mudstone for provenance and oriented sandstone to supplement other paleocurrent data. Measurements were obtained on stratigraphic parameters and paleocurrents, thicknesses, reservoir parameters, stream-sediment profiles, and gravity.

This project, a joint state-federal effort, was the result of informal discussions between above agencies in the fall of 1974. These discussions concerned mutual areas of interest and objectives, were formalized in December, 1974 with an exchange of letters recommending that this joint project be accomplished in the summer of 1975.

Specific work areas and objectives were outlined to supplement existing published geological data and to provide new data on reservoir and source-rock potential of specific stratigraphic sections.

The Alaska Division of Geological and Geophysical Surveys (DGGS) is charged with determining the state's resource potential for both onshore state lands and offshore state submerged lands. The Conservation Division of the U.S.



INDEX MAP
1975 STATE - FEDERAL
GULF OF ALASKA PROJECT

Figure 1

Geological Survey (USGS) is charged with the classification and evaluation of resources and with lease-block evaluation on all federal lands, including the Outer Continental Shelf (OCS) adjacent to the onshore Gulf of Alaska Tertiary Province. The reservoir data collected from coastal exposures are needed to provide input for parameter extrapolation for the submerged lands, including the OCS area that is proposed for leasing.

Several meetings were held over the next few months to refine work areas and to discuss disposition of samples, laboratory analyses, costs, logistics, and departure date.

PERSONNEL AND LOGISTICS

The field crew consisted of party chiefs W.M. Lyle and I.F. Palmer; geologists D.L. McGee, T.C. MacKinnon, G.R. Winkler, and J.C. Wills; field assistant J.A. Morehouse; pilot D.M. Benesch; and mechanics E.A. Wical, Jr., and W.E. McNiff.

Lyle arranged logistics and support, and Palmer checked data quality control. Food and lodging was purchased from Minnie and Irwin Eggebroten at Cape Yakataga.

The crew chartered to Yakataga in a Sea Airmotive Twin Otter. Fuel was handled by Reeve Aleutian Airways. An International Air Taxi FH-1100 was used for field transportation. Only one-half day was lost because of mechanical down time. Two and one-half days were lost to weather.

On June 8, Winkler replaced MacKinnon on the project for 1 week. Wills joined the field party on June 12 and McGee returned to Anchorage. Commissioner of Natural Resources Guy R. Martin, P.L. Dobey, and T. McGinnes visited the field operations on June 16. McNiff replaced Wical as mechanic on June 18.

Because of the mountainous and highly glaciated terrain in the area to be investigated, field personnel attended a mountaineering safety session on the Eagle Glacier near Anchorage (p. H-4, H-5).

Approval to conduct the joint program on a cost-sharing basis was received by both agencies in the spring of 1975. A reconnaissance flight was made to the area to determine snow levels in the different working areas and to arrange for housing (p. H-1) and fuel storage (p. H-17).

Field personnel left Anchorage on June 3 and returned on July 3, 1975 after completing all proposed objectives.

FIELD METHODS

Measurements of Stratigraphic Sections and Traverses

Stratigraphic sections and sandstone traverses were measured primarily with Brunton compass and tape. Occasionally it was necessary to use the helicopter, altimeter, or photographs to determine thickness. All stratigraphic thicknesses are true thicknesses; they were corrected for dip and slope either in the field or at the base camp prior to rough drafting. Lateral-traverse distance measurements were made by tape or topographic map (or both) by using plotting stations and the map scale.

Lithologic Descriptions

Lithologic descriptions generally follow the accepted format, listed below:

> Rock type, descriptive modifier, color (from GSA Rock Color Chart), grain size (either Wentworth grade name or in actual metric measurements), sorting, lithologic constituents, statements concerning degree of induration, porosity, and sedimentary structures.

Abbreviations were commonly used to save time and space; notations such as "as above" were freely used if little obvious difference was noted.

Sampling

Samples from stratigraphic sections and sandstone traverses were collected in 7- by 12-inch sample bags in sufficient quantity to provide material for laboratory analyses and for sample cuts for both agencies. Whenever possible, the freshest material available was sampled by digging small pits in the outcrop. In some cases, where the hillside was extremely precipitous or at helicopter hover-spot sample sites, the pit technique was not possible.

SAMPLES

Statistics

A total of 448 samples and gravity stations were taken. They were: 151 for porosity determinations, 92 for parts per million (ppm) hydrocarbon analysis, 22 for macrofossil identification, 55 for microfossil identification, 41 for stream-sediment geochemical analysis, 2 for oil analysis, 76 gravity stations, 3 for oriented sandstone, 1 for coal, 2 for ripple-mark orientation, 2 for office examination, and 1 for water analysis.

The porosity, permeability, and ppm-hydrocarbon determinations were made by Chemical and Geological Laboratories of Alaska, Inc. The macrofossil determinations were made by L. Marincovich of the USGS. Age of sediments, depositional environment, and water depth during deposition determinations were made by Anderson, Warren, and Associates Inc. of San Diego, Calif. The microfossils are on file at the DGGS office at 3001 Porcupine Drive, Anchorage, Alaska 99501, and are available for examination.

The stream-sediments were analyzed for parts per million of gold, copper, lead and zinc. The gravity-station data were furnished to D.F. Barnes of the USGS for compilation and map preparation. Oil and water samples were examined by the German Geological Survey at the expense of Tenneco Oil Company. Petrography was done by Winkler of the USGS at Menlo Park, Calif.

Sample Numbering System

Most samples were numbered by using the collector's initials, a sequence number, and the year (for example, WL 2 75 or 3WL75 for William Lyle, samples 2 and 3, 1975). We made an attempt to standardize our work in the latter manner. In some cases, an A, B, or C was used if three samples were taken at the same location or at top, middle, and bottom locations on sandstone traverses.

The map number assigned to each sample is for ease of locating the sample. They are numbered from left to right by township, and start in the northwest corner of each quadrangle. The map numbers are cross referenced to the sample numbers on the insert on each quadrangle map. The reasons for taking the samples are also shown on the map.

Listed below are examples of sample numbers.

1P75	(Irven Palmer)	1WL75	(William Lyle)
1JM75	(Jeff Morehouse)	1JCW75	(John Wills)
1TM75	(Tom MacKinnon)	1GW75	(Gary Winkler)
1DM75	(Don McGee)		

STRATIGRAPHY

General Statement

The geology and stratigraphy of the Gulf of Alaska Tertiary Province have been described in literature by a number of persons. Significant among these are Taliaferro, 1932; Spieker and others, 1945; Miller, 1953a, 1953b; Miller, 1957; Plafker, 1967, and Miller, 1971. Because a reiteration of the general stratigraphy would serve no useful purpose, the interested reader is referred to these authors.

The following paragraphs provide a brief summary of the stratigraphic sections measured during the joint state-federal field project (pl. A). Detail descriptions, thickness of units, and laboratory analyses appear on the graphic displays in the map tube (part two of report).

A vertical scale of 1 inch = 100 feet was used on all stratigraphic sections except West Watson Peak. This scale was chosen because it is commonly used on well logs and other stratigraphic logs.

Eight stratigraphic sections (below) were measured and sampled during this project. Measured footage totaled 14,490 feet. Several of the stratigraphic sections have not previously been reported in literature, they should fill in gaps in regional stratigraphic control.

Grindle Hills Stratigraphic Section

This section, located in sec. 13, T. 19 S., R. 12-13 E., Copper River Meridian (CRM), was measured to establish the reservoir quality of the Middle-Upper Eocene Kulthieth formation (pl. I). The section is 896 feet thick and contains 642 feet of sandstone. The sandstones are massive, cross bedded, very fine to medium grained, and lack any visible porosity or permeability (p. H-8).

Laboratory analysis indicates the maximum porosity is 6.4 percent and the average porosity is 3.9 percent. Maximum permeability is 0.48 millidarcies; the average permeability is 0.06 millidarcies.

Hanna Lake Stratigraphic Section

Hanna Lake stratigraphic section (pl. II) is located in sec. 18, T. 19 S., R. 14 E., CRM on the eastern side of Bering Glacier. The section begins at the first massive sandstone in the high gradient stream bed at the north end of Hanna Lake. It was measured and sampled to provide additional Poul Creek Formation stratigraphic control. The sandstone units are well indurated, exhibit bioturbation, convolute bedding, and rip-up fragments in places, and commonly contain well-developed cross bedding. Some of the associated mudstone and siltstone beds are fossiliferous, and contain burrows, small coal fragments, ripple laminations, bioturbations, and convolute bedding.

Mudstone and siltstone units in the upper part of the section contain concretion zones with concretions up to 1 meter in diameter. In some cases, the nucleus of the concretion is a coalified piece of wood. Laboratory data suggest an Oligocene and lower Miocene age for these rocks. Maximum sandstone porosity is 4.6 percent and average porosity is 3.1 percent. Maximum permeability is 0.01 millidarcies; average permeability is 0.01 millidarcies.

West Watson Peak Stratigraphic Section

The West Watson Peak stratigraphic section (pl. V) is located in sec. 20, T. 21 S., R. 18 E., CRM on the western plunge of Sullivan anticline near the location where the structural axis turns sharply from eastwest to southwest at Cape Yakataga (pl. A).

This relatively small section was measured and included to illustrate a depositional sequence which occurs within the Yakataga Formation at several places (p. F-1)---namely, an upward coarsening of sediments with a corresponding increasing of the total sandstone content. The two major alternative depositional environments suggested by an upward coarsening of sediments are:

1. Delta -- including the prodelta, delta front, and delta plain facies.
2. Linear clastic shoreline -- including the open-marine and sand-shoreface facies (Selley, 1970).

Both types of depositional environments may occur within the Yakataga Formation. They may exist separately or in combination, where fluvial systems enter the marine system and the resulting deposits are products of marine current and wave domination (Fisher, 1969).

Paleontological analyses indicates an upper Miocene age for rocks exposed in this section. Maximum porosity is 12.1 percent and average porosity is 10 percent, whereas maximum permeability is 0.19 millidarcies and average permeability is less than 0.1 millidarcies.

Yaga-Yakataga Stratigraphic Section

This is the northernmost stratigraphic section measured during the 1975 field season (pl. VI). The section is located in secs. 17, 18, and 19, T. 20 S., R. 20 E., CRM and is 3,047 feet thick (185 feet of Poul Creek Formation and 2,862 feet of Yakataga Formation). About 756 feet is sandstone, 15 feet is conglomerate, and 2,105 feet is mudstone and siltstone that are locally conglomeratic; the remaining 171 feet is covered.

A channel series more than 220 feet thick was examined in detail (p. F-8). Channel cut and fill is well documented in the field. Graded beds, local conglomerate pods, and poorly sorted sandstones are in sharp contact with the underlying well-bedded fossiliferous mudstones and siltstones. Coal fragments and "ripped up" shale fragments are present in the section. Some of the present glacial valleys currently being filled with sandstones, mudstones, and conglomerates may be recent models for this type of deposition. Channels may also represent submarine fan-valley or glacial-fiord fill deposition. A 131-foot-thick mudstone contains concretions up to 4 feet in diameter. The mudstone has a "swirled" appearance, possibly indicating intraformational slump.

The Poul Creek portion of the section is composed of gray, green, and red weathering concretionary siltstone (p. F-7).

Maximum porosity in these sands (Yakataga Formation) is 15.7 percent and average porosity is 6.8 percent. The maximum permeability is 2.6 millidarcies and average permeability is 1.7 millidarcies.

Mount Eberly Stratigraphic Section

This section is located in sec. 35, T. 20 S., R. 20 E., CRM, and was sampled from near the axis of Yakataga anticline, about 200 feet above the lower Miocene-Oligocene Poul Creek Formation, to the massive conglomeratic mudstone that caps the top of the mountain (pl. VII). A 75-foot base line was set and photographed to estimate the basal unmeasured 200± feet of Yakataga Formation. Thickness was measured with a 100-foot tape, and each unit was sampled. Samples were taken for microfossil and macrofossil age determinations, porosity, permeability, and hydrocarbon source-rock potential.

The measured section is 6,094 feet thick and contains 990 feet of sandstone. Several environments of deposition appear to be represented, ranging from fluvial (coal and stream deposits) to marginal marine - inner neritic (asymmetrical ripple marks, flute casts, burrows, and fossils). Some shales were deposited in an outer-neritic environment.

The maximum porosity in the Mount Eberly sandstones is 19.2 percent and average porosity is 11.6 percent. Maximum permeability is 6.1 millidarcies and the average permeability is 1.7 millidarcies.

Umbrella Reef Stratigraphic Section

The Umbrella Reef stratigraphic section is located in sec. 7, T. 22 S., R. 20 E., CRM (pl. IX). This stratigraphic section is situated on the south flank of Sullivan anticline and is exposed only at low tide. The beds strike N. 75° W. and are vertical. The section is stratigraphically higher than the overturned Munday Creek section, located about 4 miles east. Together, these two sections provide the only stratigraphic control that is readily accessible and uncovered on the south flank of the Sullivan anticline. The extrapolation of stratigraphic parameters offshore must draw heavily on these outcrops because of this shoreline position.

Paleontological analyses date these rocks as upper Miocene age. Maximum porosity is 25.8 percent and average porosity is 24.5 percent. Maximum permeability is 597 millidarcies and average permeability is 261 millidarcies.

Munday Creek Stratigraphic Section

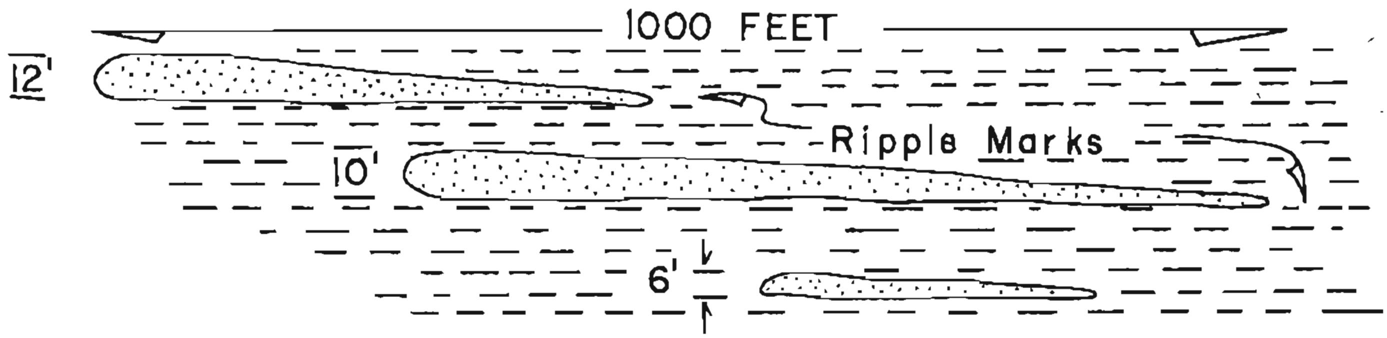
Munday Creek stratigraphic section is located in sec. 2, T. 22 S., R. 20 E., CRM (pl. XI). The Yakataga Formation is exposed in the Munday Creek stream valley about one-half mile inland from the present beach. The Munday Creek stratigraphic section is significant in that it provides the data to document the existence of thick potential reservoir sandstones on the south flank of Sullivan anticline, and at a position where there is little doubt about the possibility of extrapolation of thick potential reservoir sandstones into the nearby offshore area (p. F-4). The sandstones are medium gray, fine to medium grained, well sorted and consist of grains that are sub-rounded containing 45 percent quartz, 45 percent feldspar, and 10 percent lithic fragments as determined from field examination.

Paleontological analyses show the section to be upper Miocene in age. Maximum sandstone porosity is 20.8 percent and average porosity is 17.9 percent. Maximum permeability is 70 millidarcies and average permeability is 25.7 millidarcies.

Guyot Glacier-Nunatak Stratigraphic Section

This Yakataga Formation section was measured and sampled for reservoir and source rock potential (pl. XII). The section is located near the White River synclinal axis at the head of Icy Bay in secs. 16-21, T. 21 S., R. 23 E., CRM. The section is 862 feet thick (175 feet of conglomeratic siltstone, 80 feet of sandstone and conglomerate, 30 feet of sandstone and mudstone, 100 feet of sandstone and mudstone, 237 feet of mudstone, and 240 feet of thin-bedded siltstone containing ice-rafted pebbles and cobbles).

Three sand bodies are present within one of the major units. (See sketch on p. 9.) In about 1,000 lateral feet, the sand bodies thin from 6 feet, 10 feet, and 12 feet to a few inches of siltstone with asymmetrical ripple marks. The lenticular shape, the en echelon pattern, and the encasement in mudstone implies that each sand body is a small sandbar complex. The ripple marks strike N. 25° W. They have 1/2-inch amplitude and cover an area about 60 feet across.



SEDIMENTARY STRUCTURES AND DEPOSITIONAL FEATURES IN THE YAKATAGA FORMATION

Many of the structures of the Yakataga Formation are primary features, whereas others are the result of resedimentation mechanisms. Because of the vast area covered by the Yakataga Formation and the unusual glacial marine depositional environment, it is not surprising that there is a wide variety of sedimentary structures observed in these rocks.

Fluvial systems, deltaic systems, and glacial fiord or estuarine systems must have been active---sometimes in combination with strong marine processes. Along with these sedimentation mechanisms was a high level of both tectonic activity (evidenced by the many intraformational angular unconformities), and seismic activity (which probably served as the triggering agent that initiated the slump features evident in many outcrops).

Construction of a satisfactory depositional model must include all of the aforementioned systems; unfortunately, this is beyond the scope of this report. To facilitate efforts by others towards construction of depositional models, photographic documentation of many Yakataga Formation depositional features are included in this report (app. F).

Many of the photographs in appendix F show penecontemporaneous structures which are the results of slide masses. Olistostromes, melanges, or massive slump features are often discussed in literature with reference to deep-water deposits (Itsu, 1975; Nelson and Nilsen, 1975; and Abbate and Sagri, 1970).

Probably many of the features represented by the photographs are the result of processes very similar to contemporary sedimentation processes active along the present-day Gulf of Alaska coastline. Another section of this report will deal with these contemporary sedimentation features.

Most Yakataga Formation fauna is considered to be indicative of relatively shallow water (neritic zone). Therefore, the slump features exhibited in the Yakataga Formation were produced under somewhat different water-depth conditions than the deep-water types discussed in literature. In many of the Yakataga Formation depositional environments, channeling into laminated sediments resulted in fills of massive sandstone that are lacking in grading and other turbidite features (Whitaker, 1975). Additionally, the many penecontemporaneous structures probably resulted from mass sliding of semiconsolidated sediments, possibly triggered by seismic activity. Sliding of supersaturated material can take place from the shoreface downward in various water depths. Areas directly adjacent to fiord-type coastal reentrants would be especially subject to slumping.

The photos in appendix F may lead one to believe that these "exotic" structures are more common than even-bedded, undisturbed stratigraphic sections. This is not the case. In many places along the Sullivan anticline, the stratigraphic section is relatively undisturbed for thousands of feet; the exceptions are a few minor slide features, which are restricted to just a few beds.

In the Yakataga Formation, linear, even-bedded, sandy shoreface deposits and their down-dip equivalent siltstone and mudstone facies (Allen, 1970) are much more common than "channel" or "slump" features.

CONTEMPORARY SEDIMENTATION FEATURES

The glaciation in the Gulf of Alaska has long had a major influence on contemporary sedimentation. Large glacial fiords such as Icy Bay and Yakutat Bay are sites of massive iceberg calving. Glaciers enter these fiords heavily laden with superglacial debris ranging from mud to large boulders. This clastic debris is ice rafted into the fiords (and in some cases, to the open sea), where it is dumped. The constant "rain" of mud, along with the sporatic dropping of coarser clastic material, forms a conglomeratic mudstone (p. G-10, G-11). These same types of deposits are common in the Yakataga Formation.

In places where the terminal parts of glaciers are heavily laden with coarse clastics, great quantities of sand-sized material are carried to the sea by braided streams during high melting stages (p. G-7, G-8). The sand is moved along shore by littoral drift and by the Alaskan Gyral marine current system, with contemporary deposits being manifested in spits (p. G-9), bay mouth bars, longshore bars, and beach deposits (p. G-1, G-5). If these deposits were preserved in the subsurface, they would probably make good reservoirs.

In the Copper River delta area, fluvially derived material has been reworked by tides and waves to form a massive shoreface deposit of sand 4 to 5 miles wide and nearly 50 miles long (p. G-3). In other places, similar large rivers (such as the Alsek) also bring great quantities of sand-sized material to the sea, where it is completely redistributed by marine processes with no resultant delta buildup.

Dunes are being formed in several areas along the coastline. Dune orientations are in response to a dominately southeasterly prevailing wind (except in the Copper River delta area, where dunes are oriented north-south).

Near the terminus of Malaspina and Bering Glaciers, large glacial lakes serve as initial dumping sites for much superglacial debris. Deposition of glacial varved mud in these lakes has also been documented (p. G-6).

Present-day steep gradient streams are carrying pebble- to cobble-sized clasts into strandline beach deposits. Many of the sandstone-encased conglomerates in the Yakataga Formation were probably formed in this manner.

Evidence suggests that many of the contemporary sedimentation processes are exactly the same as those that produced the Yakataga Formation. In support of this concept, photographic documentation of many contemporary deposits are included as appendix G.

GULF OF ALASKA GLACIATION

In certain parts of mountainous North America---especially Alaska---glaciation was not restricted to the Pleistocene, but dates back to upper Miocene. This does not imply the existence of widespread continental pre-Pleistocene glaciation---only the existence of large-scale regional mountainous and piedmont glaciation. The sedimentary deposits produced by these large glaciers are no different than those produced by continental glaciation.

The Yakataga Formation contains an uncommon rock type referred to by Miller (1953a) as a marine tillite or conglomeratic sandy mudstone (p. F-5, F-21). This rock forms massive beds varying in shape from uniform to lensoid (p. F-10) and has a large lateral extent, resembles typical tillite of terrestrial origin, but differs in that it contains fossil remains of marine invertebrates and that it is interbedded with normal marine sedimentary rocks.

The conglomeratic sandy mudstones occur at all stratigraphic positions within the Yakataga Formation, which has a time span from upper Miocene through Pleistocene. These beds have been dated with macrofauna and microfauna. Excellent exposures occur on Cape Yakataga reef and at a stratigraphic position a few tens of meters above the Poul Creek-Yakataga formational contact. Therefore, an upper Miocene age is established for these glacial deposits.

The Wrangell Mountains lie north of the juncture of the Chugach and St. Elias Ranges. The White River valley, on the north flank of the Wrangells, contains thick stratigraphic sequences of interbedded tillites, fluvial units, and lava flows. Potassium-argon dates of the interbedded lava flows indicate that the tillites range from 10 to 3.6 m.y. old. The tillites are thus Miocene and Pliocene in age (Denton, 1969).

These two lines of evidence, faunal and radiometric, establish beyond all doubt that glaciation in the Gulf of Alaska began in upper Miocene, continued through the Pliocene and Pleistocene and, continues to this day. Many contemporary depositional processes and their resulting deposits currently being formed in the Gulf of Alaska are very similar to the depositional processes and sediments which characterize the Yakataga Formation.

PALEOCURRENT DATA

Introduction

Paleocurrent indicators are directional features that permit the sedimentologist to reconstruct different lithofacies or to determine spatial relationships of different depositional environments. These paleocurrent indicators are especially useful when the major objective is to determine sandstone trends. Recognition of the depositional environment in which a sand body was deposited is necessary in relating cross-bed attitudes, grain orientation, or other directional features to sandstone trends. Sometimes, features such as grain orientation are parallel to the strike of an alluvial sand; at other times, they are parallel to the dip of a marine shoreface sand.

Due to the time constraints imposed by the major objectives of the joint field project---that is, documentating the measuring and sampling of many stratigraphic sections and sandstone traverses---a great deal of time was not devoted to locating or making detailed measurements of directional features. However, when good cross beds were encountered, their attitudes were recorded. This section of the report contains those cross-bed observations.

Measurement and Rotation Techniques

Cross-bed attitudes were measured with a Brunton compass and level board. Dip directions and magnitude were obtained in the down-current trough axis where possible. Structural attitudes were also recorded at each site to permit removal of the structure at a later time. Cross-bed attitudes were grouped into 10-degree azimuth groups and averaged for plotting. These values were then rotated with the standard meridional stereographic net to remove the structural attitude recorded at each cross-bed location site. The rotated values were then plotted on the rose diagrams that appear as appendix E.

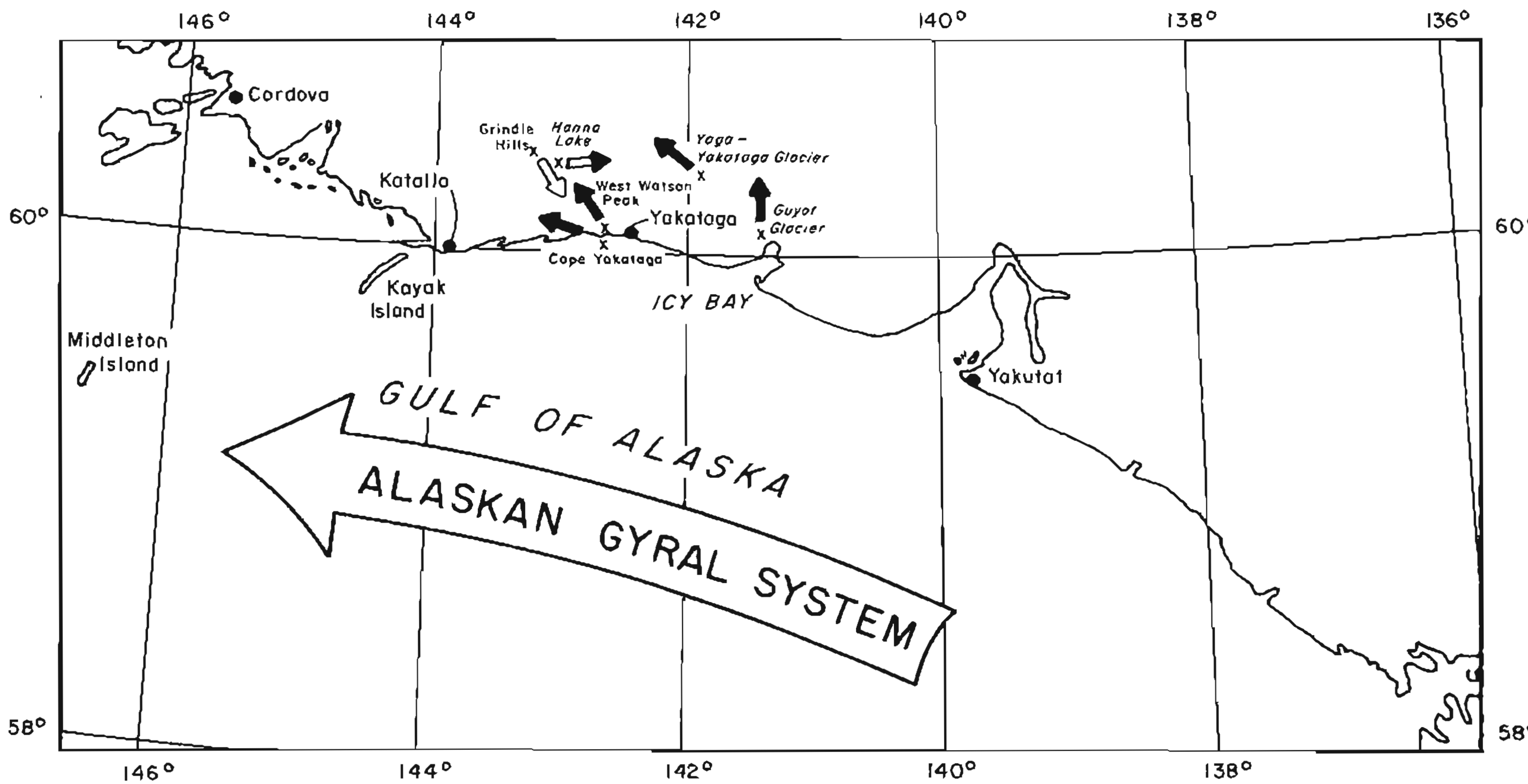
The rose-diagram plots are explained on the paleocurrent direction index. The structural dip was always removed to a zero value, even though there is usually some initial dip in any depositional environment. An error is, therefore, built into each rotational procedure; however, it is considered a small error.

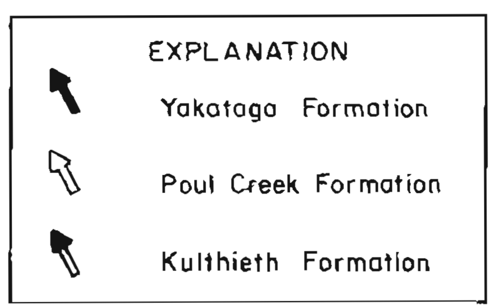
Conclusions

Paleocurrent directions derived from 56 observations from eight different locations are summarized in figure 2.

Data are too sparse to make any meaningful interpretation for paleocurrent directions during Kulthieth and Poul Creek time. One thing is certain: the paleocurrents that deposited the sands represented in the Grindle Hills (Kulthieth Formation) and Hanna Lake (Poul Creek Formation) stratigraphic sections do not conform to Yakataga Formation data. On the basis of limited information, the Yakataga Formation marine sandstones were deposited by paleocurrents flowing northwest.

Regional strike is generally east-west along the Sullivan anticline in the coastal Robinson Mountains; the exception is where the fold axis turns sharply southwest at Cape Yakataga. Here the strike is toward the northeast. Therefore, to place the Cape Yakataga rose diagrams in proper perspective with





SELECTED PALEOCURRENT AZIMUTHS
IN THE ROBINSON MOUNTAINS

Figure 2

the other Yakataga Formation data, the indicated westerly paleocurrents at Cape Yakataga must be rotated clockwise to the north.

Contemporary river- and bay-mouth bars and spits are offset westward along the coast, apparently in response to the counterclockwise rotation of the Alaskan Gyral marine current system. Along the Robinson Mountains coast, the present-day current velocity ranges from 5 to 10 miles per day to the northwest (Draft Environmental Impact Statement, 1975, Bureau of Land Management).

The paleocurrent data thus suggest that the Alaskan Gyral system has been active since Yakataga time (upper Miocene).

RESERVOIR CHARACTERISTICS

General Statement

Most published stratigraphic literature on the Gulf of Alaska Tertiary Province deals with the stratigraphic succession as observed and measured at localities from Katalla and Middleton Island on the west to Icy Point on the east. Sandstones are generally described in terms of thickness, color, and grain size, with perhaps some reference to general lithologic constituents and sedimentary structures.

One of the major objectives of the joint state-federal field project was to locate, sample, measure, and document potential sandstone reservoirs in the lateral dimension. These data, when coupled with stratigraphic section vertical data, would permit insight into sandstone geometry and spatial distribution.

Toward this end, several sandstone traverses were completed. At many lateral stations, samples of the sandstone being measured were taken both at the top and bottom (or other places where cover or inaccessibility dictated the need) for porosity, permeability, and petrographic analysis. Samples were also taken above and below the sandstone for paleontologic and hydrocarbon source-rock determinations.

The sandstone traverses (described from west to east in the next few paragraphs), together with the graphic displays of these traverses and related laboratory determinations, were made to establish not only the existence of but the lateral persistance of potential reservoir sandstones within the Yakataga Formation---considered to be the primary drilling objective in the Gulf of Alaska Tertiary Province.

WESTERN CAPE YAKATAGA TRAVERSE

The area traversed is located in sec. 36, T. 21 S., R. 17 E., CRM, on Cape Yakataga reef. It contains the next sand unit above the 30-foot-thick basal Yakataga Formation sand exposed on the reef (pl. III). It is included to show the sandstone units are finite, not ubiquitous. The sandstone is 6 feet thick at the south end at the water's edge, and extends northward for more than 700 feet before it pinches out. Cursory field examination indicates the sandstone to be very fine grained. This sandstone is probably typical of the shale-out edges of many of the thicker sandstones described below and observed in the field.

Paleontological data indicate an upper Miocene age for the rocks exposed in this traverse. Porosity ranges from 3.9 to 23.3 percent and permeability ranges from less than 0.01 to 46.0 millidarcies.

EASTERN CAPE YAKATAGA TRAVERSE

The sandstone measured and sampled in this traverse is located in sec. 36, T. 21 S., R. 17 E., CRM, on Cape Yakataga reef (pl. IV). It is the stratigraphically lowest and most easterly sandstone within the Yakataga Formation above the Poul Creek-Yakataga formational contact (p. F-17). This traverse provides potential reservoir control for the western end of the Sullivan anticline.

The sandstone is a massive unit (30 feet thick) and stands in prominent relief at the south end of the reef at the ocean. The thickness varies little, if any, over the 1,100 feet of lateral exposure; it is probable that it continues several thousand feet south and north from the exposure. The sandstone appears to be fine grained, moderately well sorted, and moderately friable, containing subrounded to subangular grains consisting of approximately equal amounts of quartz and feldspar and 10-15 percent lithic fragments with some clay interstitial fill. The top and bottom contacts are sharp and the basal part of the sand contains a fossiliferous zone composed of pelecypods and gastropods. The basal part also contains abundant coal fragments and small flecks of carbonaceous debris along most of the lateral exposure.

Most of the bedding appears planar; however, there are zones that contain good broad cross beds with sets up to 4 feet long. The cross beds occur at about midposition vertically within the sand body, at stations 4, 5, and 6 (app. E). The sandstone was probably deposited in a linear shoreface environment.

Paleontological data indicate an upper Miocene age for these rocks. Porosity ranges from 3.6 to 21.6 percent. Permeability ranges from 0.07 to 52.0 millidarcies.

WHITE RIVER GLACIER TRAVERSE

The White River Glacier was traversed (in sec. 29, T. 21 S., R. 20 E., CRM) at the position where the glacier turns abruptly westward from its southerly flow direction. This sandstone traverse was included because it is several thousand feet stratigraphically above the Yakataga-Poul Creek formational contact and because of its structural position near the White River Glacier synclinal axis.

Two sandstones separated by a silty mudstone were measured in this traverse. Samples were collected at eight stations along the 800-foot lateral exposure from within the upper sand and mudstone units and also from above and below them (pl. VII). The upper sandstone thickens from 35 to 62 feet along its length, whereas the lower sandstone thins from 48 to 41 feet. The upper sandstone is light-brownish gray, fine grained, well sorted, moderately friable, and consists of about 40-45 percent each of quartz and feldspar and 15 percent lithic grains, with a trace of clay and carbonaceous debris. Both sandstones exhibit a massive conchoidal weathering habit. In a few places, the sandstone contains fossiliferous lenses. The pebbly mudstone above the upper sand and silty mudstone between the two sands both contain pelecypods and gastropods. Both sandstones exhibit sharp upper contacts and gradational bases, and were probably deposited in a linear shoreface environment below the active swash zone of the beach.

Paleontological data indicate an upper Miocene age for rocks exposed in this traverse. Porosity ranges from 10.0 to 20.1 percent. Permeability ranges from 0.15 to 12.0 millidarcies.

MUNDAY GLACIER TRAVERSE

The sandstone measured and sampled in this traverse is located in secs. 25, 26, and 34, and secs. 30-32, T. 21 S., R. 20-21 E., CRM. The sandstone unit measured and sampled in this traverse is exposed in several glaciated valleys that deeply disect the Sullivan anticline, exposing the beds on the north flank of the structure (p. F-3). Lateral measurement was by topographic map. Vertical measurements were made with the Brunton compass and helicopter altimeter (pl. X).

The sandstone is uniform in both color and constituents wherever sampled. It is light-olive gray, fine grained, moderately well sorted, moderately friable at the top (becoming well indurated downward), and consists of about 35 percent quartz, 40 percent feldspar, and 25 percent lithic grains. It is a massive unit that exhibits no obvious bedding except faint planar laminations in a few places. The sand contains a conchoidal weathering habit, and large spall sheets appear at the base of the exposures.

The basal contact is gradational downward to siltstone and mudstone. The upper contact is sharp and the upper part of the sandstone contains conglomeratic zones.

This sandstone and several others can be seen in the south-facing cliff of Sullivan anticline. The thickness of these sands ranges from 20 feet to over 100 feet. The traversed sand extends for over 4 miles from the vicinity of Munday Glacier; it may extend much farther. Cursory field examination indicates the sand has poor to fair porosity and permeability. If areas exist where such large sands are only slightly cleaner, they would surely be potential reservoirs.

The sand was probably deposited in a marine linear shoreface environment below the active swash zone of the beach. Due to the gradational base and silt content, the environment was probably lower shoreface.

Paleontological data indicate the age of rocks in this traverse to be upper Miocene. Porosity ranges from 6.2 to 14.5 percent. Permeability ranges from 0.09 to 13.0 millidarcies.

ICY BAY TRAVERSE

This traverse was made in sec. 12, T. 22 S., R. 23 E., CRM, on the extreme eastern end of Sullivan anticline, adjacent to Icy Bay. The Cape Yakataga sandstones (pls. III, IV) provide potential reservoir control on the Sullivan structure on the western end (p. F-6), the Icy Bay sandstone provides potential reservoir control on the eastern end.

Samples were collected at 12 stations along the 2,990 feet of measured exposure. The main sand body of the traverse thickens westward to 30 feet from its pinchout edge (pl. XIII).

In general, the sandstone weathers in shades of brown, is fine to medium grained, friable, and contains about 40-50 percent each of quartz and feldspar and 10-15 percent lithic grains. There is no obvious bedding within the sand body. The contact at the top is sharp. The basal contact is mainly obscured. The main weathering habit is subconchoidal. Large sheets of the sandstone spall off and accumulate as talus at the base of the exposure.

Mudstone units above and below contain pelecypods and gastropods. The sandstones in this traverse were most likely deposited in a marine, linear shoreface environment below the active swash zone of the beach.

Paleontological data indicate an upper Miocene age for rocks exposed in this traverse. Porosity ranges from 17.0 to 27.1 percent. Permeability ranges from 23.0 to 308 millidarcies. The probability is high that sand bodies such as those exposed in this traverse would make excellent reservoirs if preserved in the subsurface.

RESERVOIR GEOMETRY AND SIZE

Examination of potential reservoir sandstones in Yakataga Formation outcrops suggest two main depositional systems for these sand bodies: linear shoreface deposits and channel deposits. The former sands could have been deposited in one of several marine depositional settings such as barrier islands, bay-mouth bars, spits, and beaches (Selley, 1970). The upper part of a beach shoreface is seldom preserved in the geological record. Most of Yakataga Formation sandstones of the linear clastic type exhibit transitional bases that grade downward to silty, muddy sediment beneath. These sands were probably deposited in the middle to lower shoreface regime. Marine faunas associated with these sands are shallow-water types; this substantiates the shoreface depositional environment.

The geometry of a sand deposited in a linear environment parallel to the shore can be quite varied. If major regressive and transgressive sea-level or tectonic movements (or both) were occurring during Yakataga time, a typical sand sheet should result. Evidence of tectonic movement exists at many places and is manifested by intraformational angular unconformities. Many of the linear bodies were probably deposited as regressive sand sheets adjacent to the rising land mass. The external morphology of these sand sheets or tabular bodies should have dimensions where the width-to-thickness ratio is 50-1,000 to 1 (Krynine, 1957). The exposures of the Yakataga Formation along the Sullivan anticline reveal sandstones that fit this tabular morphology. Thick, individual sands are visible for several miles and probably cover many tens of square miles.

Another type of sand deposit that results from deposition in a linear clastic environment is the so-called shoestring barrier sand. These deposits have a width-to-thickness ratio of less than 5 to 1 (Krynine, 1957). They would occur as isolated bars, spits, dunes, or channels. It is not known whether any of the observed Yakataga linear sands are of this type. However, some probably do exist.

The channel sand deposits within the Yakataga Formation are much more difficult to deal with. Where contorted beds are in evidence, they appear to be the product of a massive submarine slump. In other places, the sands contain erosional bases with a high conglomeratic content at the base, but become finer grained near the top; they are probably of fluvial origin (p. F-8, F-19, F-20).

Bedded rocks that have been incised by these channels (such as at Yaga-Yakataga) contain shallow-water marine fauna. However, because the channel deposits may or may not contain fossils, some of them are not strictly fluvial, but probably represent submarine extensions of fluvial systems similar to contemporary sedimentation in Icy Bay. Some channels may have been associated with delta complexes or located where fluvial systems entered estuaries or fiords. Seismic activity or loading probably triggered massive slumps sporadically, that would allow the large "slug" of channel fill to slump, contort, and cut out underlying beds. The length of these channels is not known; they should have a width-to-thickness ratio of approximately 5 to 1. All of the channel deposits are subordinate to the widespread marine linear shoreface deposits, that offer the greatest reservoir potential.

RESERVOIR THICKNESS

Discrete thickness was obtained on 85 Yakataga Formation sandstones during lateral sandstone traverse and vertical stratigraphic section measuring. When grouped into four thickness ranges, the following statistics were evident: 40 percent of Yakataga Formation sandstones are less than 10 feet thick; 36 percent are between 10 and 50 feet thick; 12 percent are 50 to 100 feet thick; and 12 percent are over 100 feet thick. There are significant numbers of thick sandstones that could be potential reservoirs.

RESERVOIR POROSITY AND PERMEABILITY

Plate I shows the maximum and average porosity and permeability of sandstones within the Yakataga Formation that have been sampled in both measured stratigraphic sections and traverses in the Robinson Mountains area. Several observations can be made from the data:

1. Sandstones in the Yakataga Formation have higher average porosities on the south side of Sullivan anticline, near the present coast, than in the hinterlands to the north. Examples from five Sullivan anticline locations are listed below.

	Average porosity (%)	Average permeability (millidarcies)
West Yakataga reef traverse	13.6	10.4
East Yakataga reef traverse	16.9	9.67
Munday Creek stratigraphic section	17.9	25.8
Umbrella Reef stratigraphic section	24.5	267.0
Icy Bay traverse	23.7	139.0

2. Shallow-water strandline sandstones exhibit the best porosities and permeabilities in the Yakataga Formation:

	Average porosity (%)	Average permeability (millidarcies)
Icy Bay traverse	23.7	139.0

3. Porosities and permeabilities are generally lower in channel fill deposits:

	Average porosity (%)	Average permeability (millidarcies)
Yaga-Yakataga glaciers stratigraphic section	6.9	0.47

4. The older Poul Creek and Kulthieth Formation samples have much lower porosities and permeabilities than those from the Yakataga Formation.

RESERVOIR-STRUCTURE SPATIAL RELATIONSHIP

One of the major goals of this field project was documentation of potential reservoirs in relation to known structures. Stratigraphic section and traverse locations were selected to facilitate this documentation. Data from these locations were supplemented by visual observations and photographs. Plate A shows the location of the stratigraphic sections and sandstone traverses in relation to major structural axes. Readers aware of previously published stratigraphic section locations will see that those sections measured during the 1975 field season supplement data obtained from earlier measured sections.

Study of the stratigraphic sections and traverses at each map location, along with examination of the photographs (app. F, G, H), will show that potential reservoir sandstones are not restricted to any particular area or side of a structure; they occur on all sides of both the Yakataga and Sullivan anticlines, in their downdip flank positions, and within the White River and Yaga synclines.

This almost ubiquitous occurrence of potential reservoir sandstone over such a large area is most significant when thought of in terms of the high probability of similar sands continuing offshore. The north-south distance over which potential reservoirs have been measured and observed from the confluence of Yakataga and Yaga Glaciers to Umbrella Reef exceeds 10 miles. Near shore eivdence appears to support the idea that similar sandstone development should extend offshore.

The probability is high that strandline sandstones, such as those described at Munday Creek (pl. XI), on the south flank of Sullivan anticline, continue some distance offshore.

PETROGRAPHY OF TERTIARY SANDSTONES

The data in this section were not ready for inclusion in the report at the time of publication. Data will be issued as an addendum in the near future.

PETROGRAPHY OF CONGLOMERATIC MUDSTONE CLASTS

The data in this section were not ready for inclusion in the report at the time of publication. Data will be issued as an addendum in the near future.

HYDROCARBON SOURCE ROCKS

Ninety-two potential hydrocarbon source-rock samples were collected adjacent to potential reservoir sandstones during the measuring and sampling of both stratigraphic sections and traverses. Plate H shows a plot of the range and average of total hydrocarbons in parts per million for the Yakataga Formation as determined at the various section and traverse locations. Appendix C shows the raw laboratory data. (The ppm values appear low; this may be partially due to weathering.)

These data should supplement well-control analyses and help provide a third dimension for regional source-rock evaluations.

It is inappropriate to discuss petroleum generation in terms of threshhold levels for the Gulf of Alaska Tertiary Province in this report. The existence of the Katalla oil field and the many documented oil seeps from Katalla to Samovar Hills is ample proof of the ability of the drillable stratigraphic section to generate petroleum. More germane to the overall hydrocarbon potential of the Gulf of Alaska Tertiary Province is the preservation of original porosity and permeability and the timing of petroleum generation, migration, and structural growth.

OIL SEEPS

Seep oil from three widely separate areas was sampled for complete chemical analyses. These areas are the katalla oil-field seep (p. H-13, H-14), the Johnston Creek seep at Sullivan anticline (p. H-2), and the Samovar Hills seep (p. H-11, H-12). The analyses of two of these seep oils appear in appendix D. The analyses were obtained by Tenneco at no cost to either the State of Alaska or the U.S. Geological Survey. It is hopeful that these analyses will provide additional data necessary for the design of treatment plants, pipelines, corrosion and pollution control, and LNG and refinery installation.

The seep oil was collected from active pools or accumulation sites rather than stagnant areas. Every effort was made to prevent contamination by vegetation or other extraneous matter. The seeps were sampled by bringing the outer surface of a glass bottle or can into contact with the oil surface and then letting the oil drip into new polyethylene bottles.

GRAVITY CONTROL

Gravity data recorded during the 1975 field season have been turned over to D.F. Barnes of the USGS in Menlo Park, Calif. These data will be incorporated into revised gravity maps as time permits.

GEOCHEMICAL CONTROL

Stream-sediment geochemical determinations were not ready for inclusion in the report at the time of publication. Data will be issued as an addendum in the near future.

CONCLUSIONS

The authors' feel that the stratigraphic data presented will fill in gaps in regional stratigraphic control, and that the results of this study should be a major contribution to those federal and state agencies charged with classifying and evaluating petroleum resources on public lands.

Significant data have been obtained on potential reservoir size, geometry, reservoir-structure spatial relationships, thickness, quality, and percent of reservoir to total section. New data have been obtained on Yakataga Formation sedimentary structures, contemporary sedimentation features, paleocurrents, petrography, provenance, hydrocarbon source-rock potential, seep-oil analyses, gravity, geochemistry of stream sediments, and stratigraphic age. Synthesis of these data should aid industry and governmental agencies in making meaningful offshore extrapolations.

ACKNOWLEDGEMENTS

The manuscript was reviewed by R.G. Schaff, L.F. Larson, D.L. McGee, W.M. Lyle, I.F. Palmer, R.H. McMullin, and J.E. Callahan.

Seep-oil and water analyses were obtained through Tenneco Oil Company. Special thanks are extended to G.R. Winkler and L. Marincovich of the U.S. Geological Survey, Geologic Division, for their contributions on petrography, provenance, and megafossil determinations. We also thank H.S. Potworowski of the DGGS laboratory for performing the stream-sediment geochemical analyses.

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POROSITY AND PERMEABILITY ANALYSES

APPENDIX A

GRINDLE HILLS STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
12-JCW-75	3.3	<0.01
14-JCW-75	3.8	<0.01
16-JCW-75	3.2	<0.01
17-JCW-75	3.8	<0.01
18-JCW-75	3.9	<0.01
19-JCW-75	4.1	<0.01
WL-46-75	1.9	<0.01
WL-48-75	4.9	<0.01
WL-49-75	3.3	0.01
WL-53-75	6.4	0.48

HANNA LAKE STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
P-64-75	2.7	<0.01
P-70-75	2.1	<0.01
P-77-75	4.6	<0.01

WEST YAKATAGA REEF TRAVERSE

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
35B-JM-75	4.2	<0.01
36B-JM-75	19.5	5.55
37B-JM-75	20.3	11.
38B-JM-75	23.3	45.
39B-JM-75	10.1	0.71

EAST YAKATAGA REEF TRAVERSE

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
1A-JM-75	3.6	0.07
1B-JM-75	7.3	3.89
2A-JM-75	18.5	33.
2B-JM-75	20.6	9.50
3A-JM-75	19.0	23.
3B-JM-75	19.2	6.23
4A-JM-75	18.6	17.
4B-JM-75	20.3	4.59
5A-JM-75	20.8	52.
5B-JM-75	18.5	2.83
6A-JM-75	21.6	17.
6B-JM-75	19.0	4.55
7A-JM-75	17.4	10.
7B-JM-75	18.4	5.27
8A-JM-75	18.5	3.87
1A-JCW-75	15.6	2.40
1B-JCW-75	16.1	0.98
2A-JCW-75	16.0	0.50
2B-JCW-75	17.2	0.30
3A-JCW-75	18.5	11.
3B-JCW-75	17.7	4.55
4A-JCW-75	10.3	0.12

WEST WATSON PEAK DETAILED STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
P-61-75	7.9	<0.01
P-63-75	12.1	0.36

YAGA-YAKATAGA STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
6-JCW-75	15.7	0.09
9-JCW-75	6.4	0.43
10-JCW-75	2.5	<0.01
P-33-75	7.6	0.04
P-56-75	2.5	<0.01
P-58-75	5.4	<0.01
P-60-75	5.8	<0.01
WL-22A-75	11.2	0.04
WL-22-75	8.2	0.23
WL-23-75	8.1	0.36
WL-24-75	8.2	0.24
WL-25-75	7.6	0.47
WL-26-75	6.8	0.12
WL-28-75	8.6	0.02
WL-29-75	7.1	1.63
WL-30-75	9.3	2.62
WL-35-75	6.5	1.06
WL-38-75	3.4	0.11
WL-43-75	6.7	0.31

MOUNT EBERLY STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
JCW-22-75	6.3	<0.01
JCW-24-75	10.7	0.32
JCW-26-75	9.9	0.35
JCW-28-75	12.4	0.39
JCW-29-75	9.7	0.94
JCW-30-75	2.7	<0.01
JCW-31-75	7.7	0.53
32-JCW-75	11.6	0.86
P-92-75	10.6	<0.01
P-101-75	9.7	4.23
P-102-75	14.4	0.13
P-103-75	17.5	0.47
WL-111-75	14.6	1.52
WL-117-75	12.6	5.02
WL-122-75	19.2	6.11
WL-130-75	16.6	6.34

WHITE RIVER GLACIER TRAVERSE

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
WL-41B-75	13.7	1.18
WL-41C-75	14.4	3.15
WL-42A-75	11.2	0.24
WL-42B-75	18.3	6.78
WL-42C-75	20.1	11.
WL-55-75	10.0	0.15
WL-56-75	13.3	1.52
WL-57-75	18.3	12.
WL-58-75	12.5	10.
WL-60-75	15.5	2.40
WL-61-75	17.2	10.
WL-63-75	16.5	4.50
WL-64-75	17.8	7.53
WL-66-75	17.8	3.63
WL-69-75	10.0	8.08

UMBRELLA REEF STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
P-84-75	25.0	180.
P-87-75	25.8	268.
P-90-75	25.6	597.
P-91-75	21.4	25.

MUNDAY GLACIER TRAVERSE

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
40-JM-75	9.0	0.34
41-JM-75	14.5	3.77
JCW-36-75	13.9	2.29
P-114-75	6.2	<0.01
WL-92-75	11.4	0.83
WL-100-75	8.2	0.09
WL-101-75	14.5	13.

MUNDAY CREEK STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
DLM-1-75	16.9	48.
DLM-3-75	20.6	18.
DLM-5-75	18.2	17.
DLM-7-75	19.1	30.
DLM-8-75	20.0	18.
DLM-9-75	16.8	12.
DLM-10-75	20.1	24.
DLM-11-75	5.2	.02
DLM-12-75	20.5	48.
DLM-14-75	20.1	24.
DLM-15-75	20.8	20.
16-DM-75	10.9	5.89
19-DM-75	24.0	70.

GUYOT GLACIER NUNATAK STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
TM-9-11-75	12.3	0.70
TM-12-75	9.4	3.05
TM-14-75	8.3	0.33
WL-2-75	4.7	0.36
WL-3-75	1.1	<0.01
WL-8-75	3.8	<0.01
WL-9-75	17.0	99.
WL-10-75	15.9	70.
WL-11-75	10.8	12.
WL-12-75	21.6	520.
WL-13-75	22.1	450.
WL-14-75	24.1	508.

ICY BAY TRAVERSE

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
P-4-75	24.2	217.
P-6-75	27.1	308.
P-8-75	24.5	141.
P-10-75	24.6	195.
P-11-75	23.9	210.
P-12-75	24.1	109.
P-14-75	25.5	192.
P-15-75	23.7	158.
P-16-75	24.2	96.
P-17-75	25.1	122.
P-19-75	21.2	34.
P-20-75	17.0	23.
P-22-75	23.7	91.
P-23-75	23.4	45.

MISCELLANEOUS SAMPLE

Surface Samples

Sample No.	Porosity Percent	Permeability Millidarcies Horizontal
WL-66B-75	5.7	0.02

PALEO DETERMINATIONS

APPENDIX B

ANDERSON, WARREN & ASSOCIATES, INC.
CONSULTING MICROPALEONTOLOGY
11526 Sorrento Valley Road Suite G
San Diego, California 92121
(714) 755-1524
Cable: Micropaleo San Diego

September 16, 1975

TO: U.S.G.S.

RE: State of Alaska - U.S.G.S.
Gulf of Alaska Surface Samples

FORAMINIFERA REPORT

3-P-75

Buccella frigida (R), B. tenerrima ? (F), Cassidulina californica (R), C. cf. teretis (F), Elphidium bartletti (R), E. clavatum (A), Glandulina laevigata (R), Haplophragmoides deformes (C), Lagena sp. (R), Marginulina glabra ? (R), Quinqueloculina sp. (R), shell fragments (F).

AGE: Pliocene to Pleistocene
ENVIRONMENT: Neritic, possible Inner to Middle Neritic

5-P-75

Buccella sp. (R), Cassidulina cf. limbata (R), C. cf. teretis (F), Elphidium clavatum (C), Haplophragmoides deformes (F), Pulvinulinella pacifica (F), coal (R).

AGE: Pliocene to Pleistocene
ENVIRONMENT: Neritic to Upper Bathyal

7-P-75

Buccella frigida (R), Cassidulina cf. teretis (R), Elphidium bartletti (R), E. clavatum (F), E. oregonense (R), Pulvinulinella pacifica (R), shell fragments (R), coal (F).

AGE: Pliocene to Pleistocene
ENVIRONMENT: Neritic to Upper Bathyal

RE: Gulf of Alaska Surface Samples

9-P-75

Buccella ? sp. (R), Cassidulina cf. limbata (R), Cibicides fletcheri (R), Elphidium bartletti (R), E. clavatum (C), Haplophragmoides deformes (F), Polymorphina ? sp. (R), Pulvinulinella pacifica (F), Quinqueloculina sp. (R), shell fragments (R), coal (F).

AGE:	Pliocene to Pleistocene
ENVIRONMENT:	Possible Outer Neritic to Upper Bathyal

21-P-75

Cassidulina cf. translucens (R), C. cf. teretis (R), Elphidium bartletti (R), E. clavatum (F), E. oregonense (R), Glandulina laevigata (R), Haplophragmoides deformes (R), Nonionella auricula ? (R), Pulvinulinella pacifica (R).

AGE:	Pliocene to Pleistocene
ENVIRONMENT:	Neritic to Upper Bathyal

34-P-75

Haplophragmoides spp. reworked ? (R).

AGE:	Indeterminate
ENVIRONMENT:	Indeterminate

55-P-75

Cassidulina cf. laevigata (C), Elphidium cf. bartletti (R), E. clavatum (R), Glandulina laevigata (R), Haplophragmoides cf. deformes (R), coal (R).

AGE:	Possible Late Miocene to Pliocene
ENVIRONMENT:	Possible Neritic

RE: Gulf of Alaska Surface Samples

62-P-75

Bulimina auriculata ? (F), Cassidulina californica (R), Cyclammina cf. pacifica (R), Dentalina ? fragments (R), Eilohedra levicula (R), Glandulina laevigata (R), Haplophragmoides deformes (A), H. cf. trullissata (R), H. cf. obliquicameratus (F), H. sp. (F), Pullenia malkinae (R), Pulvinulinella exigua (R), P. cf. pacifica (R), Uvigerina cushmani (C), Globigerina sp. (R), echinoid remains (R), shell fragments (R), coal (C), pyrite (F).

AGE: Probable Late ? Miocene to Pliocene

ENVIRONMENT: Outer Neritic to Upper Bathyal

65-P-75

Haplophragmoides spp. (R), Valvulineria willapaensis (R), glauconite (A), pyrite (R).

AGE: Possible Refugian to Zemorrian

ENVIRONMENT: Marine

67-P-75

Haplophragmoides translucens (R), H. sp. (R), coal (F).

AGE: Probable Eocene to Oligocene

ENVIRONMENT: Neritic ?

68-P-75

Bathysiphon sp. (R), Cassidulina crassipunctata (R), Cibicides elmaensis (F), Elphidiella sp. (C), Eggerella ? sp. (R),

RE: Gulf of Alaska Surface Samples

68-P-75 (con't.)

Gyroidina sp. (R), Haplophragmoides krishtafovitchae (R), H. translucens (F), H. "excavata" (R), H. spp. (C), Nonion pompilioides (R), Pseudoglandulina inflata (R), Robulus sp. (R), Sigmomorphina schencki (R).

AGE: Refugian to Zemorrian, possible Early Zemorrian

ENVIRONMENT: Lower Bathyal to Abyssal

69-P-75

Anomalina glabrata (R), Bathysiphon sp. (F), Cibicides elmaensis (F), Cyclammina pacifica (R), Elphidiella sp. (C), Gyroidina soldanii var. (R), Haplophragmoides cf. becki (R), H. translucens (F), H. cf. "excavata" (F), H. spp. (A), pyrite (C).

AGE: Refugian to Zemorrian, possible Early Zemorrian

ENVIRONMENT: Middle to Lower Bathyal

71-P-75

Bathysiphon sp. (F), Cassidulina crassipunctata (R), Chilostomella ? sp. (R), Cibicides elmaensis (F), Cribrononion cf. roemeri (A), Cyclammina pacifica (R), Guttulina irregularis ? (R), Haplophragmoides krishtafovitchae (F), H. translucens (R), H. spp. (C), Nonion pompilioides (R), Quinqueloculina ? sp. (R), Robulus sp. (R), Sigmomorphina ? sp. (R), echinoid remains (F).

AGE: Probable Early Zemorrian

ENVIRONMENT: Lower Bathyal to Abyssal

RE: Gulf of Alaska Surface Samples

76-P-75

Ammodiscus sp. large (R), Bathysiphon sp. (R), Cassidulina crassipunctata (R), Cibicides elmaensis (R), Cyclammina pacifica (F), Dentalina sp. (R), Gyroidina soldanii var. (R), Haplophragmoides becki (R), H. translucens (F), H. "excavata" (R), H. spp. (A), Nonion cf. incisum (R), N. pompilioides (R), Pseudoglandulina inflata (R), echinoid remains (R), pyrite (C).

AGE: Refugian to Zemorrian, possibly the latter

ENVIRONMENT: Lower Bathyal to Abyssal

80-P-75

Guttulina sp. (R), Haplophragmoides sp. (R).

AGE: Possible Refugian to Zemorrian

ENVIRONMENT: Marine

81-P-75

Arenaceous spp. crushed (A), Bathysiphon sp. (R), Cyclammina pacifica (F), Haplophragmoides obliquicameratus (R), H. translucens (R).

AGE: Possible Eocene to Oligocene

ENVIRONMENT: Bathyal

83-P-75

Buccella tenerrima ? (R), Cassidulina cf. translucens (R), Elphidium clavatum (C), Glandulina laevigata ? (R), shell fragments (R).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Possible Neritic

RE: Gulf of Alaska Surface Samples

85-P-75

Cassidulina sp. (R), Elphidium clavatum (C), E. cf. frigidum (C), Eponides columbiensis (R), Quinqueloculina stalkeri (R), bryozoans (R), shell fragments (R).

AGE:	Probable Pliocene to Pleistocene
ENVIRONMENT:	Neritic, possible Inner to Middle Neritic

88-P-75

Buccella frigida (R), B. tenerrima (R), Cassidulina cf. limbata (R), C. minuta (R), C. cf. teretis (F), Elphidium clavatum (A), Glandulina laevigata (R), Nonionella auricula (R), Pulvinulinella pacifica (F), Pyrgo sp. (R), shell fragments (F), coal (F).

AGE:	Probable Pliocene to Pleistocene
ENVIRONMENT:	Outer Neritic to Upper Bathyal

95-P-75

Anomalina glabrata (F), Cassidulina laevigata (F), C. cf. teretis (R), Cyclammina pacifica (R), Elphidium clavatum (F), Fissurina sp. (R), Glandulina laevigata (R), Haplophragmoides deformes (C), Pulvinulinella cf. pacifica (R), Uvigerina sp. (R), pyrite (C).

AGE:	Probable Miocene
ENVIRONMENT:	Bathyal

RE: Gulf of Alaska Surface Samples

97-P-75

Anomalina glabrata (C), Cassidulina laevigata (A), C. minuta (F), C. norvangi (R), C. cf. translucens (R), C. cf. teretis (F), Cibicides cf. evolutus (R), C. fletcheri (F), Elphidium clavatum (R), Glandulina laevigata (R), Haplophragmoides sp. (R), Nonionella miocenica (R), Pullenia cf. malkinae (R), Quinqueloculina sp. (R), Virgulina sp. (R), Globigerina pachyderma ? (R), shell fragments (R).

AGE: Probable Late ? Miocene to Pliocene

ENVIRONMENT: Neritic to Upper Bathyal

100-P-75

Barren of foraminifera.

AGE: Indeterminate

ENVIRONMENT: Indeterminate

106-P-75

Cassidulina laevigata ? (R), Elphidium clavatum (R), shell fragments (R).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Marine

112-P-75

Bolivina ? sp. (R), Buccella tenerrima ? (R), Cassidulina laevigata ? (A), C. minuta (F), Cibicides fletcheri (F), Elphidium clavatum (A), Quinqueloculina sp. (R), Virgulina ? sp. (R), ostracods (R), shell fragments (F).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Neritic to Upper Bathyal

RE: Gulf of Alaska Surface Samples

16-WL-75

Buccella tenerrima (R), Cassidulina californica (R), C. cf. limbata (F), C. cf. translucens (R), C. cf. teretis (F), Elphidiella hannai (F), Elphidium bartletti (R), E. clavatum (A), Glandulina laevigata (F), Haplophragmoides cf. deformes (A), Nonionella auricula (F), N. cf. labradorica (R), Pullenia malkinae (R), Globigerina bulloides (R), G. pachyderma (F), G. quadrilatera (C), G. quinqueloba (R), shell fragments (C), coal (F).

AGE:	Pliocene to Pleistocene, possible Late Pliocene to Early Pleistocene
ENVIRONMENT:	Middle to Outer Neritic

21-WL-75

? Anomalina glabrata (R), Cassidulina laevigata ? (F), C. minuta (R), C. cf. teretis (R), Elphidium clavatum (R), Glandulina laevigata (R), Haplophragmoides deformes (R).

AGE:	Late ? Miocene to Pliocene
ENVIRONMENT:	Neritic to Upper Bathyal

27-WL-75

Buccella frigida ? (R), Cassidulina laevigata ? (C), C. cf. translucens (R), Cibicides evolutus (R), Dentalina sp. (R), Elphidium clavatum (F), Haplophragmoides cf. deformes (R), Pulvinulinella cf. pacifica (R).

AGE:	Late ? Miocene to Pliocene
ENVIRONMENT:	Outer Neritic to Upper Bathyal ?

RE: Gulf of Alaska Surface Samples

31-WL-75

Buccella frigida ? (R), Cassidulina laevigata (C), C. cf. teretis (R), Dentalina sp. (R), Elphidium bartletti (R), E. clavatum (R), Glandulina laevigata (R), Haplophragmoides deformes (C), H. cf. obliquicameratus (R), H. sp. flat (R), Pulvinulinella cf. pacifica (R), shell fragments (F).

AGE:	Late ? Miocene to Pliocene
ENVIRONMENT:	Outer Neritic ? to Upper Bathyal

32-WL-75

Cassidulina laevigata (F), C. cf. teretis (R), Elphidium clavatum (F), E. sibiricum (R), Glandulina laevigata (R), Haplophragmoides deformes (F), H. sp. (R), Globigerina pachyderma ? (R), G. sp. (R).

AGE:	Late Miocene to Pliocene, possibly the former
ENVIRONMENT:	Neritic to Upper Bathyal

36-WL-75

Glomospirella sp. reworked (R).

AGE:	Indeterminate
ENVIRONMENT:	Indeterminate

91-WL-75

Cibicides fletcheri (R), Elphidium clavatum (F).

AGE:	Late ? Miocene to Pleistocene
ENVIRONMENT:	Neritic ?

RE: Gulf of Alaska Surface Samples

95-WL-75

Cassidulina laevigata ? (C), C. minuta (A), Cibicides fletcheri (R), Elphidium bartletti (R), E. clavatum (F), Haplophragmoides deformes (C), Miliammina sp. (R), Nonionella auricula (F), N. labradorica (R), Pullenia malkinae (R), Virgulina sp. (R), Globigerina pachyderma ? (R), G. quadrilatera (R), pyrite (F).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Middle Neritic to Upper Bathyal

102-WL-75

Buccella frigida ? (R), Cassidulina laevigata ? (F), C. minuta (C), Dentalina sp. (R), Elphidium bartletti (R), E. clavatum (F), Glandulina laevigata (R), Haplophragmoides deformes (A), Pullenia ? sp. (R), Pulvinulinella cf. pacifica (R), Quinqueloculina sp. (R), Globigerina quadrilatera (R).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Middle Neritic to Upper Bathyal

104-WL-75

Haplophragmoides deformes (C), H. cf. trullissata (R).

AGE: ? Late Miocene to Pliocene ?

ENVIRONMENT: Marine

114-WL-75

Bulimina auriculata ? (R), Cassidulina laevigata ? (A),

RE: Gulf of Alaska Surface Samples

114-WL-75 (con't.)

Cassidulina minuta (C), Elphidium clavatum (A), Glandulina laevigata (F), Haplophragmoides deformes (A), H. cf. trullissata (F), Nonionella auricula (F), N. miocenica (F), Pullenia malkinae (R), Pulvinulinella pacifica (R), Globigerina quadrilatera (R), echinoid remains (R), fish remains (R), coal (C).

AGE: Late ? Miocene to Pliocene

ENVIRONMENT: Outer Neritic to Upper Bathyal

124-WL-75

Bolivina cf. obliqua (R), Buccella frigida ? (R), Elphidium clavatum (A), Glandulina laevigata (R), Pulvinulinella cf. pacifica (R), diatoms (R), echinoid remains (R), shell fragments (C).

AGE: ? Late Miocene to Pliocene ?

ENVIRONMENT: Neritic to Upper Bathyal

126-WL-75

Buccella frigida (R), Cibicides fletcheri (R), Elphidium clavatum (C), Nonionella ? sp. (R), shell fragments (R), coal (R).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Inner to Middle Neritic

RE: Gulf of Alaska Surface Samples

128-WL-75

Arenaceous fragments (R), Haplophragmoides sp. (R).

AGE: Indeterminate

ENVIRONMENT: Marine

132-WL-75

Elphidium clavatum (R), shell fragments (R), coal (R).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Neritic ?

1-DM-75

Buccella tenerrima (R), Elphidiella hannai ? (R), Elphidium clavatum (R), coal (C).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Inner Neritic

13-DM-75

Buccella ? sp. (R), Cassidulina sp. (R), Elphidium bartletti (F), E. clavatum (F), E. discoidale ? (R), E. oregonense (R), shell fragments (R), coal (F).

AGE: Late ? Miocene to Pleistocene

ENVIRONMENT: Inner to Middle Neritic

1-TM-75

Buccella tenerrima (F), Cassidulina cf. limbata (F), C. cf. teretis (C), Elphidiella hannai (F), Elphidium bartletti (F),

RE: Gulf of Alaska Surface Samples

1-TM-75 (con't.)

Elphidium clavatum (A), Glandulina laevigata (F), Haplophragmoides cf. deformes (F), Nonionella auricula (C), N. miocenica (C), Globigerina bulloides (R), G. pachyderma (F), G. quadrilatera (C), coal (F).

AGE: Pliocene to Pleistocene, possible Late Pliocene to Pleistocene

ENVIRONMENT: Inner to Middle Neritic

2-TM-75

Buccella tenerrima (R), Elphidiella hannai (F), Elphidium bartletti (F), E. clavatum (F), Globigerina quadrilatera (R).

AGE: Pliocene to Pleistocene

ENVIRONMENT: Inner Neritic

3-TM-75

Buccella frigida ? (R), B. tenerrima (F), Elphidiella hannai (F), Elphidium clavatum (C), E. oregonense (R), E. sibiricum (R), coal (C).

AGE: Pliocene to Pleistocene

ENVIRONMENT: Inner Neritic

5-TM-75

Buccella frigida ? (R), B. tenerrima (R), Cassidulina cf. limbata (R), C. cf. teretis (R), Elphidium clavatum (F), shell fragments (R), coal (F).

AGE: Pliocene to Pleistocene

ENVIRONMENT: Inner to Middle Neritic

RE: Gulf of Alaska Surface Samples

6-TM-75

Buccella tenerrima (R), Elphidium clavatum (R), shell fragments (C).

AGE:	Late ? Miocene to Pleistocene
ENVIRONMENT:	Inner Neritic ?

3D-JM-75

Buccella frigida (R), B. tenerrima (R), Elphidium clavatum (F), Haplophragmoides deformes (C), Quinqueloculina sp. (R), Globigerina pachyderma (R), G. sp. (R), diatoms (R), fish remains (R), shell fragments (R), coal (F).

AGE:	Late ? Miocene to Pleistocene
ENVIRONMENT:	Neritic

20-JCW-75

Cyclammina pacifica (R), Haplophragmoides translucens (R), glauconite (R).

AGE:	Indeterminate
ENVIRONMENT:	Bathyal

21-JCW-75

Anomalina glabrata (F), Bulimina ovata (R), Cassidulina laevigata (C), Cibicides evolutus (R), C. fletcheri ? (R), Dentalina sp. (R), Elphidiella sp. (R), Haplophragmoides cf. becki (R), H. deformes (C), H. obliquicameratus (F), H. sp. (F), Nonion cf. barleeanum (C), diatoms (R).

AGE:	Probable Late ? Miocene to Early Pliocene
ENVIRONMENT:	Middle to Lower Bathyal

RE: Gulf of Alaska Surface Samples

34-JCW-75

Haplophragmoides sp. (R), diatoms (R).

AGE: Indeterminate

ENVIRONMENT: Marine

Interpreted by:

R. S. Boettcher

R. S. Boettcher

ANDERSON, WARREN & ASSOCIATES, INC.

Richard E. Anderson

Richard E. Anderson

SOURCE ROCK ANALYSES

HYDROCARBON DETERMINATIONS (PPM)

APPENDIX C

KAYAK ISLAND (POUL CREEK FORMATION)

Surface Samples

Sample No.	Hydrocarbons, ppm
P-30-75	61

GRINDLE HILLS STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Hydrocarbons, ppm
JCW-13-75	47
WL-47-75	42
WL-51A-75	79
WL-51-75	68
WL-52-75	38

HANNA LAKE STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Hydrocarbons, ppm
P-66-75	19
P-73-75	38
P-75-75	10

WEST YAKATAGA REEF TRAVERSE

Surface Samples

Sample No.	Hydrocarbons, ppm
JM-34A-75	14
JM-35A-75	9
JM-36A-75	7
JM-37A-75	25
JM-38A-75	45
JM-39A-75	20

EAST YAKATAGA REEF TRAVERSE

Surface Samples

Sample No.	Hydrocarbons, ppm
JCW-1C-75	53
JCW-2C-75	60
JM-1C-75	4
JM-2C-75	17
JM-3C-75	10
JM-4C-75	28
JM-5C-75	22
JM-6C-75	14
JM-2F-75	30

YAGA-YAKATAGA STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Hydrocarbons, ppm
P-36-75	28
P-57-75	3
P-59-75	2
P-79-75	4
JCW-5-75	21
JCW-7-75	31
JCW-8-75	19
JCW-11-75	35
WL-18-75	6
WL-19-75	15
WL-20-75	14
WL-33-75	2
WL-34-75	6
WL-36-75	43
WL-40-75	26
WL-44-75	44

MOUNT EBERLY STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Hydrocarbons, ppm
JCW-25-75	20
JCW-27-75	21
JLW-23-75	3
P-94-75	23
P-96-75	6
P-99-75	451
P-105-75	3
P-107-75	19
WL-94-75	5
WL-101-75	102
WL-105-75	30
WL-106-75	18
WL-108-75	20
WL-109-75	17
WL-113-75	6
WL-115-75	32
WL-116-75	21
WL-119-75	22
WL-121-75	22
WL-123-75	476
WL-127-75	17
WL-129-75	858
WL-131-75	4

WHITE RIVER GLACIER TRAVERSE

Surface Samples

Sample No.	Hydrocarbons, ppm
WL-41A-75	32
WL-59A-75	4
WL-59-75	6
WL-62-75	12
WL-65-75	2
WL-68-75	18

UMBRELLA REEF STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Hydrocarbons, ppm
P-82-75	16
P-86-75	43
P-89-75	20

MUNDAY GLACIER TRAVERSE

Surface Samples

Sample No.	Hydrocarbons, ppm
JLW-35-75	8
JM-42-75	3
WL-90-75	22
P-113-75	19

MUNDAY CREEK STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Hydrocarbons, ppm
DM-16A-75	9
DM-18-75	15
DM-20-75	41

GUYOT GLACIER NUNATAK STRATIGRAPHIC SECTION

Surface Samples

Sample No.	Hydrocarbons, ppm
P-1-75	109
P-2-75	141
TM-3-75	6
TM-9-75	14
TM-13-75	10
TM-15-75	4
WL-1-75	29
WL-4-75	5
WL-5-75	10
WL-6-75	78
WL-7-75	24
WL-15-75	65
WL-16-75	20

ICY BAY TRAVERSE

Surface Samples

Sample No.	Hydrocarbons, ppm
P-13-75	14
P-18-75	28

SEEP OIL ANALYSES AND WATER ANALYSIS

APPENDIX D

Tenneco Oil
A Tenneco Company

Tenneco Building
P.O. Box 2511
Houston, Texas 77001
(713) 229-2131

September 26, 1975

Mr. William Lyle
State of Alaska
Division of Geological and Geophysical Surveys
3001 Porcupine Drive
Anchorage, Alaska, 99504

Re: Crude Oil and Water Samples
Gulf of Alaska

Dear Bill:

Attached you should find a comprehensive analysis of the Gulf of Alaska oil samples which you sent me from Johnson Creek and Samovar Hills and a water sample analysis from Monday Creek.

The only work which has not been completed is a carbon isotope analysis. I will mail this to you in the near future.

Bill, thank you for allowing Tenneco to do this work.

Sincerely,

TENNECO OIL COMPANY

Don

Don L. Kirksey
Geological Specialist
Frontier Projects - N. America

DLK/lkb
Attachment

TENNECO OIL COMPANY
(COMPANY)

INTEROFFICE COMMUNICATION

TO: FRONTIER PROJECTS

DATE: SEPTEMBER 22, 1975

FOR: DON L. KIRKSEY

FROM: B. D. CAREY, JR.

RE: CRUDE OIL AND WATER SAMPLES - GULF OF ALASKA

Analytical Methods:

Samples labeled Johnson Creek crude oil, Samovar Hills crude oil and Monday Creek water were sent to our laboratory for analysis. A portion of the crude oils were sent to Germany for analysis by the German Geological Survey. The remainder was analyzed in our laboratory. The water sample (Monday Creek) was sent to Spectro-Chemical labs for water analysis.

Results of Analyses:

Oil gravity was measured after centrifuging the samples to remove contamination. API gravity was determined by the pycnometer method. The density and gravity of the two oils are:

Johnson Creek crude oil - density = 0.9183 gms/cc
API gravity = 21.1° at 60° F.

Samovar Hills crude oil - density = 0.9699 gms/cc
API gravity = 13.2° at 60° F.

Both crude oils were submitted to Southern Petroleum Laboratories and Saybolt Laboratories for ASTM distillations; these labs were unable to run distillations due to small amount of sample and mud and water contamination.

Gas chromatograph analysis of the paraffinic and napthenic fractions showed both crude oils to be biodegraded and to have almost identical G.C. patterns. This indicates they were from the same or similar source rocks (Figures 1 and 2).

Most of the alkanes that are present are in the C_{14}-C_{20} range which suggests that the crude oil prior to biodegradation was fairly high gravity and probably from a mature oil source rock section.

The chemical analyses by the German Geological Survey are shown on Table I. This data shows the oils are very similar in composition after the asphaltene compounds are removed. This confirms the conclusion drawn from the similarity of the chromatographic analyses of the two oils. The essential differences in the oils are in the amount of volatiles which explains the gravity differences and in the amount of asphaltene compounds. The higher asphaltene content probably represents a higher state of biodegradation.

According to Connon and Van Der Weide, bacterially degraded oils frequently resemble immature unaltered oils as to their physical properties and their gross composition.

Increasing maturity of crude oils and rock extracts is shown by their increasing saturate content and their decreasing A/S ratio. Accordingly, plotting these two parameters for various samples on an x-y diagram provides a visual aid for comparison of relative maturities. Such a graph, obtained for a large number of unaltered crudes and rock extracts of various origins and maturity, including oils resulting from the artificial thermal evolution of kerogen is shown in Figure 3. The representative points are located along the upper, left-hand half of an approximately hypobolic curve; immature oils occupy the central part (the circled area) while, with increasing maturity, the points asymptotically approach the y-axis.

Increasing alteration by contact with meteoric-type waters (indicated by the composition of the water analysis in Table II; i.e. mildly brackish) along with bacterial degradation, leads, inversely, to a gradual decrease in saturates and to a corresponding increase of the A/S ratio. On the x-y diagram, the representative points are located along the same hyperbola as in the previous case; however, with increasing alteration, they move in a direction opposite to that of increasing diagenesis (Figure 4). In contrast to unaltered oils, the points representing bacterially degraded oils may be located, if the alteration is severe enough, beyond the central "immature" part of the curve and asymptotically tend to the x-axis.

If we plot the two oils (Table I) on the graphs (red dots, Figure 4), we see that the low-gravity oil falls on the curve of the altered mature oils, and the higher gravity oil has been altered so much that it falls in the range of the unaltered immature oils. Mildly bacterially degraded oils, as mentioned previously, frequently resemble immature, unaltered oils as to their physical properties and gross composition.

From this analysis, it appears that both oils were relativley mature and have been altered as shown by Figure 4. Paradoxically, the higher gravity oil appears to be more altered than the low, but has somehow managed to retain more of the volatile fractions.

The carbon isotope analyses of the oils has not yet been finished. Since biodegradation does not generally change the isotope values, this could give us useful information as to whether the oils are derived from Tertiary or Mesozoic source rocks.

B. D. Carey, Jr.

BDCJr:ww
Enclosures

TABLE II

WATER SAMPLE ANALYSIS
MUNDAY CREEK

Parameter	Major Ions, mg/l	% of Total Major Ions
Sodium	472	24.16
Calcium	260	13.30
Magnesium	6	.31
Potassium	6	.31
Chloride	917	46.93
Bicarbonate	293	14.99
Carbonate	0	-
Sulfate	0	-
Hardness (Ca^{++} + Mg^{++})	674	

Total Solids by Evaporation 1954 mg/l

Resistivity 3.278×10^4 ohm-meter at 77° F.

pH 7.60 Specific Gravity .995 at 77° F.

TABLE I

CHEMICAL ANALYSIS - GULF OF ALASKA CRUDE OILS

					Composition of Deasphalted Oil			Composition of Dried Crude Oil					
Sample No.	Lab No.	Locality	Age	% Volatiles on Drying	% Saturated HC	Aromatic HC	Resins	Saturated HC	Aromatic HC	Resins	% Asphaltenes	Sat. HC / Aromatic HC	Gravity
11091	3640	Alaska - Samovar Hills	Surf. Seep	8.9	23.4	40.3	36.3	20.2	34.7	23.7	21.4	0.58	13.2 @ 60° F.
11092	3641	Alaska - Sullivan Anticline	Surf. Seep	22.0	25.9	36.1	38.0	9.4	13.1	5.8	71.7	0.72	21.1 @ 60° F.

No estimate of maturity levels can be made on severely biodegraded oils.

Samples 11091-11092 are severely biodegraded because of the lack of normal alkanes in the saturated hydrocarbons.

Ratios Used in Maturity Plots (Figures 3 and 4)

	Sample 11091	Sample 11092
Aromatics/Saturates Ratio (x-axis)	1.7	1.4
Saturates (y-axis)	20.2	9.4

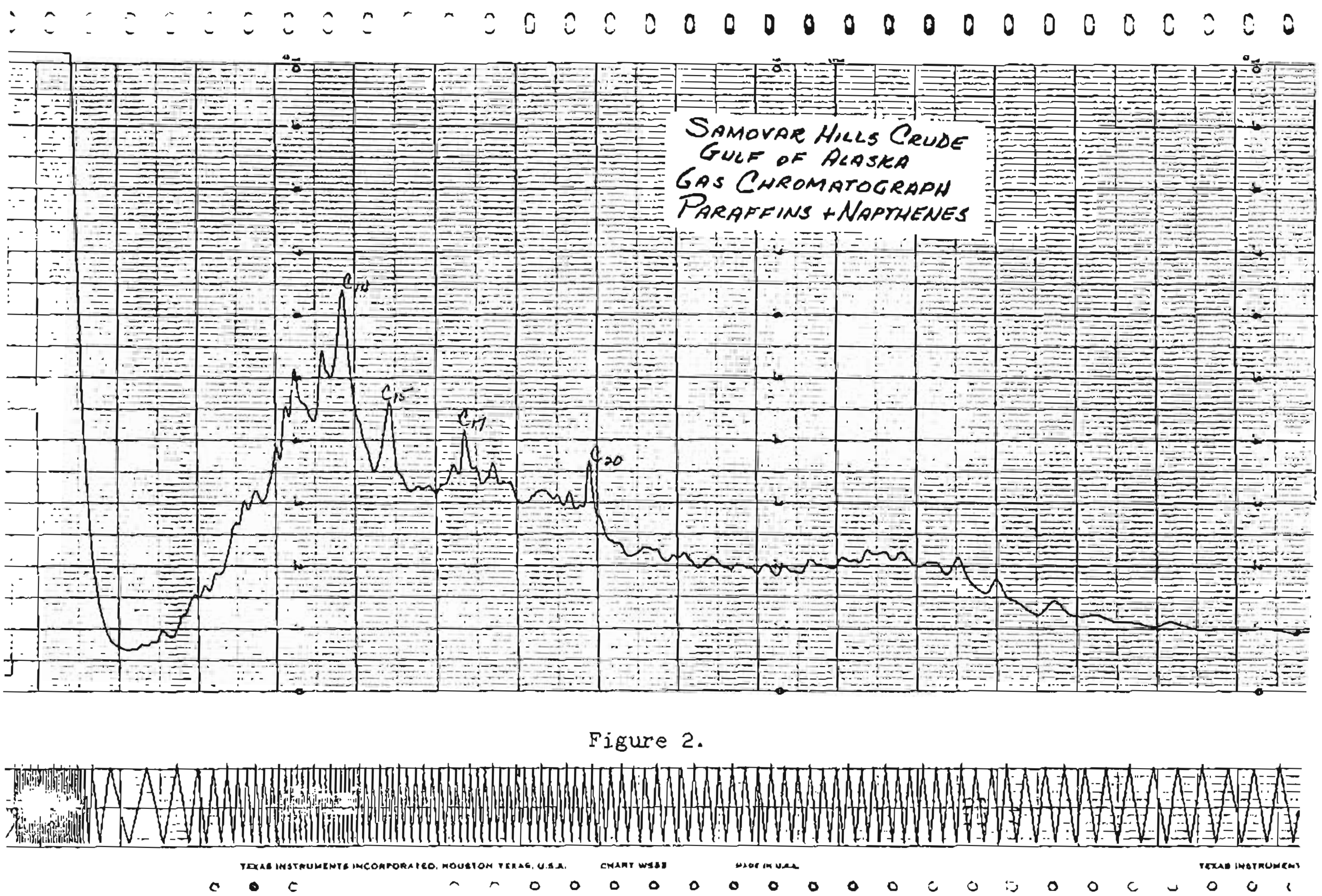

SAMOVAR HILLS CRUDE
GULF OF ALASKA
GAS CHROMATOGRAPH
PARAFFINS + NAPTHENES
C15
C17
C20
TEXAS INSTRUMENTS INCORPORATED, HOUSTON TEXAS, U.S.A.
CHART WS33
MADE IN U.S.A.
TEXAS INSTRUMENTS

Figure 2.

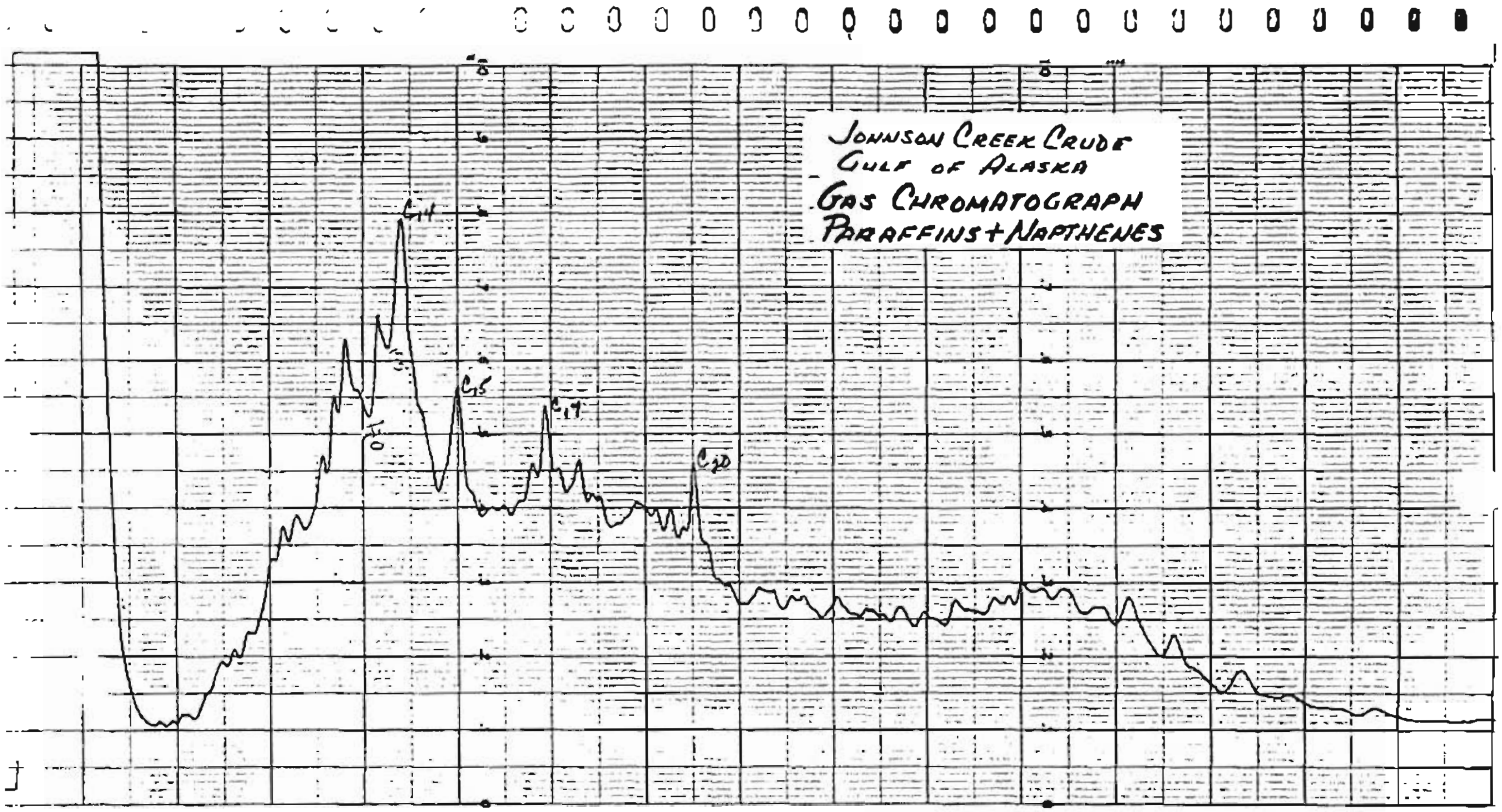

JOHNSON CREEK CRUDE
GULF OF ALASKA
GAS CHROMATOGRAPH
PARAFFINS + NAPTHENES
C14
C15
C17
C20

Figure 1.

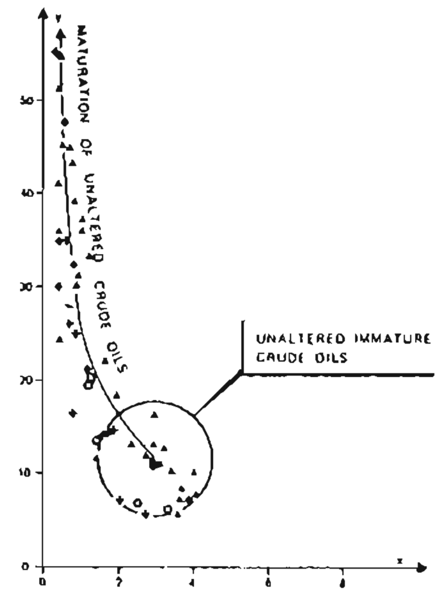


Fig. 3. x-y diagram for unaltered oils from Aquitaine.
x-axis : aromatics/saturates ratio-
y-axis : saturate content
•Upper Jurassic
▲Lower Cretaceous
○Heating experiments
(Bajor et al., 1969)

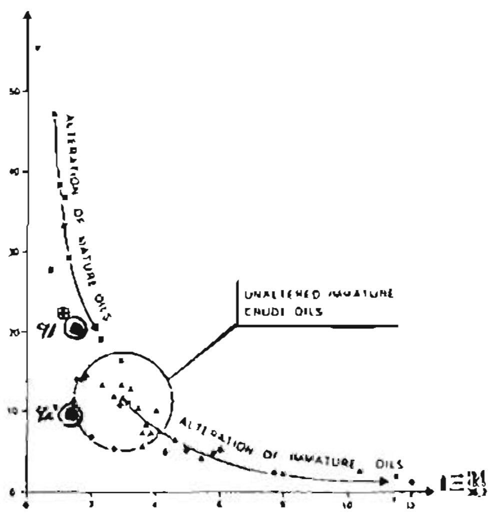


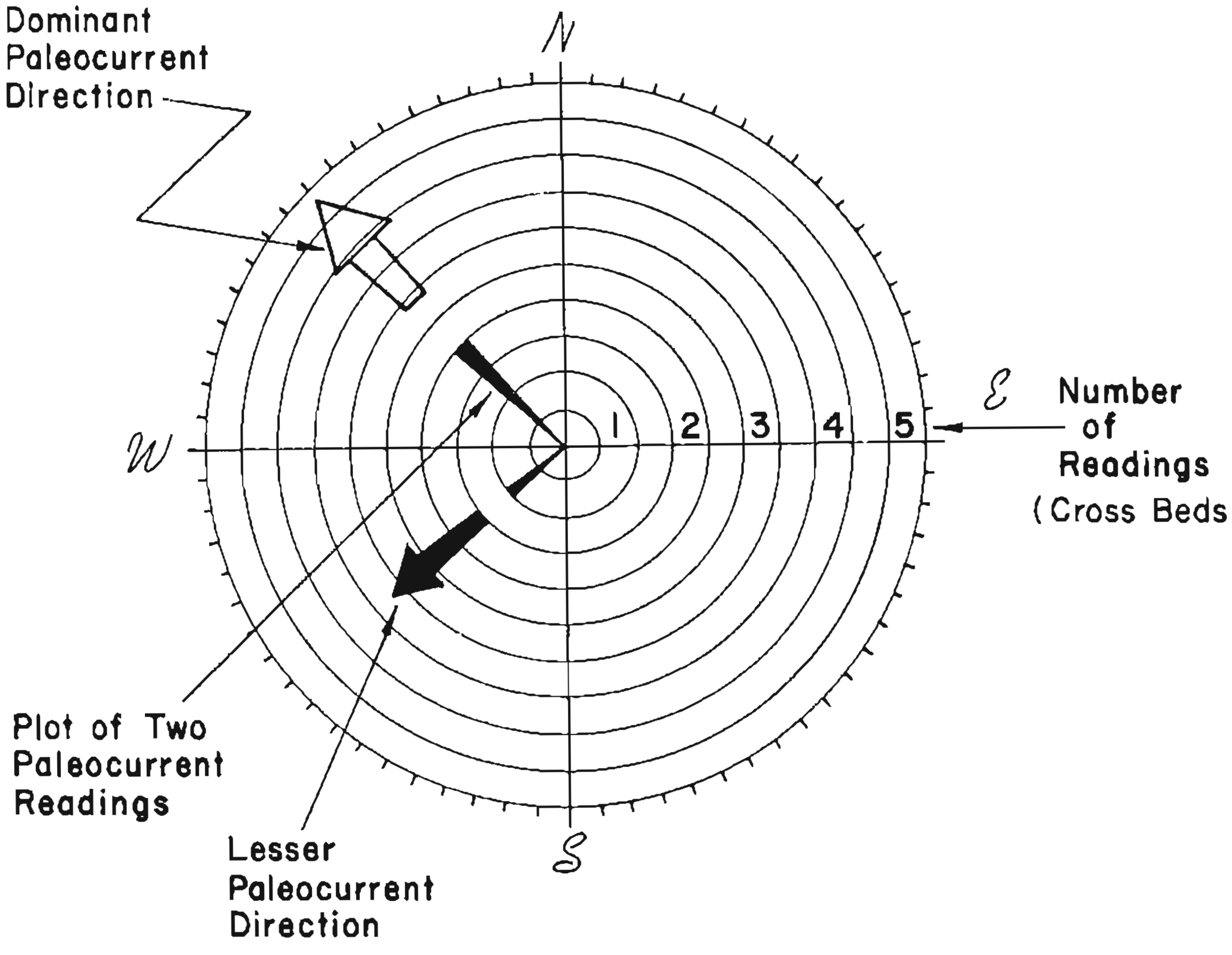
Fig. 4. x-y diagram for altered oils from Aquitaine

- Upper Cretaceous
- Upper Jurassic
- Lower Cretaceous
- Mississippian (Saskatchewan, Canada : ⊕Evans et al., 1971)

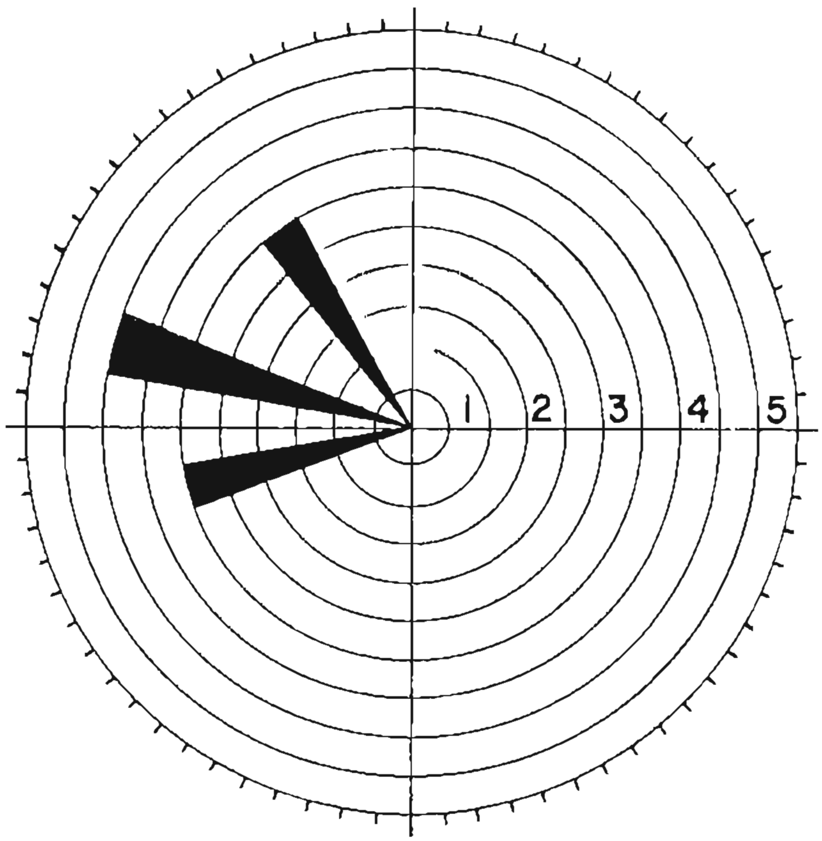
Asphalt from Val de Travers, Switzerland.

PALEOCURRENT ROSES

APPENDIX E



PALEOCURRENT DIRECTION INDEX

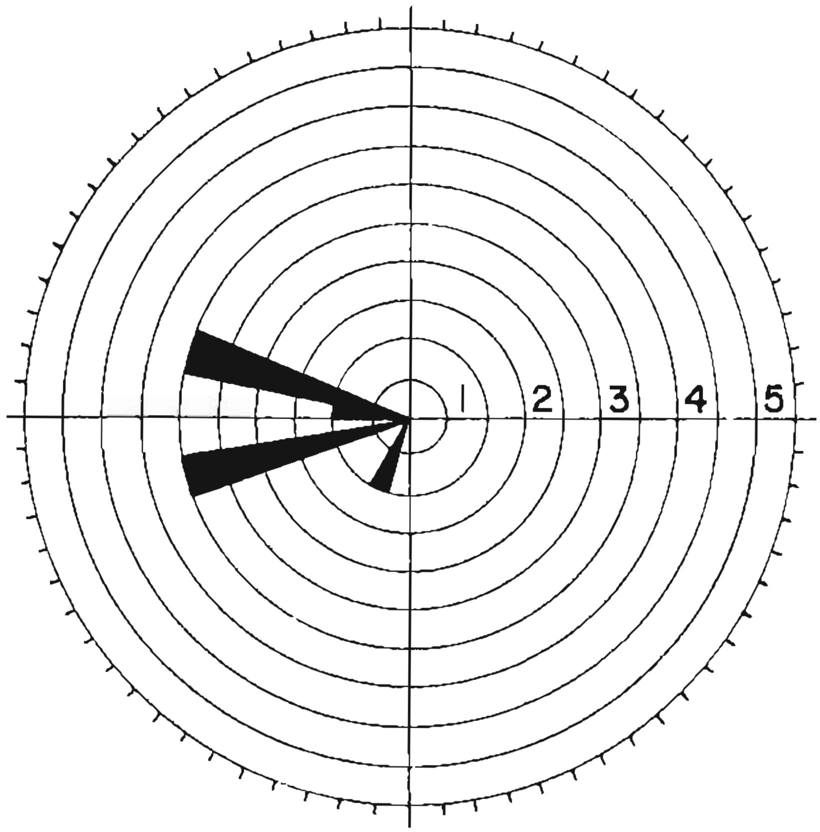


CAPE YAKATAGA

YAKATAGA FORMATION

UPPER CROSS BED ZONE

10 READINGS

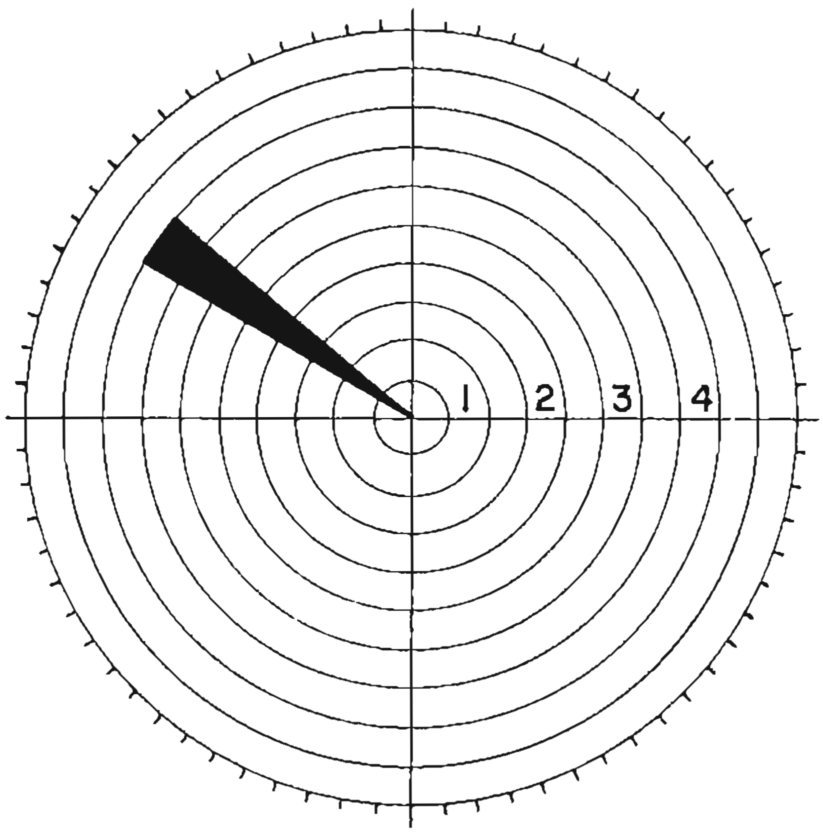


CAPE YAKATAGA REEF

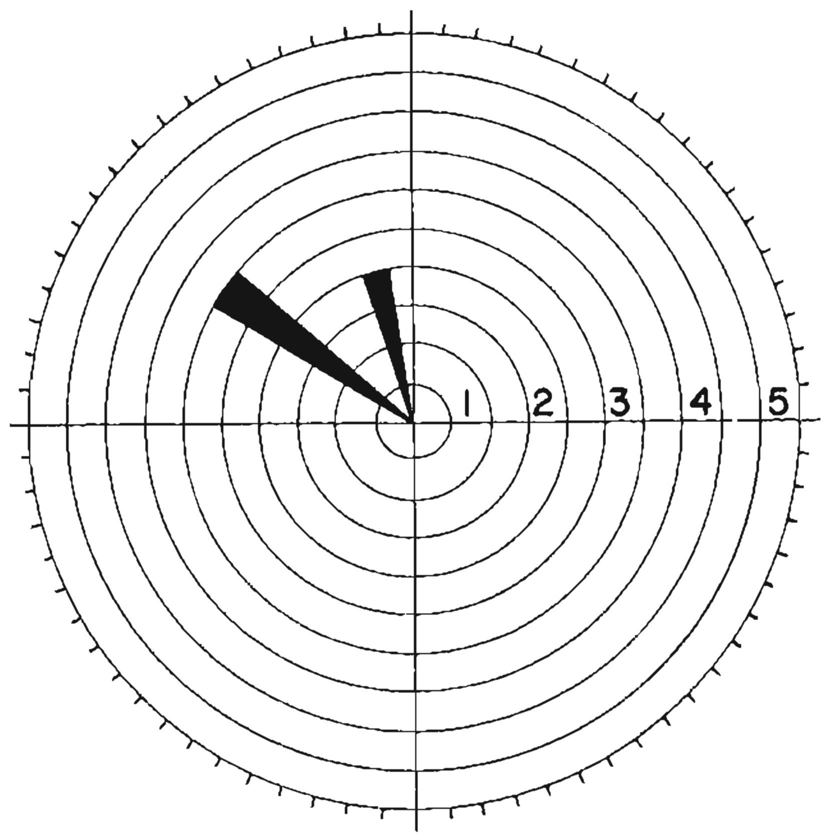
YAKATAGA FORMATION

BASAL SANDSTONE

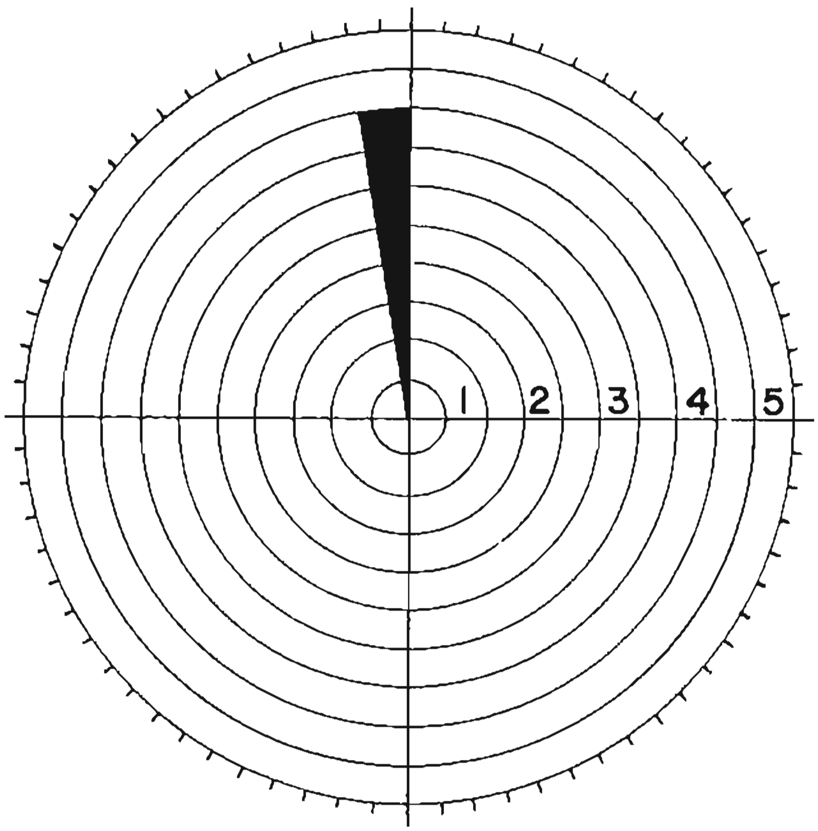
8 READINGS



WEST WATSON PEAK
STRATIGRAPHIC SECTION
YAKATAGA FORMATION
5 READINGS



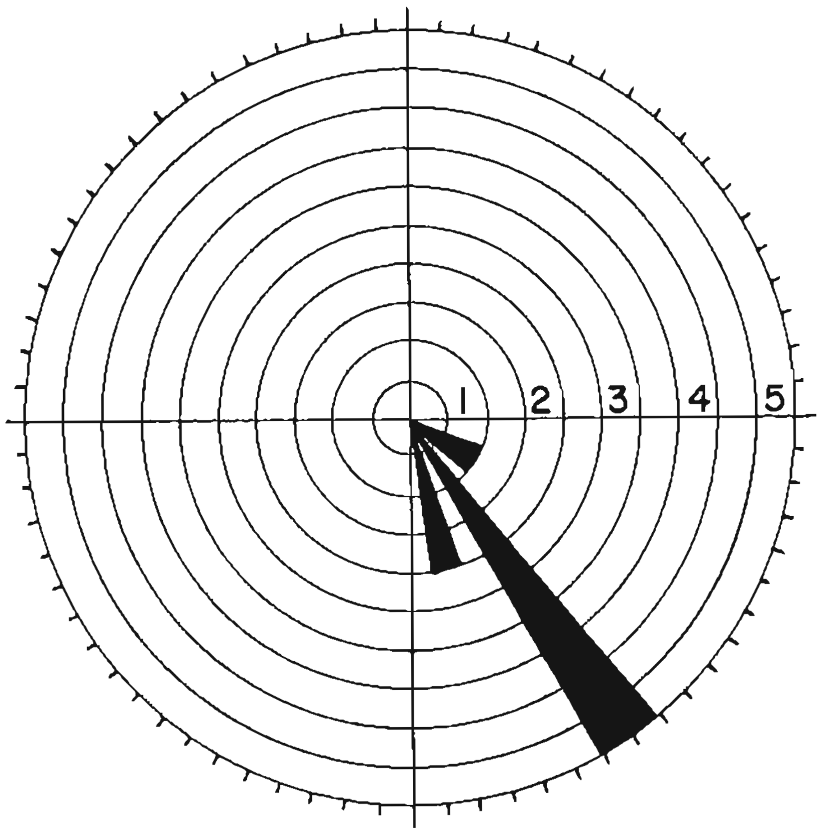
YAGA - YAKATAGA GLACIER
STRATIGRAPHIC SECTION
YAKATAGA FORMATION
5 READINGS



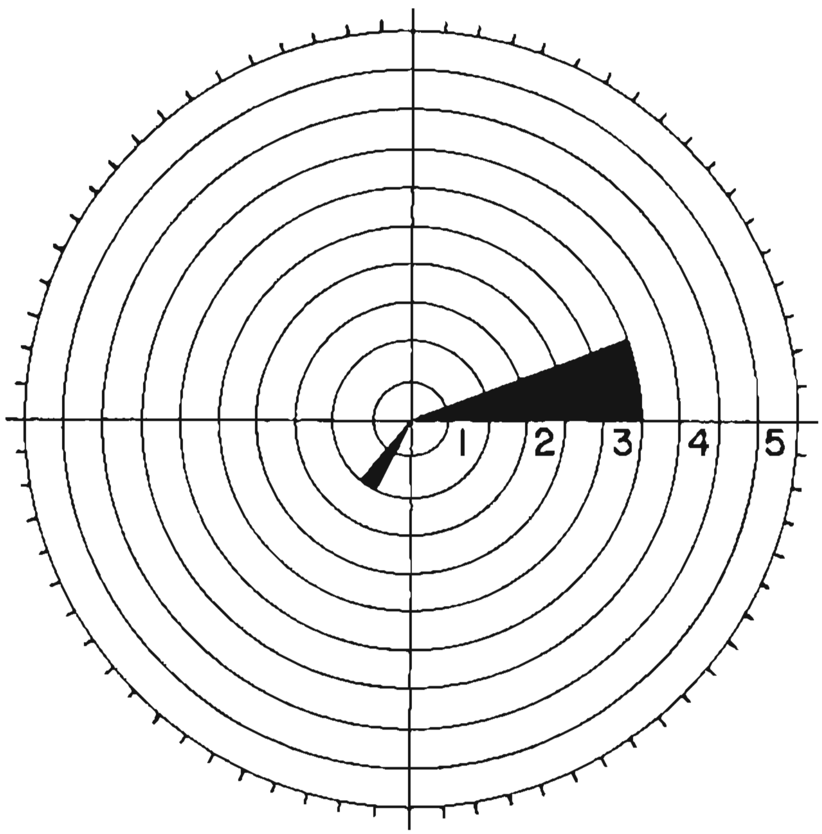
GUYOT GLACIER STRATIGRAPHIC SECTION

YAKATAGA FORMATION

4 READINGS



GRINDLE HILLS
STRATIGRAPHIC SECTION
KULTHIETH FORMATION
9 READINGS

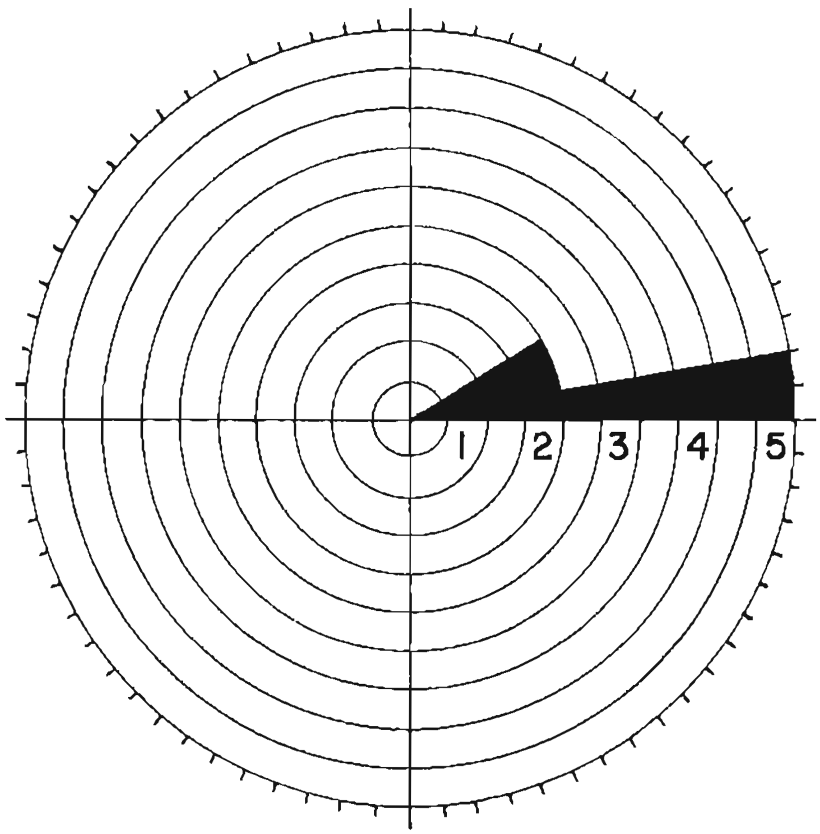


HANNA LAKE STRATIGRAPHIC SECTION

POUL CREEK FORMATION

LOWER CROSS BED ZONE

9 READINGS



HANNA LAKE STRATIGRAPHIC SECTION

POUL CREEK FORMATION

UPPER CROSS BED ZONE

9 READINGS

YAKATAGA FORMATION SEDIMENTARY

STRUCTURES AND DEPOSITIONAL

FEATURES

PHOTOGRAPHIC FIGURES

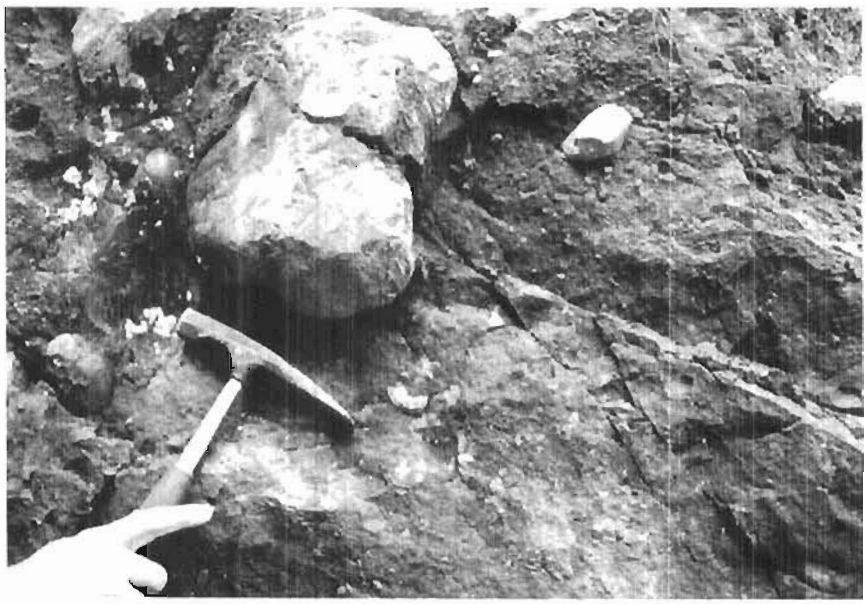
APPENDIX F

West Watson Peak stratigraphic section showing the coarsening upward sequence.

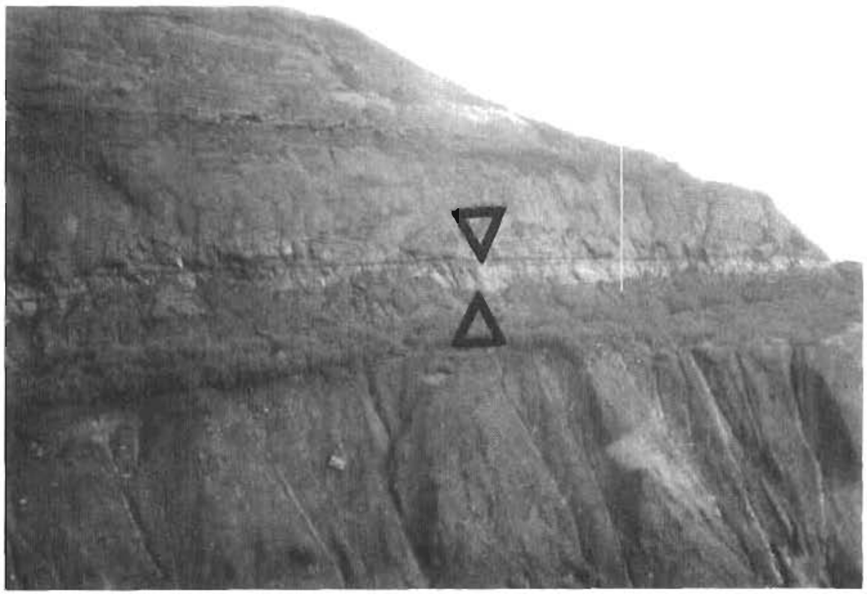
Light-colored unit is a thick, linear, clastic, shoreface type sandstone in the Yakataga Formation exposed in the steeply dipping, ±70°, south face of Yakataga Ridge anticline. View is west looking down western plunge.

North-looking view of part of the Munday Creek traverse showing massive Yakataga Formation sandstone unit measured and sampled. Exposure is part of the north flank of the Sullivan structure. Many active avalanches make working in these glacial chutes very hazardous.

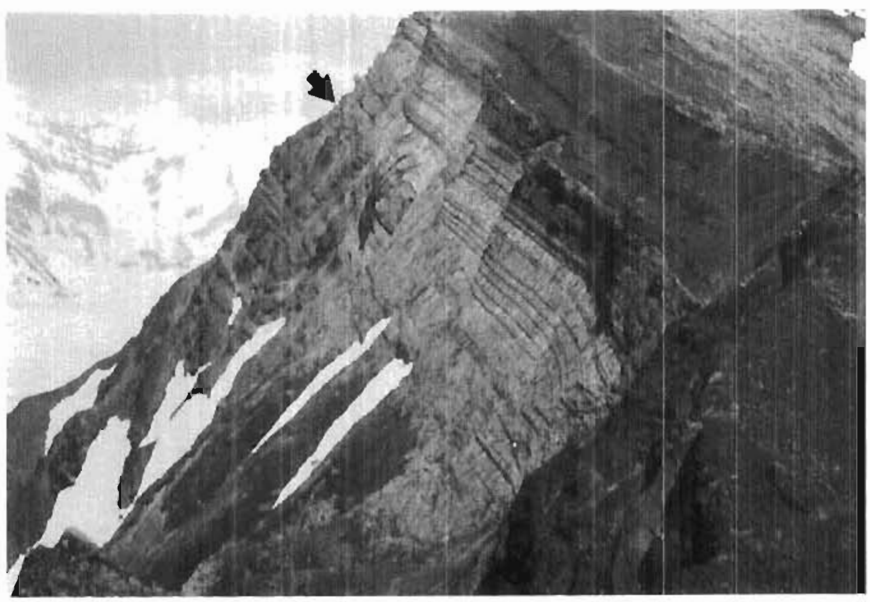
Munday Creek stratigraphic section sandstone overturned in direction of hammer handle. Over 500 feet of potential reservoir sandstone is exposed here, approximately one-half mile from the present beach.



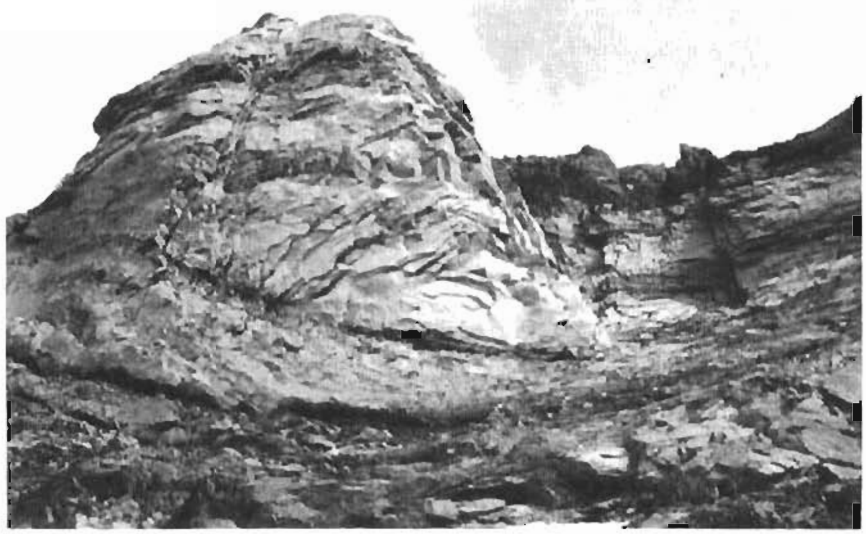
Boulder "drop stone" exhibiting glacial striations in Yakataga Formation conglomeratic mudstone exposed at Munday Creek.



Icy Bay Traverse sandstone. This tabular, linear, clastic, shoreface sandbody is typical of many Yakataga Formation potential reservoirs. View is north. Midphoto sandstone thickness is about 25 feet.



Poul Creek (red weathering)--Yakataga (gray weathering) contact at Yaga-Yakataga Glaciers stratigraphic section. View is toward the north looking up Yakataga Glacier. Note massive, planar-bedded, linear, clastic, shoreface sandstones containing thin interbeds of mudstone near the base of the Yakataga Formation.

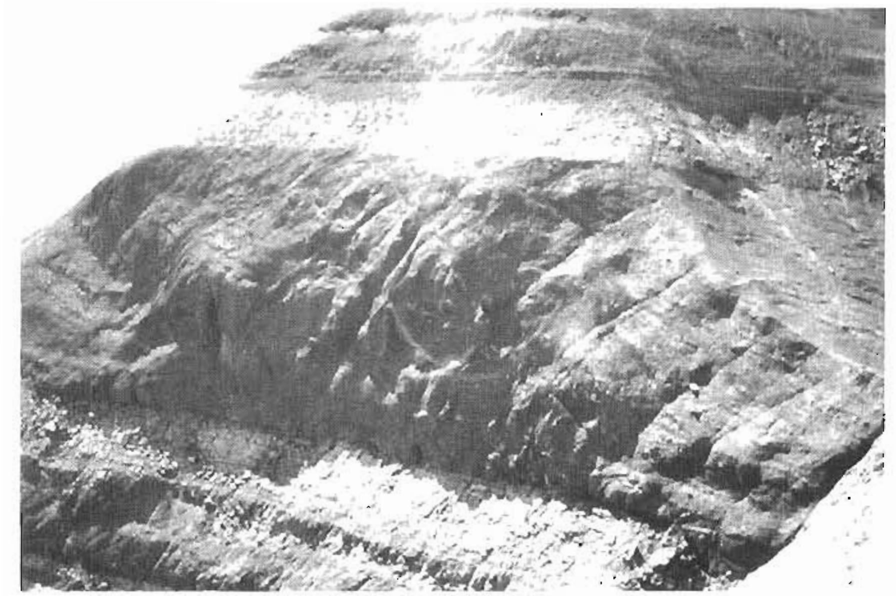


Close-up view of part of the massive Yakataga Formation channel sand complex exposed in the Yaga-Yakataga Glaciers stratigraphic section. This massive sand body exceeds 200 feet in thickness.

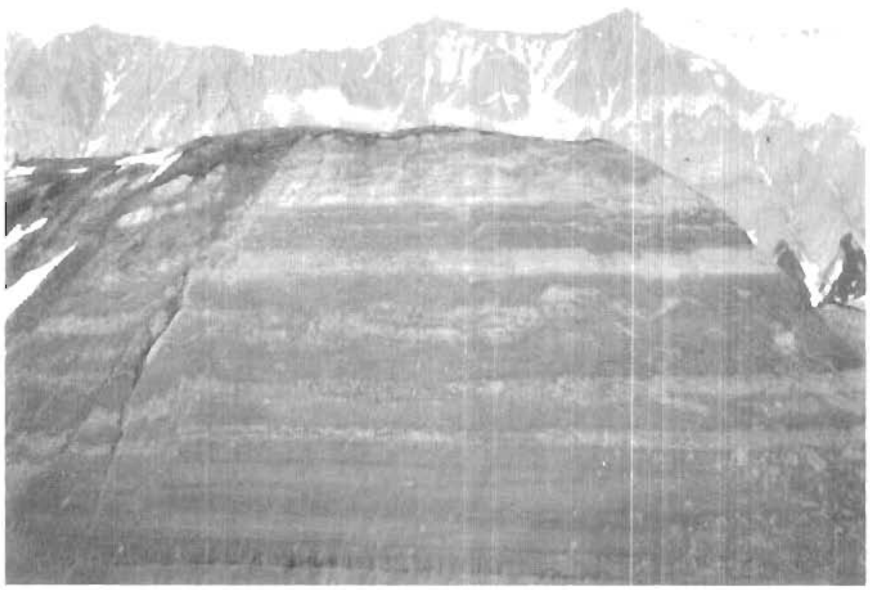
Penecontemporaneous structure in Yakataga Formation mudstone exhibiting a "swirled" mass of mud containing irregularly shaped calcareous concretionary lenses. Undisturbed even-bedded siltstones and mudstones occur both above and below. Exposure is part of Yaga-Yakataga Glaciers stratigraphic section.

Lens-shaped conglomeratic mudstone unit in Yakataga Formation exposed in the White River Glacier area.

Penecontemporaneous structures in Yakataga Formation exposed in the White River Glacier area.

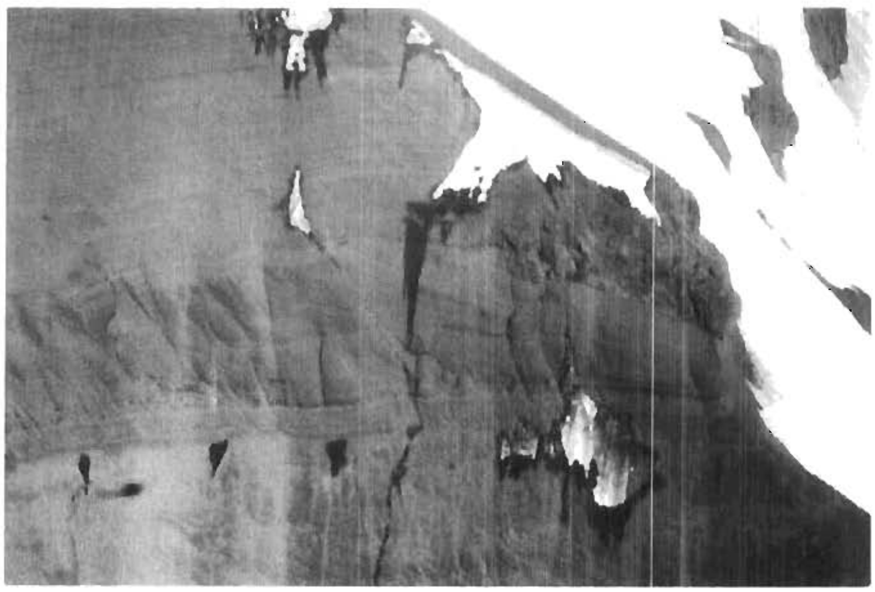


Two relatively undisturbed 20- to 25-foot-thick sandstones above and below a highly contorted and obviously much less competent mudstone unit exposed in the Yakataga Formation at the eastern end of Brower Ridge near White River Glacier syncline. It appears that potential reservoir sandstones such as these "sandwiched" between thick mudstone units would have an adequate reservoir seal in the subsurface.

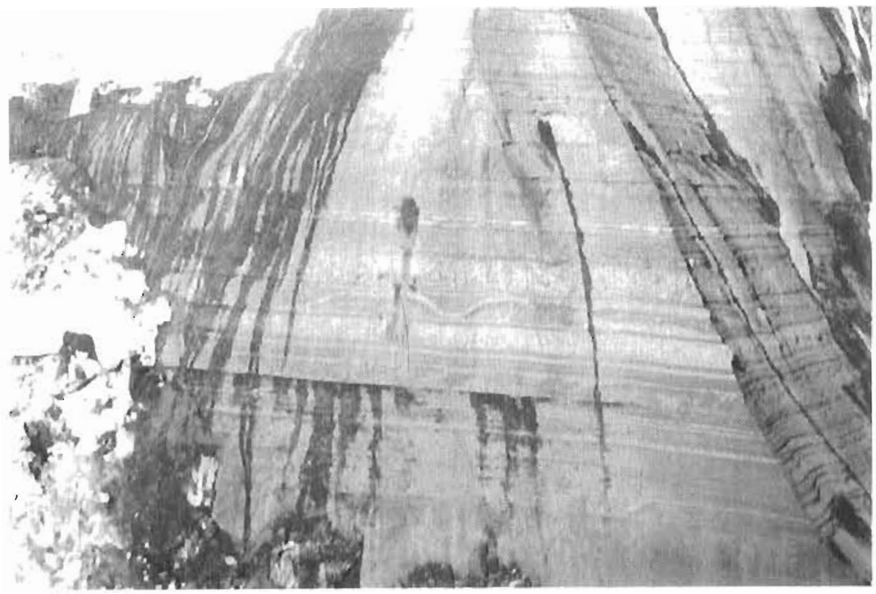


Large "swirled" sand-pod deformational features in Yakataga Formation exposed on south-facing cliff along Brower Ridge near White River Glacier syncline.

Penecontemporaneous structures in Yakataga Formation near Beare Glacier on Sullivan anticline. Both "loading" type folds (solid arrow) and shear zones open (arrow) are evident. Note that the deformation is limited to only a few beds.



"Channel" sandstone complex in the Yakataga Formation exposed in the Lare Glacier area of Sullivan anticline. This type of deposit may represent a proximal part of a shallow-water (neritic depths) submarine fan.

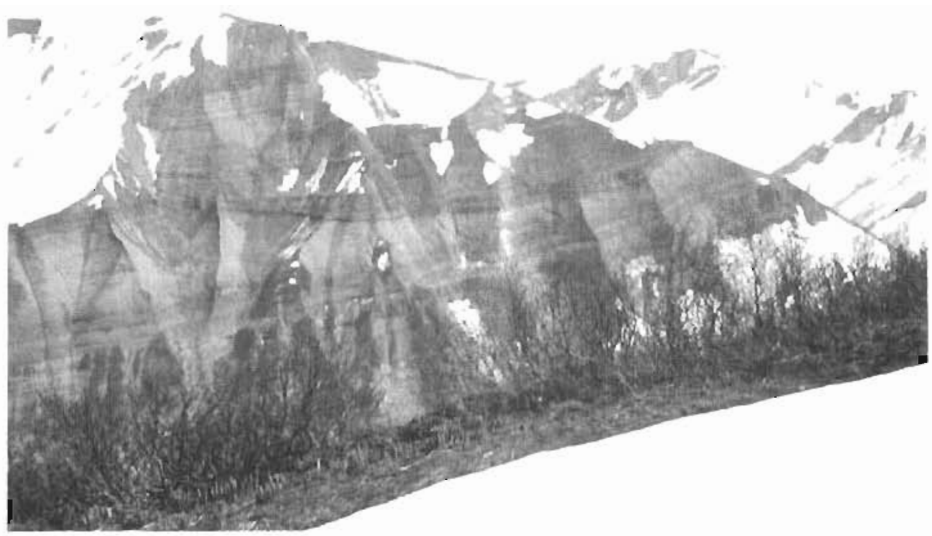


Penecontemporaneous structures in Yakataga Formation near Lare Glacier on Sullivan anticline. Note that deformation is largely confined to two beds.

Eastern Cape Yakataga Traverse sandstone. View is south.

Northeast view in Munday Glacier area showing Yakataga Formation. Light-colored beds are sandstones.

View showing broad "channel complex" in Yakataga Formation at north end of Chaix Hills.



View of channel, "cut and fill" deposition
Yakataga Formation--White River Glacier area

Close-up of above

Close-up view of Yakataga Formation conglomeratic sandy mudstone exposed on Cape Yakataga Reef

CONTEMPORARY SEDIMENTATION FEATURES

PHOTOGRAPHIC FIGURES

APPENDIX G

Beach bar west of Cape Yakataga. The Duktoth River is deflected westward many miles before entering the sea. An older beach berm is seen at middle left. The lower parts of such shoreface deposits would probably make excellent reservoirs if preserved in the subsurface.

Copper River delta plain showing stream meanders and isolated lakes. View is south toward the delta front.

Copper River delta sand bars exposed at high tide. View is north.

View of Copper River delta plain showing partially stabilized dunes.

Gulf of Alaska
Beach view to the west along Sullivan anticline

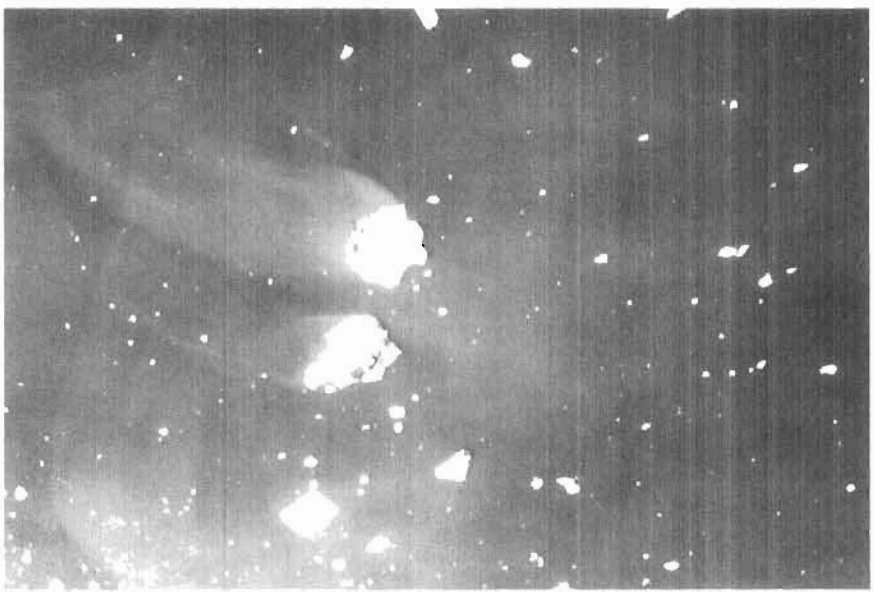
Glacial lake deposits disected by melt-water streams at Malaspina Glacier terminus near northern Icy Bay.

Bering Glacier terminus (arrow) and associated braided stream complex. The terminus of the glacier is heavily loaded with all clastic-size grades. This material is dumped at the terminus and is supplied to the nearby marine environment for reworking by waves and currents.

Typical glacial melt-water braided stream complex associated with many of the active glaciers along the northern Gulf of Alaska coastline. View is southeast from the tree-covered Malaspina Glacier terminus toward Yakutat, across the bay.

The Riou spit at Riou Bay. Spit elongation is toward north-northwest.

Northeast view of White River Glacier showing heavy load of superglacial material being carried by the glacier.



Overhead view of icebergs in Icy Bay. Note plumes of mud entering bay from bergs. Several bergs were observed as they rolled over, dumping all size grades of superglacial material into the bay. Fiords such as Icy Bay were the probable depositional sites of the conglomeratic mudstones typical of the Yakataga Formation.

GENERAL INTEREST

PHOTOGRAPHIC FIGURES

APPENDIX H

This log cabin complex owned by Mr. & Mrs. Eggebrotten at Cape Yakataga served as campsite for field operations.

Johnston Creek oil seep. Rocks and vegetation are covered by a black tarry residue. The water surface is covered by an oil film and there is a slight odor of kerosene. No noticeable effects are evident a few hundred feet downstream.

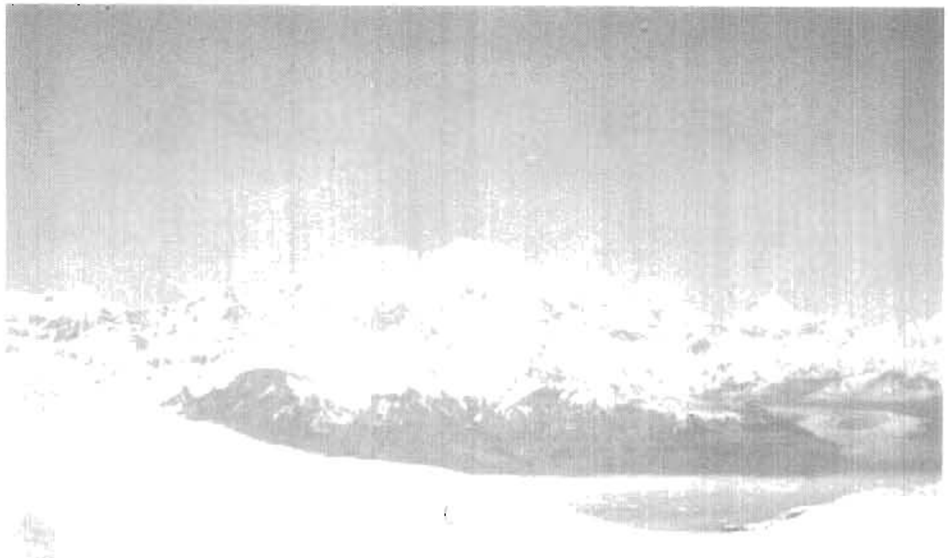
Commissioner Guy Martin
State of Alaska, Dept. of Natural Resources
near Icy Bay, Gulf of Alaska

Safety class
prior to summer work on glaciers
Don McGee (foreground)--Bill Lyle (background)

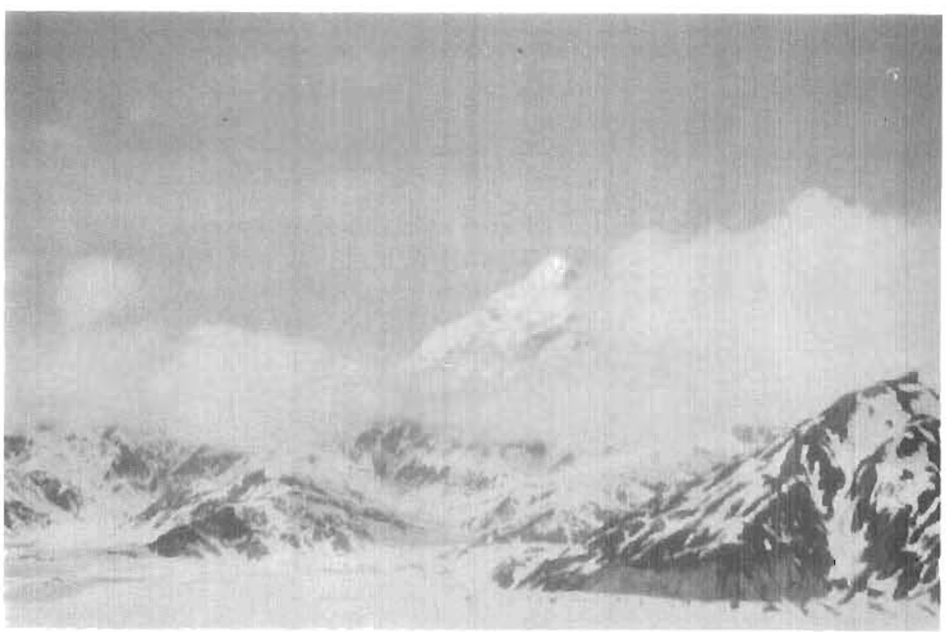
Safety class
prior to summer work on glaciers
Don McGee (foreground)

Safety class
prior to summer work on glaciers

White River syncline (foreground)
south flank of Yakataga anticline (background)



Icy Bay--view to the east
Mt. St. Elias



Mt. St. Elias

Kulthieth Formation--sandstone outcrops
Grindle Hills

Wellhead of General Petroleum Co.--Sullivan No. 1. This well was drilled near the active Johnston Creek oil seep in 1926-27 to a depth of 2,005 feet and was the first well to test the Sullivan structure. Small bubbles of methane gas issues from around the casing, and a small quantity is emitted from the tubing orifice.

Katalla oil field, Well 7

Samovar Hills oil seep. Thermal water associated with the oil keeps snow from accumulating at the site. The grass growing on oil-soaked peat material is about four to six inches in length.

Irv Palmer
Oil seep---upper end of Malaspina Glacier

Bill Lyle
Oil seep--Samovar Hills

Don McGee, left, and Bill Lyle examining the oil seep at the Katalla oil field site.

Irv Palmer, left, and Bill Lyle collecting seep oil at Katalla Slough oil seep near Katalla oil Field site.

Wellhead of first well drilled in the Katalla Oil Field near the head of Katalla Slough. Katalla No. 1 was drilled in 1902 by the Alaska Steam Coal and Petroleum Syndicate to a depth of 366 feet. On pump it produced oil and considerable gas and helped maintain the Katalla refinery, completed in 1912.

Cape Yakataga Reef. The west-trending Sullivan structure turns sharply toward the south and the Gulf of Alaska. The contact between Yakataga and Poul Creek Formations is exposed at low tide.

Refueling helicopter at fuel cache at Yakataga airstrip. All fuel drums were removed from the site by air charter upon completion of the field project.

SAMPLE LOCATIONS, NUMBERS AND PURPOSE

APPENDIX 1

CORDOVA QUAD
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
1	50JM75							X
2	51JM75					X		X
3	49JM75							X
4	52JM75					X		X
5	48JM75							X
6	53JM75					X		X
7	54JM75					X		X
8	26P75					X		X
9	27P75							X
10	208JM75					X		X
11	28P75							X
12	198JM75					X		X
13	29P75							X
14	30P75		X					

Bering Glacier Quad
1:250,000

PLATE I
GRINDLE HILLS
Stratigraphic Section

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
16	30JM75					X		X
17	27JM75					X		X
17A	28JM75					X		
18	25P75					X		X
19	47JM75							X
20	46JM75							X
21	45JM75							X
22	44JM75							X
23	15JM75							X
24	14BJM75							X
25	14AJM75							X
26	13JM75							X
27	12JM75							X
28	11JM75							X
29	10JM75							X
30	20JCW75				X			
31	19JCW75	X						
32	18JCW75	X						
33	17JCW75	X						
34	15JCW75							ORIENTED SS
35	16JCW75	X						
36	14JCW75	X						
37	13JCW75		X					
38	47WL75		X					
39	48WL75	X						
40	49WL75	X						
41	50WL75							COAL
42	51WL75		X					
43	52W75		X					
44	53WL75	X						

PLATE I (cont.) — Map Nos. 45–46

PLATE II HANNA LAKE Stratigraphic Section — Map Nos. 47–74

Bering Glacier Quad
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
45	54WL75	X						
46	12JCW75	X						
47	77P75	X						
48	76P75				X			
49	75P75		X					
50	74P75			X				
51	73P75		X					
52	72P75			X				
53	71P75				X			
54	70P75	X						
55	69P75				X			
56	68P75				X			
57	67P75				X			
58	66P75		X					
59	65P75				X			
60	64P75	X						
61	16JM75					X		X
62	23JM75					X		X
63	22JM75					X		X
64	25JM75					X		X
65	26JM75					X		
66	31JM75					X		X
67	111P75					X		X
68	24JM75					X		X
69	17JM75							X
70	17AJM75					X		
71	17BJM75					X		
72	32JM75					X		X
73	32P75							X
74	19AJM75							X

PLATE II MANNA LAKE Stratigraphic Section (Map Nos. 75–92)

PLATE VI YAGA-YAKATAGA GLACIER Stratigraphic Section (Map Nos. 93–104)

Bering Glacier Quad
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
75	112P75							X
76	31P75					X		X
77	38P75					X		X
78	39P75							X
79	24P75					X		X
80	40P75					X		X
81	41P75							X
82	42P75					X		X
83	43P75							X
84	37P75							X
85	44P75							X
86	10JM75					X		X
87	45P75							X
88	9JM75					X		X
89	20AJM75							X
90	33JM75					X		X
91	47P75					X		X
92	46P75					X		X
93	43WL75	X						
94	44WL75		X					
95	45WL75	X						
96	11JCW75		X					
97	10JCW75	X						
98	9JCW75	X						
99	8JCW75		X					
100	7JCW75		X					
101	6JCW75	X						
102	5JCW75		X					
103	WL3375		X					
104	WL3275		X		X			

PLATE VI
YAGA-YAKATAGA GLACIER
Stratigraphic Section

Bering Glacier Quad
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
105	60P75	X						
106	59P75		X					
107	WL3175				X			
108	58P75	X						
109	57P75		X					
110	56P75	X						
111	55P75				X			
112	WL3075	X						
113	1TM75	X						
114	WL2975	X						
115	2TM75				X			
116	WL2875	X						
117	WL2775				X			
118	3TM75		X					
119	WL2675	X						
120	4TM75	X						
121	5TM75				X			
122	6TM75				X			
123	7TM75	X						
124	WL2575							RIPPLE MARK
125	WL2475	X						
126	WL2375	X						
127	WL2275	X						
128	WL22A75	X						
129	WL2175				X			
130	WL2075		X					
131	WL1975		X					
132	WL1875		X					
133	36P75		X					
134	WL3975			X				

Plate	Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
		Bering Glacier Quad 1:250,000							
PLATE VI (cont.)	135	WL4075		X					
	136	WL3875	X						
	137	WL3775			X	X			
	138	WL3675			X				
	140	WL3575	X						
	141	35P75							OFFICE
	142	34P75				X			
	143	81P75				X			
	144	82P75		X					
	145	79P75		X					
	146	80P75				X			
PLATE VII MT. EBERLY Stratigraphic Section	147	132WL75				X			
	148	131WL75		X					
	149	130WL75	X						
	150	129WL75		X					
	151	127WL75		X					
	152	128WL75				X			
	153	125WL75			X				
	154	126WL75				X			
	155	124WL75				X			
	156	123WL75		X					
	157	122WL75	X						
	158	121WL75		X					
	159	120WL75			X				
	160	119WL75		X					
	161	118WL75			X				
	162	116WL75		X					
	163	115WL75		X					
	164	114WL75				X			
	165	113WL75		X					

PLATE VII
MT. EBERLY
Stratigraphic Section

Bering Glacier Quad 1:250,000								
Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
166	112WL75			X				
167	111WL75	X						
168	110WL75			X				
169	109WL75		X					
170	108WL75		X					
171	107WL75			X				
172	106WL75		X					
173	105WL75		X					
174	34JCW75				X			
175	33JCW75		X					
176	32JCW75	X						
177	31JCW75	X						
178	30JCW75	X						
179	30AJCW75			X				
180	29JCW75	X						
181	28JCW75	X						
182	27JCW75		X					
183	26JCW75	X						
184	25JCW75		X					
185	24JCW75	X						
186	23JCW75		X					
187	22JCW75	X						
188	21JCW75				X			
189	110P75			X				
190	109P75		X					
191	108P75	X						
192	107P75		X					
193	106P75				X			
194	105P75		X					
195	106P75	X						

PLATE VII (cont.) — Map Nos. 196–207

PLATE III WEST YAKATAGA REEF Traverse — Map Nos. 208–220

PLATE IV — Map Nos. 221–225

Bering Glacier Quad 1:250,000								
Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
196	103P75	X						
197	102P75	X						
198	101P75	X						
199	100P75				X			
200	99P75		X					
201	57P75				X			
202	98P75			X				
203	96P75		X					
204	95P75				X			
205	94P75		X					
206	93P75			X				
207	92P75	X						
208	34AJM75		X					
209	34BJM75	X						
210	35AJM75		X					
211	35BJM75	X						
212	36AJM75		X					
213	36BJM75	X						
214	37AJM75		X					
215	37BJM75	X						
216	37CJM75			X				
217	38AJM75		X					
218	38BJM75	X						
219	39AJM75		X					
220	39BJM75	X						
221	4AJCW75	X						
222	3AJCW75	X						
223	3BJCW75	X						
224	2AJCW75	X						
225	2BJCW75	X						

PLATE IV
EAST YAKATAGA REEF
Traverse

Bering Glacier Quad
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
226	2CJCW75		X					
227	1AJCW75	X						
228	1BJCW75	X						
229	1CJCW75		X					
230	1AJM75	X						
231	1BJM75	X						
232	1CJM75		X					
233	2AJM75	X						
234	2BJM75	X						
235	2CJM75		X					
236	2DJM75			X				
237	2FJM75		X					
238	3AJM75	X						
239	3BJM75	X						
240	3CJM75		X					
241	3DJM75				X			
242	3EJM75			X				
243	4AJM75	X						
244	4BJM75	X						
245	4CJM75		X					
246	4DJM75				X			
247	4EJM75			X				
248	5AJM75	X						
249	5BJM75	X						
250	5CJM75		X					
251	6AJM75	X						
252	6BJM76	X						
253	6CJM75		X					
254	7AJM75	X						
255	7BJM75	X						

PLATE IV (cont.)

PLATE V — W. WATSON PK. Strat. Sec.

PLATE VIII WHITE RIVER GLACIER Traverse

PLATE IX

Bering Glacier Quad 1:250,000								
Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
256	8AJH75	X						
257	63P75	X						
258	62P75				X			
259	61P75	X						
260	41AWL75		X					
261	41BWL75	X						
262	41CWL75	X						
263	42AWL75	X						
264	42BWL75	X						
265	42CWL75	X						
266	56WL75	X						
267	55WL75	X						
268	59WL75		X					
269	58WL75	X						
270	57WL75	X						
271	62WL75		X					
272	61WL75	X						
273	60WL75	X						
274	65WL75		X					
275	64WL75	X						
276	63WL75	X						
277	69WL75		X					
278	67WL75	X						
279	66WL75	X						
280	70WL75							
281	69WL75	X						
282	91P75	X						
283	90P75	X						
284	89P75		X					
285	88P75				X			

PLATE IX UMBRELLA REEF Stratigraphic Section

PLATE X MUNDAY GLACIER Traverse

PLATE XI

Bering Glacier Quad
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
286	87P75	X						
287	86P75		X					
288	85P75				X			
289	84P75	X						
290	83P75				X			
291	103WL75		X					
292	102WL75				X			
293	101WL75	X						
294	100WL75	X						
295	94WL75		X					
296	95WL75				X			
297	93WL75							ORIENTED SAND
298	92WL75	X						
299	90WL75		X					
300	91WL75				X			
301	35JW75		X					
302	36JW75	X						
303	114P75	X						
304	112P75				X			
305	113P75		X					
306	40JM75	X						
307	41JM75	X						
308	42JM75		X					
309	DLM175	X						
310	DLM275			X				
311	DLM375	X						
312	DLM475							WATER AND GAS SAMPLE
313	DLM575	X						
314	DLM675							ORIENTED SS
315	DLM775	X						

Bering Glacier Quad
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
316	DLM875	X						
317	DLM975	X						
318	DLM1275	X						
319	DLM10A75	X						
320	DLM13A75				X			
321	DLM1175	X						
322	DLM1375				X			
323	DLM1475	X						
324	DLM1575	X						
325	21DM75			X				
326	20DM75		X					
327	9DM75	X						
328	8DM75		X					
329	16DM75	X						
330	16ADM75		X					
331	17DM75				X			
332	49P75				X			X
333	89WL75				X			X
334	TM1375		X					
335	TM1475	X						
336	TM1375		X					
337	TM1275	X						
338	TM1175	X						
339	TM1075	X						
340	TM975		X					
341	TM875							OFFICE
342	TM775	X						
343	TM675				X			
344	TM575				X			
345	TM475	X						

PLATE XI MUNDAY CREEK Stratigraphic Section (Map Nos. 316–331)

PLATE XII GUYOT GLACIER Stratigraphic Section (Map Nos. 334–345)

Bering Glacier Quad
1:250,000

PLATE XII GUYOT GLACIER Stratigraphic Section (Map Nos. 346–368)

PLATE XIII ICY BAY Traverse (Map Nos. 369–376)

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
346	TM375		X					
347	TM275				X			
348	TM175				X			
349	WML1775			X				
350	WML1675				X			
351	WML1575		X					
352	WML1475	X						
353	WML1375	X						
354	WML1275	X						
355	WML1175	X						
356	WML1075	X						
357	WML975	X						
358	WML875	X						
359	WML775							RIPPLE MARKS
360	WML675		X					
361	WML575		X					
362	WML475		X					
363	WML375	X						
364	WML275	X						
365	WML175		X					
366	1P75		X					
367	2P75		X					
368	3P75				X			
369	4P75	X						
370	5P75				X			
371	6P75	X						
372	7P75				X			
373	8P75	X						
374	9P75				X			
375	10P75	X						
376	11P75	X						

PLATE XIII ICY BAY Traverse

Bering Glacier Quad
:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
377	12P75	X						
378	13P75		X					
379	14P75	X						
380	15P75	X						
381	16P75	X						
382	17P75	X						
383	18P75		X					
384	19P75	X						
385	20P75	X						
386	21P75				X			
387	22P75	X						
388	23P75	X						
389	24P75	X						
390	86WL75							X

Icy Bay Quad
1:250,000

Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
391	50P75					X		X
392	71WL75					X		
393	52P75							X
394	51P75							X
395	87WL75							X

Mt. St. Elias 1:250,000								
Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
396	85WL75							X
397	84WL75							OIL

Yakutat Quad 1:250,000								
Map No.	Sample No.	Porosity	Hydrocarbon	Macro fossils	Micro fossils	Geochem	Oil	Gravity or other
398	83WL75					x		x
399	74WL75							x
400	72WL75					x		x
401	73WL75							x
402	75WL75							x
403	82WL75							x
404	76WL75					x		x
405	77WL75					x		x
406	81WL75					x		x
407	78WL75							x
408	79WL75					x		x
409	80WL75					x		x

ADDENDUM 1

MACROFOSSIL PALEONTOLOGICAL DATA

STRATIGRAPHIC RANGE	Oligocene and Miocene	SHIPMENT NUMBER	CD-75-1M
GENERAL LOCALITY	Alaska	REGION	Yakataga Dist
QUADRANGLE OR AREA	Yakataga District	DATE RECEIVED	9/75
KINDS OF FOSSILS	Mollusks and echinoids	STATUS OF WORK	Complete
REFERRED BY	Irven Palmer, Conservation Division	DATE REPORTED	12/15/75
REPORT PREPARED BY	Louie N. Marincovich		

This report deals with 19 collections of middle Tertiary mollusks and echinoids from the Yakataga District of the Gulf of Alaska Tertiary Province, made at six different sites. The collections are grouped below by stratigraphic section and listed by field locality number and map number (as given on the location map accompanying the collections). Material assigned USGS Cenozoic locality numbers is being retained, other material is being discarded.

HANNA LAKE STRATIGRAPHIC SECTION

Field loc. 72-P-75, map number 1 (USGS Cenozoic loc. M6529). Latitude: 60 degs. 16 min. 12 sec. N., longitude: 143 degs. 17 min. 42 sec. W, Yakataga District, Alaska.

Bivalve:
?PORTLANDIA sp.

Scaphopod:
DENTALIUM cf. D. NONUMAE Takeda

Field loc. 74-P-75, map number 2. Latitude: 60 degs. 16 min. 12 sec. N., longitude 143 degs. 17 min. 42 sec. W, Yakataga District, Alaska.

Inorganic (probably chert) fragments in center of concretion

Age: The DENTALIUM species is reported in the lower and upper Poul Creek Formation, but its exact stratigraphic occurrence is not documented beyond Oligocene to lower Miocene.

Environment: DENTALIUM in the modern northeastern Pacific has a bathymetric range of 5 to 2,320 metres, shallowly buried in soft substrate.

YAKATAGA REEF STRATIGRAPHIC SECTION

Field loc. 2D-JM-75, map number 3. Latitude: 60 degs. @

STRATIGRAPHIC RANGE
GENERAL LOCALITY
QUADRANGLE OR AREA
KINDS OF FOSSILS
REFERRED BY
REPORT PREPARED BY

SHIPMENT NUMBER CD-75-1M
REGION
DATE RECEIVED
STATUS OF WORK
DATE REPORTED

Field loc. 2D-JM-75 (continued)

3 min. 50 sec. N., longitude: 142 degs. 25 min. 45 sec. W., Yakataga District, Alaska.

Shale chips lacking megafossils

Field loc. 3E-JM-75, map number 4. Same coordinates as above.

Incomplete internal mold of one specimen, showing both valves; genus and species indeterminate.

Field loc. 4E-JM-75 (cited as *4C-JM-75* on map), map number 5 (USGS Cenozoic loc. M6530). Same coordinates as above.

Bivalve:
MYA (MYA) TRUNCATA Linnaeus

Field loc. 32C-JM-75 (cited as *37C-JM-75* on map and sample list), map number 6. Same coordinates as above.

Bivalves:
Partial external molds of two specimens, badly worn and broken; genus and species indeterminate.

Age: The MYA species ranges from early middle Miocene to Holocene in the North Pacific. Its earliest known occurrences anywhere is in the lower Yakataga Formation.

Environment: MYA occurs from intertidal to 50 metres depth in sandy mud in the modern northeastern Pacific. The specimen here is broken but not worn, and the valves are articulated and closed, suggesting that the specimen was not transported before burial. @

S\ GRAPHIC RANGE

GENERAL LOCALITY

QUADRANGLE OR AREA

KINDS OF FOSSILS

REFERRED BY

REPORT PREPARED BY

SHIPMENT NUMBER CD-75-1M

REGION

DATE RECEIVED

STATUS OF WORK

DATE REPORTED

YAGA-YAKATAGA GLACIERS STRATIGRAPHIC SECTION

Field loc. WL-37-75, map number 7 (USGS Cenozoic loc. M6531). Latitude: 60 degs. 10 min. 25 sec. N., longitude 142 degs. 3 min. 10 sec. W., Yakataga District, Alaska.

Bivalve:
Indeterminate fragment of an external mold of one valve

Gastropod:
TURRITELLA (NEOHAUSTATOR) HAMILTONENSIS Clark

Field loc. WL-39-75, map number 8 (USGS Cenozoic loc. M6532). Same coordinates as above.

Bivalves:
MACOMA ARCTATA (Conrad)
SERRIPES HAMILTONENSIS (Clark)

Gastropods:
NATICA (CRYPTONATICA) CLAUSA Broderip & Sowerby
TURRITELLA (NEOHAUSTATOR) HAMILTONENSIS Clark

Age: Probable early to middle Miocene.

Environment: SERRIPES in the modern northeastern Pacific has a bathymetric range of 0-135 metres, whereas TURRITELLA is known in 20-185 metres depth.

MOUNT EBERLY STRATIGRAPHIC SECTION

Field loc. 93-P-75, map number 9 (USGS Cenozoic loc. M6533). Latitude 60 degs. 7 min. 13 sec. N., longitude 141 degs. 58 min. 15 sec. W., Yakataga District, Alaska.

Bivalves:
NUCULANA (BORISSIA) ALFEROVI SAKHALINENSIS Krishtofovich
YOLDIA sp. a

STRATIGRAPHIC RANGE

GENERAL LOCALITY

QUADRANGLE OR AREA

KINDS OF FOSSILS

REFERRED BY

REPORT PREPARED BY

SHIPMENT NUMBER CD-75-1M

REGION

DATE RECEIVED

STATUS OF WORK

DATE REPORTED

Field loc. 93-P-75 (USGS Cenozoic loc. M6533) (continued)

Bivalves (continued):
?MACOMA sp. - fragment

Field loc. 98-P-75, map number 10 (USGS Cenozoic loc. M6534). Latitude: 60 degs. 7 min. 15 sec. N., longitude 141 degs. 58 min. 15 sec. W., Yakataga District, Alaska.

Bivalve:
Pectinid fragments

Gastropod:
NATICA (CRYPTONATICA) CLAUSA Broderip & Sowerby

Field loc. 110-P-75, map number 11. Latitude: 60 degs. 7 min. 35 sec. N., longitude: 141 degs. 58 min. 15 sec. W., Yakataga District, Alaska.

Bivalve:
CLINOCARDIUM sp. - small, worn fragments of external molds

Field loc. 30A-JCW-75, map number 12 (USGS Cenozoic loc. M6535). Latitude: 60 degs. 7 min. 37 sec. N., longitude: 141 degs. 58 min. 15 sec. W., Yakataga District, Alaska.

Bivalves:
ACILA (TRUNCACILA) TALIAFERROI Schenck
CONCHOCELE DISJUNCTA Gabb
CLINOCARDIUM cf. C. BROOKSI (Clark)

Field loc. 107-WL-75, map number 13. Latitude: 60 degs. 7 min. 40 sec. N., longitude: 141 degs. 57 min. 55 sec. W., Yakataga District, Alaska. @

RATIGRAPHIC RANGE		SHIPMENT NUMBER	CD-75-1M
GENERAL LOCALITY		REGION	
QUADRANGLE OR AREA		DATE RECEIVED	
KINDS OF FOSSILS		STATUS OF WORK	
REFERRED BY		DATE REPORTED	
REPORT PREPARED BY			

Field loc. 107-WL-75 (continued)

Bivalves:
Fragments of external molds of small specimens, badly worn

Echinoid:
One fragment of an echinoid test

Field loc. 110-WL-75, map number 14. Latitude: 60 degs. 7 min. 45 sec. N., longitude 141 degs. 57 min. 50 sec. W., Yakataga District, Alaska.

Sample not included in shipment sent to me.

Field loc. 112-WL-75, map number 15. Latitude: 60 degs. 7 min. 45 sec. N., longitude: 141 degs. 57 min. 45 sec. W., Yakataga District, Alaska.

Bivalves:
ACILA sp. - worn fragments
CYCLOCARDIA sp. - worn fragments

Field loc. 118-WL-75, map number 16 (USGS Cenozoic loc. M6536). Latitude: 60 degs. 8 min. 9 sec. N., longitude: 141 degs. 57 min. 45 sec. W., Yakataga District, Alaska.

Bivalve:
CYCLOCARDIA sp.. - fragment

Gastropod:
NATICA (CRYPTONATICA) CLAUSA Broderip & Sowerby

Field loc. 120-WL-75, map number 17 (USGS Cenozoic loc. M6537). Latitude: 60 degs. 8 min. 6 sec. N., longitude 141 degs. 57 min. 37 sec. W., Yakataga District, Alaska. @

STRATIGRAPHIC RANGE

GENERAL LOCALITY

QUADRANGLE OR AREA

KINDS OF FOSSILS

REFERRED BY

REPORT PREPARED BY

SHIPMENT NUMBER CD-75-1M

REGION

DATE RECEIVED

STATUS OF WORK

DATE REPORTED

Field loc. 120-WL-75 (USGS Cenozoic loc. M6537) (continued)

Bivalve:
ACILA (TRUNCACILA) TALIAFERROI Schenck

Field loc. 125-WL-75, map number 18 (USGS Cenozoic loc. M6538). Latitude: 60 degs. 8 min. 9 sec. N., longitude: 141 degs. 57 min. 30 sec. W., Yakataga District, Alaska.

Bivalves:
ACILA (TRUNCACILA) TALIAFERROI Schenck
CYCLOCARDIA sp.
MACOMA sp.

Age: Early to middle Miocene.

Environment: No species with a narrowly limited bathymetric range are included here, beyond saying that the fauna represents deposition in neritic (0-200 metres) depths.

MUNDAY CREEK STRATIGRAPHIC SECTION

Field loc. 2-DM-75, map number 19 (USGS Cenozoic loc. M6539). Latitude: 60 degs. 1 min. 28 sec. N., longitude: 141 degs. 56 min. 40 sec. W., Yakataga District, Alaska.

Bivalves:
MACOMA cf. M. INCONGRUA (von Martens)
MACOMA sp. - internal molds

Field loc. 21-DM-75, map number 20, Latitude: 60 degs. 1 min. 17 sec. N., longitude: 141 degs. 56 min. 45 sec. W., Yakataga District, Alaska.

Bivalve: MACOMA sp. - worn and broken valve

Continued in CD-75-1M part A @

STRATIGRAPHIC RANGE	Oligocene and Miocene	SHIPMENT NUMBER	CD-75-1M-A
GENERAL LOCALITY	Alaska	REGION	Yakataga Dist
QUADRANGLE OR AREA	Yakataga District	DATE RECEIVED	9/75
KINDS OF FOSSILS	Mollusks and echinoids	STATUS OF WORK	Complete
REFERRED BY	Irven Palmer, Conservation Division	DATE REPORTED	12/15/75
REPORT PREPARED BY	Louie N. Marincovich		

Continued from CD-75-1M

Field loc. 21-DM-75 (continued)

Age: MACOMA INCONGRUA ranges from late Oligocene or early Miocene to Holocene.

Environment: Ecological data for M. INCONGRUA are not available; the genus ranges from intertidal to 1,500 metres in the modern northeastern Pacific, but is most common at shelf depths (0-200 metres).

GUYOT GLACIER - NUNATAK STRATIGRAPHIC SECTION

Field loc. 17-WL-75, map number 21 (USGS Cenozoic loc. M6540). Latitude: 60 degs. 5 min. 11 sec. N., longitude: 141 degs. 28 min. 45 sec. W., Yakataga District, Alaska.

Bivalve:
CLINOCARDIUM YAKATAGENSE (Clark)

Age: middle Miocene

Environment: The genus is reported in the modern northeastern Pacific in depths of 0-200 metres.

* denotes quotes @

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Louie N. Marincovich CMC

ADDENDUM 2

PETROGRAPHY OF TERTIARY SANDSTONES

Pages 1 - 7

(Refer to page 20 of text)

AND

PETROGRAPHY OF CONGLOMERATIC MUDSTONE CLASTS

Pages 7 - 10

(Refer to page 20 of text)

PETROGRAPHY OF TERTIARY SANDSTONES

General Statement

Outcrop samples of sandstones of Paleocene through Pleistocene age from the onshore Gulf of Alaska Tertiary Province characteristically are texturally immature and mineralogically unstable (Galloway, 1972; Winkler, McLean, and Plafker, 1976). Texturally, most sandstones are subwackes (Dapples, 1972); mineralogically, their average compositions are lithofeldspathic (Dickinson, 1970). Diagenetic alteration of framework grains throughout the stratigraphic sequence has produced widespread phyllosilicate grain coatings, interstitial cement, pseudomatrix, and even scattered grain overgrowths. These diagenetic alterations adversely affect sandstone porosity and permeability, particularly in the older Tertiary rocks. In the younger Tertiary rocks, alteration locally is less pervasive and less severe.

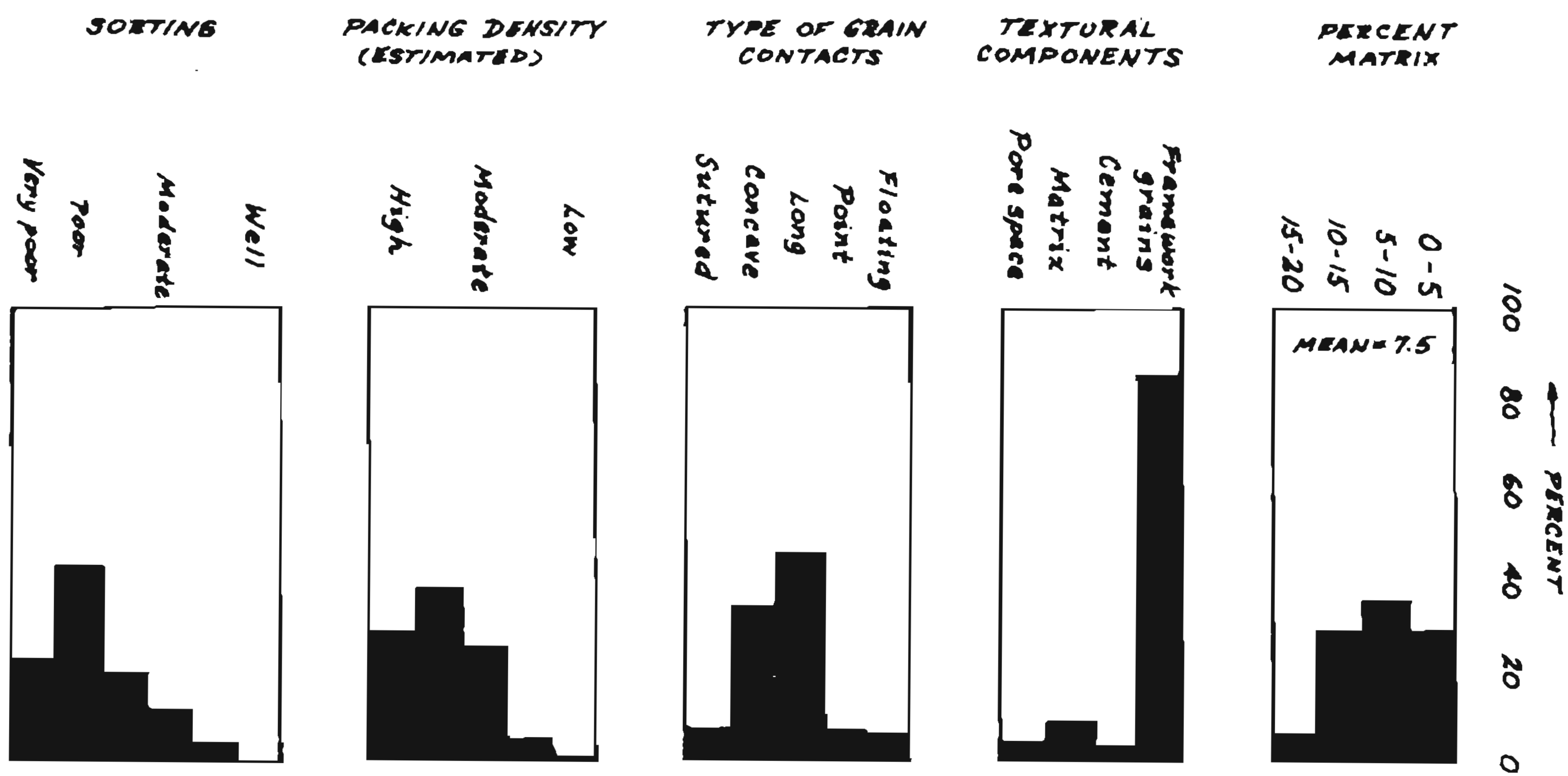
Pre-Yakataga Formation Sandstones

Multiple deformation and deep burial of Paleocene and Eocene stratigraphic units--the Orca Group, the shale of Haydon Peak, and the Kushtaka, Kulthieth, and Tokun Formations--caused extensive alteration and interpenetration of framework grains. Volcanic lithic grains and plagioclase feldspar are most severely affected, being moderately to strongly altered to chlorite, sericite, and laumontite. In a few cases, quartz-prehnite-carbonate veins or even pumpellyite in volcanic lithic grains are present. Interstices are filled with chlorite or laumontite. Galloway (1974) has found that such changes begin as shallowly as 1500 m (5000 ft) in the Queen Charlotte Basin of British Columbia. In the Gulf of Alaska Tertiary Province, deeper burial probably is indicated by partial recrystallization of some matrix minerals, advanced alteration of volcanic rock fragments, and a "welded" fabric produced by complex interpenetration of many grain boundaries.

Sedimentary sequences of Oligocene age typically have diagenetic features that are suggestive of shallower burial, such as carbonate cement and authigenic phyllosilicate coatings around framework grains. Carbonate cement constitutes as much as 50 percent of some sandstones in the Katalla and Poul Creek Formations. Where carbonate cement is abundant, little other cement and only minor grain alteration and pseudomatrix are present--an indication that early formation of carbonate cement may inhibit deterioration of the texture and mineralogy of framework grains. Where carbonate cement is scanty or lacking, the continued presence of mineralogically unstable framework grains (particularly intraformational volcanic detritus) has allowed considerable alteration of grains and pore-space reduction by growth of phyllosilicate coatings and matrix. Winkler, McLean, and Plafker (1976, p. 15) have suggested that most matrix in pre-Yakataga Formation sandstones from the Gulf of Alaska Tertiary Province is derived secondarily.

Yakataga Formation Sandstones

Sandstones from the Miocene-Pleistocene Yakataga Formation are texturally more diverse than the older rocks. Figure 1 shows histograms of five different



TEXTURAL FEATURES OF YAKATAGA SANDSTONES

FIGURE 1

textural features that were evaluated in thin sections of 54 sandstones from the Yakataga Formation between Grindle Hills on the west and Icy Bay on the east.

(1) Sorting was estimated visually by referring to sorting images illustrated in Pettijohn, Potter, and Siever (1972, p. 585).

(2) Packing Density was estimated where "High" = framework grains tightly packed with abundant interpenetration involving squeezing of relatively soft lithic fragments between and around more resistant grains such as quartz and feldspar; "Moderate" = closely packed framework with minor grain interpenetration and little or no deformation of lithic fragments; and "Low" = framework separated by or floating in matrix or authigenic cement with no observable grain interpenetration.

(3) Type of Grain Contacts (Taylor, 1950) include a) sutured grains, mutual stylolitic interpenetration of two or more grains, usually attributed to much pressure solution; b) concavo-convex contacts, usually attributed to moderate pressure solution; c) long or straight contacts, indicative of only minor compaction and pressure solution; d) point or tangential contacts, minor or no pressure solution; and e) floating grains which are not in contact with other framework constituents. Most samples exhibit more than one type of grain contact; occurrences were recalculated so that their summation equals 100 percent.

(4) Textural Components were determined by modal analyses ("point counts") of a subset of seventeen thin sections selected at random. Modal pore space was consistently approximately one-half of the percent porosity measured in the laboratory.

(5) Percent Matrix is a somewhat subjective index that may include intergranular material of diverse origin. In sandstones such as these with moderate to advanced framework alteration and ubiquitous phyllosilicate coatings and pore filling, it may be difficult to distinguish original matrix from altered rock fragments or pseudomatrix. Probably both types of matrix occur in these sandstones; since their influence on ultimate rock texture is the same, they have been combined for this diagram.

There is an obvious interrelationship of textural features which will have an important effect on sandstone reservoir quality. There is a strong inverse correlation between packing density and percentage of matrix or cement in each sample. Packing density also normally will be related indirectly to the type of grain contacts and to porosity; tightly appressed grains with sutured, concavo-convex, and long contacts usually occur in sandstones with a high packing density and low porosity, unless fracture porosity is present.

Generally sandstones of the Yakataga Formation tend to be better sorted and less tightly compacted than the older Tertiary sandstones, with less pressure solution and pseudomatrix. Where matrix is abundant, it tends to be a primary admixture, although commonly chlorite and sericite, and occasionally laumontite, are present as matrix minerals. Carbonate cement also is common, but seldom is abundant in single samples. Surprisingly, some dense, thoroughly altered samples with strong interpenetration of framework grains and laumontite or phyllosilicate pore fillings are preserved in Yakataga sequences as young as Pliocene. Thus, Yakataga Formation sandstones are represented in almost every textural category on figure 1. The "average" Yakataga Formation sandstone consists predominantly of framework grains that are poorly sorted, moderately to tightly packed, and in long or concavo-convex contact. The percent of matrix material ranges from 1.5

to 17.5, with a mean of 7.5; the percent of cement ranges from 0 to 18.5, with a mean of 3.5.

Sandstones of the Yakataga Formation are subquartzose (i.e., total of quartzose grains is less than 50 percent); although detrital modes vary widely, the average composition of seventeen samples is lithofeldspathic (fig. 2). Polycrystalline quartz constitutes about 13 percent of total quartzose grains, plagioclase (much of it strongly altered) constitutes about 89 percent of total feldspar, and altered mafic to intermediate volcanic grains constitute about 59 percent of total lithic grains. However, there is considerable variation in proportions of the three lithic constituents between samples (as expressed by the wide range in the V/L ratio).

Mineralogical relations of the Yakataga Formation sandstones are similar to those of continental margin Tertiary sandstones from the Queen Charlotte Basin (Galloway, 1974) and the western Olympic Peninsula and Vancouver Island (Stewart, 1974); they are very different from detrital modes of sandstones deposited in arc-related troughs, such as the Tertiary of the Bristol Basin of Alaska and the Grays Harbor-Chehalis Basins of Washington (Galloway, 1974) or the Upper Mesozoic of the Kodiak Shelf (Moore, 1973), which have many more lithic grains and plot much closer to the rock fragments apex of the Q-F-L diagram (fig. 2).

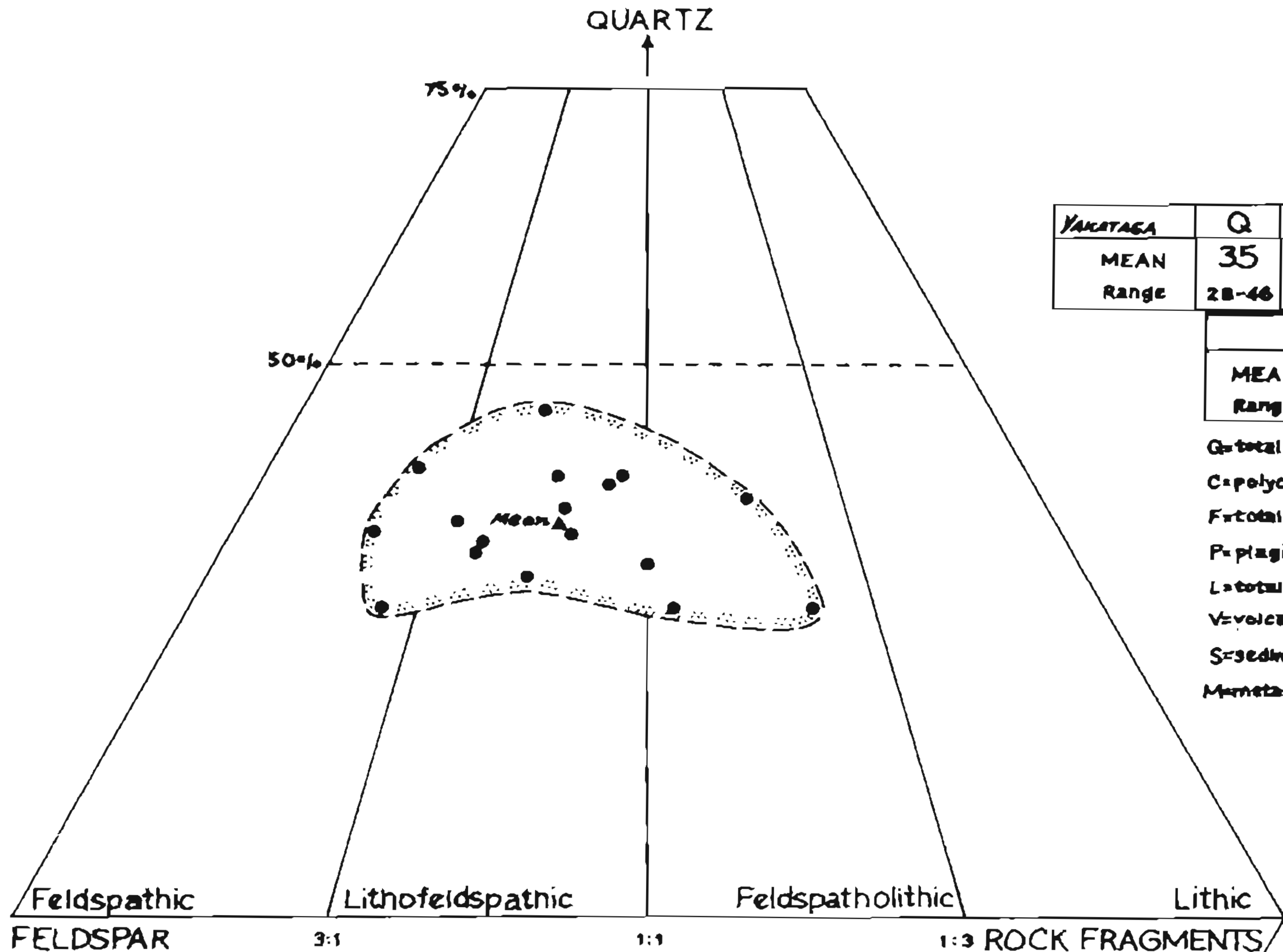
Percentages of heavy mineral assemblages and detrital biotite from Yakataga Formation sandstones are depicted in the pie diagram of figure 3. Modes of heavy minerals range from 0.5 to 12.5 percent, with a mean of 4.8 percent. Epidote and amphibole family minerals and biotite dominate all assemblages; but garnet, clinopyroxene, and sphene are consistently present in small amounts. Other heavy mineral species, including zircon, muscovite, tourmaline, allanite, pumpellyite, orthopyroxene, and staurolite occur sporadically in trace amounts.

Yakataga Formation sandstones with relatively higher measured porosities had lower densities and shorter grain contacts. However, no other consistent differences in texture or mineralogy were apparent between sandstones with relatively higher or lower porosities. In particular, sorting was not improved, matrix did not decrease, and the percentages of altered framework grains did not decrease in more porous samples such as those from the Icy Bay traverse. These sandstones are not texturally mature or mineralogically stable.

Despite considerable scatter in data, there is a general increase in porosity upward stratigraphically in the Yakataga Formation (Winkler, McLean, and Plafker, 1976, p. 17-18), suggesting that depth of burial may be an important factor in controlling porosity. Furthermore, framework alteration and pore-space reduction in some Yakataga Formation sandstones may have been heightened by proximity to sharp anticlinal flexures or to major faults. Thus, local occurrence of sandstones with improved reservoir properties may be a combination of stratigraphic and structural, as well as facies, control.

Provenance

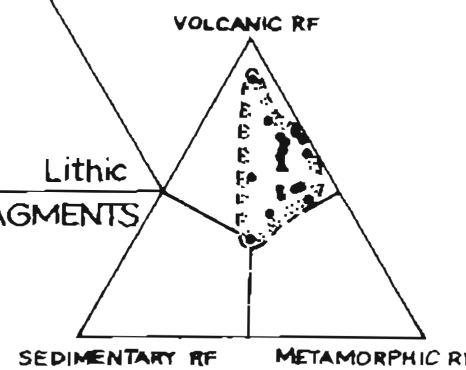
Yakataga Formation sandstones appear to have been derived from mixed northerly and easterly sources. The moderate percentage of quartz and the presence of polycrystalline quartzose grains, foliated lithic grains, epidote,



YAKATAGA	Q	F	L	V	S	M
MEAN	35	40	25	59	12	29
Range	28-46	23-57	11-49	33-88	1-33	6-42

	C/Q	P/F	V/L
MEAN	.13	.89	.59
Range	.06-.20	.82-.95	.33-.88

Q=total quartzose grains
C=polycrystalline quartzose grains
F=total feldspar
P=plagioclase
L=total rock fragments (RF)
V=volcanic RF
S=sedimentary RF
M=metamorphic RF



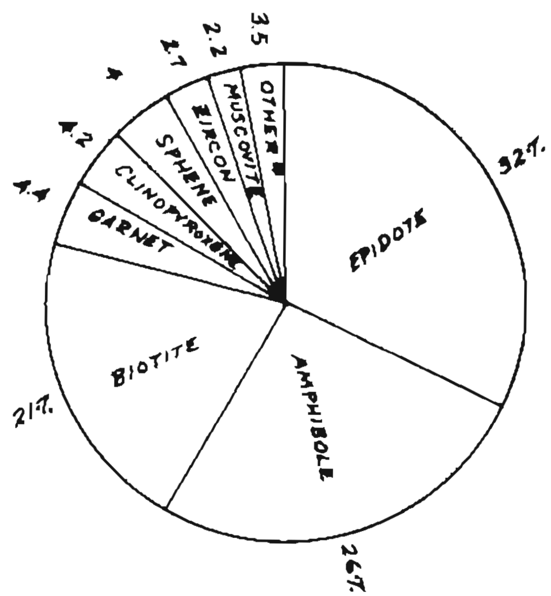
MINERALOGY OF YAKATAGA FORMATION SANDSTONES

FIGURE 2

FIGURE 3

HEAVY MINERAL PROPORTIONS, YAKATAGA SANDSTONES

(AS PERCENT OF TOTAL HM GRAINS)



* TRACE AMOUNTS OF GLAUCONITE PRESENT IN 41% OF SAMPLES

garnet, and comparatively abundant mica are characteristics of a "tectonic" provenance (Dickinson, 1970). In addition, high feldspar and low lithic percentages are suggestive of some input from a plutonic provenance; because little potash feldspar is present, the plutonic rocks probably were of intermediate composition. Recycling of some detritus from a composite sedimentary and volcanic terrane is probable, because of the abundance of altered feldspar grains, the frequent occurrence of strongly altered mafic volcanic detritus, and the sporadic occurrence of quartz grains with overgrowths that have been slightly rounded.

These mineralogical characteristics indicate that Yakataga detritus apparently was derived from a tectonized and intruded sedimentary and volcanic terrane. The most likely source was the adjacent Chugach-Saint Elias-Fairweather Mountains, which consist of low grade slate, graywacke, and greenstone surrounding core complexes of high grade crystalline schist, gneiss, and plutonic rocks (the Mesozoic "Chugach" and Paleozoic "Taku-Skolai" and "Alexander" terranes of Berg, Jones, and Richter, 1972).

PETROGRAPHY OF CONGLOMERATIC MUDSTONE CLASTS

Marine glacial conglomeratic mudstones (diamictites) are both abundant and widespread in the Yakataga Formation (Plafker and Addicott, 1976). Apparently the Yakataga basin had a structurally positive northern margin sufficiently mountainous to nourish tidewater glaciers. Minor unconformities and thick beds of conglomerate in the lower part of the Yakataga Formation indicate local uplift and erosion began in early Miocene time; multiple angular unconformities in the upper part of the Yakataga Formation indicate that structures within the basin were growing deposits within the formation and the absence of continental equivalents along the northern margin of the basin suggest that the coast was generally steep or ice-fronted during much of Neogene time. Thus, present conditions along the northern Gulf of Alaska coast provide a good analog for conditions that must have prevailed during deposition of the Yakataga Formation, although the ice-rafting that continues today in parts of the region is at a considerably reduced rate from its Plio-Pleistocene maximum.

Hand specimen and thin section examination of many clasts from diamictite in the lower part of the Yakataga Formation at Yakataga Reef has confirmed that terranes proximal to the present northern and eastern limits of the Yakataga Formation were sources by Miocene time for the coarse detritus. Clasts of meta-diorite, meta-andesite, and meta-andesite tuff most likely were derived from the Paleozoic metamorphic terrane somewhat north and east of the present axis of the Chugach, Saint Elias, and Fairweather Mountains. In addition, lesser quantities of slate, graywacke, epidote amphibolite, and foliated or nonfoliated hornblende or biotite granodiorite certainly were derived from intervening Mesozoic and Lower Tertiary terranes. Apparently through-going glacier drainages tapped detritus from the full breadth of the Pacific Border Ranges. Thus, detrital mineralogy of both Yakataga Formation diamictites and sandstones indicates provincial, if not local, sources for the bulk of the sediment.

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Appendix--List of thin sections examined for textural and mineralogical features by localities and field numbers

TEXTURE	MINERALOGY
Munday Creek Stratigraphic Section	
DM-1-75	
DM-3-75	
DM-5-75	DM-5-75
DM-10-75	DM-10-75
DM-12-75	
DM-15-75	
East Yakataga Reef Traverse	
JM-1A-75	JM-1A-75
JM-2A-75	JM-2A-75
JM-4A-75	
JM-5A-75	
JM-6A-75	JM-6A-75
JM-8A-75	
JCW-1A-75	JCW-1A-75
JCW-2A-75	
JCW-4A-75	
West Yakataga Reef Traverse	
JM-35B-75	
JM-36B-75	
JM-37B-75	
JM-38B-75	
Munday Glacier Traverse	
JM-40-75	JM-40-75
JCW-36-75	
WL-92-75	
WL-101-75	
Yaga-Yakataga Stratigraphic Section	
JCW-10-75	
WL-9-75	WL-9-75
WL-23-75	
WL-35-75	WL-35-75
Grindle Hills Stratigraphic Section	
JCW-16-75	
JCW-18-75	JCW-18-75
WL-53-75	WL-53-75

Appendix--continued

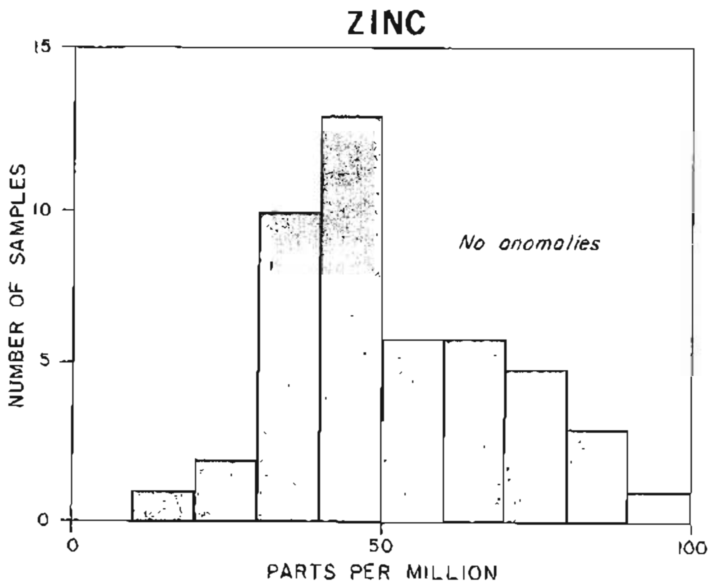
TEXTURE	MINERALOGY
Mt. Eberly Stratigraphic Section	
JCW-26-75	JCW-26-75
JCW-31-75	
P-102-75	
P-103-75	
WL-111-75	
WL-117-75	WL-117-75
WL-122-75	
WL-130-75	
Icy Bay Traverse	
P-4-75	P-4-75
P-8-75	
P-16-75	
P-19-75	P-19-75
P-23-75	
West Watson Peak Stratigraphic Section	
P-63-75	
Hanna Lake Stratigraphic Section	
P-64-75	
P-70-75	
Guyot Glacier Traverse	
TM-14-75	
WL-11-75	WL-11-75
White River Glacier Traverse	
WL-41B-75	
WL-42C-75	
WL-56-75	
WL-60-75	WL-60-75
WL-64-75	
WL-69-75	
Total: 54 sandstones	Total: 17 sandstones
West Yakataga Reef*	
P-53-75	P-53-75

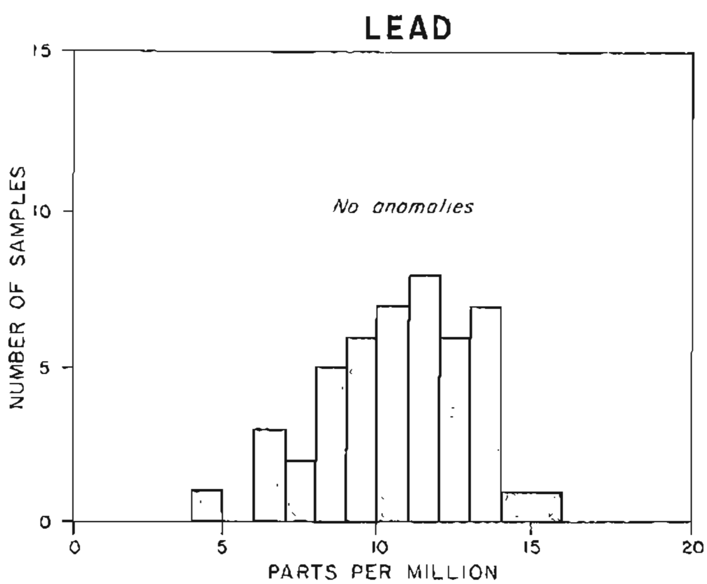
*8 diamictite clasts

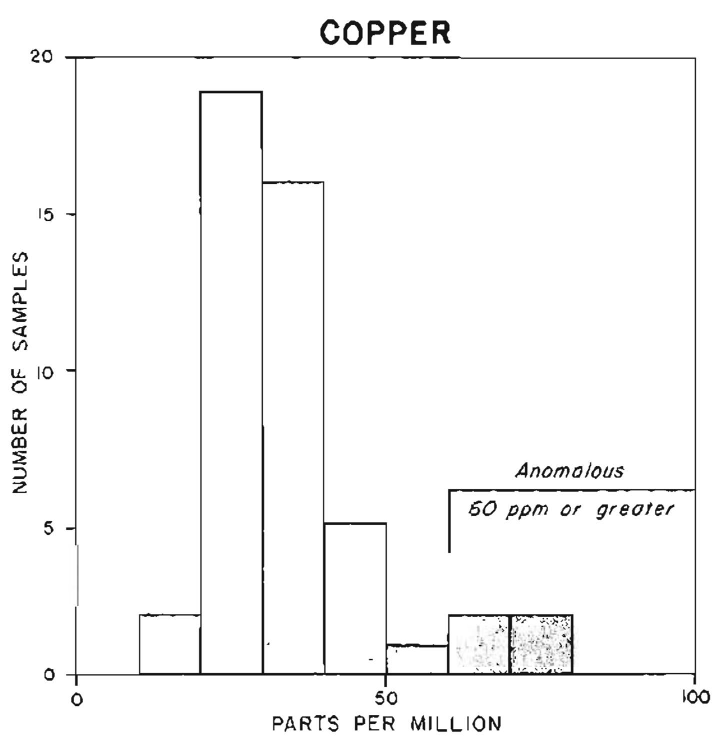
ADDENDUM 3

GEOCHEMICAL CONTROL

(Refer to page 21 of text)


ZINC
NUMBER OF SAMPLES
0
5
10
15
No anomalies
0
50
100
PARTS PER MILLION


LEAD
NUMBER OF SAMPLES
0
5
10
15
No anomalies
0
5
10
15
20
PARTS PER MILLION


COPPER
NUMBER OF SAMPLES
0
5
10
15
20
Anomalous
60 ppm or greater
0
50
100
PARTS PER MILLION

STREAM SEDIMENT SAMPLES

Field #	Tag #	Gold	Silver	Copper	Lead	Zinc	Molybdenum	Antimony
24 P75	1 BL	Nil	Nil	71	7	43	Nil	5
25 P75	2 BL	Nil	Nil	40	10	53	Nil	2
31 P75	3 BL	Nil	Nil	60	10	43	16	1
38 P75	4 BL	Nil	Nil	43	11	56	14	2
40 P75	5 BL	Nil	Nil	60	7	50	16	1
42 P75	6 BL	.02	Nil	45	7	38	Nil	2
46A P75	7 BL		N O	D A T A				
47 P75	8 BL	Nil	Nil	28	5	36	Nil	1
48 P75	9 BL	Nil	Nil	26	9	69	Nil	Nil
49 P75	10 BL	.03	0.10	37	12	61	Nil	1
111 P75	11 BL	Nil	0.10	37	8	40	Nil	2
9 JM75	12 BL	Nil	0.10	34	14	82	Nil	1
16 JM75	13 BL	.01	Nil	50	11	49	Nil	Nil
17 JM75	14 BL	Nil	1.20	29	11	51	Nil	1
18 JM75	15 BL	Nil	0.10	23	12	65	Nil	Nil
22 JM75	16 BL	.06	Nil	25	14	70	Nil	2
23 JM75	17 BL	.03	Nil	31	14	77	1	Nil
24 JM75	18 BL	.03	Nil	76	12	49	Nil	1

Field #	Tag #	Gold	Silver	Copper	Lead	Zinc	Molybdenum	Antimony
25 JM75	19 BL	.01	0.10	20	14	65	Nil	Nil
26 JM75	20 BL	Nil	Nil	20	13	64	Nil	Nil
27 JM75	21 BL	.04	Nil	27	14	76	1	3
28 JM75	22 BL	Nil	Nil	29	13	73	1	Nil
29 JM75	23 BL	.01	Nil	36	15	82	1	1
30 JM75	24 BL	.04	Nil	37	14	84	1	1
89 WL75	25 BL	Nil	Nil	24	10	44	1	1
32 JM75	26 BL	Nil	Nil	27	11	56	1	Nil
33 JM75	27 BL	Nil	0.10	33	9	48	1	Nil
31 JM75	28 BL	Nil	Nil	34	12	73	1	1
17 DM75	29 BL	Nil	Nil	34	11	49	1	Nil
50 P75	30 BL	Nil	Nil	34	10	42	1	Nil
71 WL75	31 BL	.01	Nil	29	9	38	Nil	2
19 BJM75	32 BL	Nil	Nil	31	12	40	Nil	4
20 JM75	33 BL	Nil	Nil	36	13	44	Nil	3
26 P75	34 BL	.01	Nil	21	11	40	Nil	3
51 JM75	35 BL	.04	0.80	30	13	37	Nil	Nil
52 JM75	36 BL	.02	0.10	25	13	34	Nil	4
53 JM75	37 BL	.01	Nil	26	12	36	Nil	3

Field #	Tag #	Gold	Silver	Copper	Lead	Zinc	Molybdenum	Antimony
54 JM75	38 BL	Nil	Nil	25	14	43	1	1
72 WL75	39 BL		N O	D A T A				
76 WL75	40 BL	Nil	Nil	25	12	30	11	3
77 WL75	41 BL	Nil	Nil	32	9	29	5	1
79 WL75	42 BL	.02	0.40	43	9	30	14	Nil
80 WL75	43 BL	Nil	Nil	34	8	19	1	1
81 WL75	44 BL	Nil	Nil	43	12	44	1	2
83 WL75	45 BL	Nil	Nil	30	11	47	1	1
18 JM75A	46 BL	Nil	Nil	27	13	69	1	2
93 WL75	47 BL	Nil	Nil	13	10	31	4	2
6 DM75	48 BL	Nil	Nil	19	10	31	9	3
15 JM75	49 BL	Nil	Nil	23	16	90	9	2
46 P75A	50 BL		N O	D A T A				
27 JM75B	51 BL		S A M P L E		M I S S I N G			