UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

THE PETROLEUM GEOLOGY AND HYDROCARBON POTENTIAL OF
NAVAL PETROLEUM RESERVE NO. 4 NORTH SLOPE, ALASKA

OPEN-FILE REPORT 77-475

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

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By
R. D. Carter, C. G. Mull, K. J. Bird, and R. B. Powers

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SUMMARY

The Naval Petroleum Reserves Production Act of 1976 provides for the transfer of jurisdiction of Naval Petroleum Reserve No. 4 from the Department of the Navy to the Department of the Interior on June 1, 1977. In anticipation of the enactment of the law, the U.S. Geological Survey prepared an administrative report in 1976 to provide background information, to describe the state of knowledge of the geology of NPR-4, and to recommend studies necessary for an evaluation of the hydrocarbon potential of the Reserve.

This paper is based on the above administrative report which in turn depended upon published literature, unpublished U. S. Geological Survey data, and the background knowledge of Survey geologists with extensive experience in the regional geology and petroleum geology of the North Slope of Alaska. In addition, results of the ongoing Navy exploration of NPR-4 were made available to the Geological Survey following the signing of the Act by the President on April 5, 1976. These results were reviewed for possible conflicts with interpretations and conclusions reached in this report and no incompatibilities of significance were found.

Surface geology exploration by the USGS in the NPR-4 area began in 1904 and has continued sporadically to the present. The PET-4 program 1944-1953, designed "to appraise the oil possibilities of Naval Petroleum Reserve No. 4 and surrounding areas," produced the first subsurface information and resulted in the discovery of several minor oil and gas deposits. There was little exploration activity following the termination of the PET-4 program until 1974 when the Navy initiated a vigorous program of geophysical and drilling exploration.
and the eastern boundary, they are very thin or absent from NPR-4. Geo-
chemical data indicate that Cretaceous, Jurassic, and Upper Triassic shales
have source-rock potential. Mississippian and Lower Triassic rocks are low
in source-rock potential probably because of low organic content and thermal
over-maturity in deeper parts of the basin. The supergiant Prudhoe Bay field
is the result of rich, thermally mature Cretaceous source beds superposed on
the truncated edges of a series of good reservoir beds. Unfortunately, this
juxtaposition will probably not be found in most of NPR-4. Within the Reserve
the unconformity accounting for this superposition is apparently present on-
shore only in very limited areas along the north coast. Two of the most
important Prudhoe Bay reservoirs, the Lisburne and Sadlerochit, may be present
in a favorable structural-stratigraphic position only in the extreme north-
eastern part of NPR-4. Regional dips would seem to preclude oil migration
from the Prudhoe Bay area westward into the Reserve. Known oil and gas
occurrences in NPR-4 are found in Upper Triassic, Jurassic, and Cretaceous
rocks whereas older beds have had no reported shows. Cretaceous or Jurassic
rocks containing the richer source beds, or reservoir beds of any age within
fluid migration distance of them, would appear to be the major objectives in
NPR-4.

Three broad exploration trends with a number of plays can be predicted
for NPR-4. The Coastal Plain trend is prospective for oil and gas in
structural, stratigraphic, and combination traps in pre-Middle Cretaceous
rocks. The Northern Foothills trend might find oil and gas in shallow
structural traps in Middle Cretaceous and in limited Upper Cretaceous reservoirs.
Deeper structural and stratigraphic traps in Lower Cretaceous formations are
prospective for gas. A major play in both the above trends is the Nanushuk
Group of Middle Cretaceous age, a coarse clastic wedge present over much of
the northern Brooks Range Foothills and the southern coastal plain area.
Stratigraphic relationships are analogous to the Cretaceous Mesa Verde Group
of the Rocky Mountains. Intertonguing of marine and non-marine sediments
combined with structural features may result in potential traps. Coal is
abundant and suggests a probable gas play. Many of the sediments are medium-
to coarse-grained sandstones, but a clay matrix inhibits porosity and perme-
ability, and the prediction of porosity trends will be a major concern.

In the Southern Foothills trend gas may be found in complex structural
traps in Mississippian allochthons, and in Triassic and Lower Cretaceous rocks.
Estimated depths of over 25,000 feet to autochthonous Paleozoic rocks may pre-
clude them from exploration. Experience in similar thrust belts suggests
that total reserves are likely to be smaller than in less deformed areas.
A known prospect in the Lisburne Group in the southeastern corner of the
Reserve exhibits several hundred feet of porous dolomite, some of which con-
tains pyrobitumen. The rocks dip northward into the basin and could be a
drilling objective.

Current knowledge of North Slope geology suggests several hydrocarbon
plays that might be considered in assessing the potential of the Reserve.
Analysis of the plays indicates slight likelihood of Prudhoe Bay-type
accumulations.
data gathered by the on-going Navy exploration program in-
augurated in 1974 became available to the Geological
Survey shortly after the transfer Act was signed. By no
means all of this considerable mass of information has been
assimilated, but well and seismic results have been reviewed.
No confidential or proprietary Navy data are included in
this report. However, significant facts pertinent to a
description of the geology and an assessment of the hydro-
carbon potential of NPR-4 were carefully considered for
their effect on statements and conclusions put forward in
this paper, and no inconsistencies were noted. Geological
interpretations will undoubtedly be modified in the future
as more of this geophysical, geochemical, and well infor-
mation is digested, and as additional material becomes
available.

This paper describes the history of exploration of
NPR-4 and documents the information base presently avail-
able for hydrocarbon-resource assessment. From this data
base and first-hand knowledge the framework and petroleum
geology are described, and a comparison made between NPR-4
and the Prudhoe Bay area. A discussion of the three ap-
parent exploration trends is followed by a detailed de-
scription of the types of plays possible in NPR-4.
Test well drilling resulted in the discovery of an oil field at Umiat; a gas field at Gubik; a small gas field at Barrow; three possible gas fields at Meade, Square Lake, and Wolf Creek; and two minor oil deposits at Simpson and Fish Creek (Gryc, 1970, p. c3; fig. 1). The P. 4 program was recessed in March 1953.

Since 1953 the Air Force has drilled a well at Barrow to replace a Navy well destroyed by fire (Porterfield, 1974), and the Navy has drilled South Barrow wells Nos. 6 through 13 in order to assure a continuing supply of gas for the natives and the government facilities at Barrow. South Barrow well 12 (1974) was drilled 6 miles east of the field and completed as a marginal gas well (fig. 1). Recent Navy exploratory wells include the Iko No. 1 (gas well?) and the Cape Halkett No. 1 (standing), both drilled in 1975; the East Teshekpuk No. 1 (abandoned) drilled in 1976; and six wells proposed for fiscal year 1977. Of the latter, the South Harrison Bay No. 1 and the Atigaru Point No. 1 have been drilled and plugged; the South Barrow No. 14, drilled about 1 mile southeast of South Barrow No. 12, has been completed as a gas well; and the West Fish Creek No. 1, the W. T. Foran No. 1, and the South Simpson No. 1 are presently drilling (March, 1977, fig. 1).

The increase in fiscal year 1974 funding for NPR-4 allowed the Navy to embark on a vigorous exploration program of seismic-and gravity-data collection in addition
EXISTING DATA BASE

Publications

Early geologic exploration of NPR-4 through 1926 was reported on by the U.S.G.S. (Schrader and Peters, 1904; Smith and Mertie, 1930). The results of the PET-4 program were discussed at length in U.S.G.S. Professional Papers 301, 302 A-D, 303 A-H, 304 A, and 305 A-L. A comprehensive report on the subsurface, stratigraphic, structural, and economic geology of NPR-4 was published by Collins and Robinson (1967). Papers and reports on NPR-4, and the North Slope in general, by the Geological Survey and others are listed in two recent bibliographies by Maher and Trollman (1970) and by Carter, Denman, and Pierpoint (1975). Subsequent significant papers include those by Detterman and others (1975), Grantz, Holmes, and Kososki (1975), Bird and Jordan (1976), Blean (1976), and Jones and Speers (1976). Unpublished data in March, 1977 include a folio of subsurface mapping of the eastern North Slope area, gravity mapping and rock-density tabulation in the northern portion of the Arctic National Wildlife Range, and a northern Alaska paleomagnetism-plate tectonics study. Geologic mapping coverage is shown on fig. 2.

Test wells

Test well data in NPR-4 are shown in fig. 1 and in table 1. The 45 core tests (page 10) are shown neither on fig. 1 nor in table 1. A few were drilled in widely scattered areas,
<table>
<thead>
<tr>
<th>WELL Development Wells</th>
<th>NO.</th>
<th>TOTAL DEPTH IN FEET</th>
<th>FORMATION AT TOTAL DEPTH</th>
<th>COMPLETED</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Barrow</td>
<td>5</td>
<td>2,456</td>
<td>Jurassic</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>2,363</td>
<td>Jurassic</td>
<td>Gas</td>
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<tr>
<td></td>
<td>7</td>
<td>2,351</td>
<td>Jurassic</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2,359</td>
<td>Jurassic</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>2,450</td>
<td>Jurassic</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2,349</td>
<td>Jurassic</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>2,350+</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>2,287</td>
<td>Jurassic</td>
<td>Gas</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>2,534</td>
<td>Pre-Dev. argillite</td>
<td>Gas (Susp.)</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>2,257</td>
<td>Jurassic</td>
<td>Gas</td>
</tr>
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</table>


Table 1 (Cont): Test and development wells, NPR-4.
Table 2. Oil and gas fields, Alaska north slope.

<table>
<thead>
<tr>
<th>Field</th>
<th>Production</th>
<th>Producing Formation</th>
<th>Reservoir Lithology</th>
<th>Approximate Depth of Production in feet</th>
<th>Identified Resources (Econ. &amp; Subecon.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Umiat NPR-4</td>
<td>Oil</td>
<td>Lower Cret.</td>
<td>Nanushuk Group</td>
<td>250-1,350</td>
<td>70</td>
</tr>
<tr>
<td>Gubik</td>
<td>Gas</td>
<td>Upper Cret.</td>
<td>Prince Creek Fm.</td>
<td>1,450-1,750</td>
<td>22-295</td>
</tr>
<tr>
<td>South Barrow NPR-4</td>
<td>Gas</td>
<td>Jurassic</td>
<td>7</td>
<td>3,550</td>
<td>18</td>
</tr>
<tr>
<td>Meade NPR-4</td>
<td>Gas</td>
<td>Lower Cret.</td>
<td>Nanushuk Group</td>
<td>4,200</td>
<td>10</td>
</tr>
<tr>
<td>Square Lake NPR-4</td>
<td>Gas</td>
<td>Upper Cret.</td>
<td>Seabee Fm.</td>
<td>1,650-1,850</td>
<td>33-58</td>
</tr>
<tr>
<td>Wolf Creek NPR-4</td>
<td>Gas</td>
<td>Lower Cret.</td>
<td>Nanushuk Group</td>
<td>1,500</td>
<td>No est.</td>
</tr>
<tr>
<td>Simpson NPR-4</td>
<td>Oil</td>
<td>Upper Cret.</td>
<td>Nanushuk-Seabee Fm.</td>
<td>300</td>
<td>No est.</td>
</tr>
<tr>
<td>Fish Creek NPR-4</td>
<td>Oil</td>
<td>Lower Cret.</td>
<td>Topagoruk Fm.</td>
<td>3,000</td>
<td>30</td>
</tr>
<tr>
<td>Prudhoe Bay</td>
<td>Oil &amp; Gas</td>
<td>Jurassic</td>
<td>Kuparuk River</td>
<td>8,000</td>
<td>No est.</td>
</tr>
<tr>
<td></td>
<td>Oil &amp; Gas</td>
<td>U. Triassic-Perm.</td>
<td>Shublik Fm.</td>
<td>10,000</td>
<td>No est.</td>
</tr>
<tr>
<td></td>
<td>Oil &amp; Gas</td>
<td>L. Triassic-Perm.</td>
<td>Sadlerochit Grp.</td>
<td>10,500</td>
<td>9.6 bill. bbls. oil</td>
</tr>
<tr>
<td></td>
<td>Oil &amp; Gas</td>
<td>Miss. &amp; Penn.</td>
<td>Lisburne Grp.</td>
<td>11,500</td>
<td>No est.</td>
</tr>
<tr>
<td>Kavik</td>
<td>Gas</td>
<td>Triassic</td>
<td>Sag River Fm.</td>
<td>4,250</td>
<td>No est.</td>
</tr>
<tr>
<td>Kemik</td>
<td>Gas</td>
<td>Triassic</td>
<td>Sadlerochit Grp.</td>
<td>4,600</td>
<td>No est.</td>
</tr>
</tbody>
</table>

Sources: Harrison and others (1973); American Petroleum Institute and others (1974); Morris and Smith (1972)
SEISMIC REFLECTION DATA  
(Single Fold Dynamite)

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Profiles</th>
<th>Line Miles</th>
<th>Year Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Navy</td>
<td>297</td>
<td>74.25</td>
<td>1945</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>850</td>
<td>212.50</td>
<td>1946</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>1,412</td>
<td>353.00</td>
<td>1947</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>1,944</td>
<td>486.00</td>
<td>1948</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>3,191</td>
<td>797.75</td>
<td>1949</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>3,501</td>
<td>875.25</td>
<td>1950</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>790</td>
<td>197.50</td>
<td>1951</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>1,305</td>
<td>326.25</td>
<td>1952</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>141</td>
<td>35.25</td>
<td>1953</td>
</tr>
</tbody>
</table>

Totals: 13,431 3,357.75

Mileage based on seismic profile spacing of 1,320 ft.

SEISMIC REFRACTION DATA

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Profiles</th>
<th>Year Completed</th>
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<tbody>
<tr>
<td>U.S. Navy</td>
<td>21</td>
<td>1946</td>
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<tr>
<td>U.S. Navy</td>
<td>246</td>
<td>1948</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>77</td>
<td>1949</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>15</td>
<td>1950</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>32</td>
<td>1952</td>
</tr>
</tbody>
</table>

Total: 391

Refraction profiles were usually shot with 8,000-ft spread lengths.

Note: Does not include 5,000+ miles of seismic records recently acquired by the U. S. Navy.

Sources: Woolson and others (1962); Keller and Henderson (1947).

Table 3 (Cont): Geophysical Data, PET-4 program, NPR-4
Figure 4. Tectonic elements of the north slope of Alaska
COASTAL PLAIN | CONTINENTAL SHELF

- Oil show
- Gas show

ECONOMIC BASEMENT

Shoreline

250 300 350 400 450 Kilometers

160 180 200 220 240 260 280 300 Miles

DEPTIl IN KILOMETRES

250 300 350 400 450 Kilometers

250 300 350 400 450 Miles
Figure 6. Generalized stratigraphic sections, NPR-4
Brookian Sequence

The Brookian (Late Jurassic, Cretaceous, Tertiary) sequence consists of large amounts of greywacke sandstone and shale derived from an orogeny that began in Late Jurassic and continued into Late Cretaceous and perhaps Early Tertiary time in the western Brooks Range and apparently into the Neogene in the northeastern Brooks Range. This orogeny, a result of intense compression, caused large-scale relatively northward thrusting of Paleozoic to Cretaceous age rocks. Aggregate shortening in the western Brooks Range is estimated to be 100 km (62 mi) (Martin, 1970) or more than 240 km (149 mi) (Snelson and Tailleur, 1968).

The orogeny drastically changed the paleogeography of Arctic Alaska. Northern sources were replaced by southern sources—the Brooks Range. Initially, however, sediments were supplied from both northern (Ellesmerian) and southern (Brookian) sources. The northern source subsided and was overlapped in Early Cretaceous (Neocomian) time. Subsidence of this source area is recorded by the overlapping sediments and subsequent northward downwarping and faulting along a linear zone approximately parallel to the present shoreline. The resultant structure, the Barrow Arch, is a linear basement ridge plunging to the southeast (fig. 4). The Prudhoe and South Barrow fields are located on the crest of this feature.

Throughout the orogeny large volumes of clastic debris were shed northward into a migrating foredeep. The Early
PETROLEUM GEOLOGY

Introduction

A petroleum province requires the relatively close association of petroleum source rock, porous reservoir rock, and sealing beds adjacent to the reservoir to form traps. An additional and most critical requirement is a favorable geologic history, generally referred to as "timing". A favorable history requires the following events: 1) burial of source rocks sufficiently deep for petroleum generation, 2) the presence of permeable rock to provide a migration path for the petroleum as it is generated and expelled from the source rock, and 3) the formation of traps in reservoirs updip from, or adjacent to, the source beds in order to entrap the migrating petroleum and to prevent its escape to the surface.

The petroleum potential of a province, therefore, depends on the quality of source and reservoir rock, the size of the traps, and the geologic history of the basin. The discovery initially of several oil and gas seeps and later several small oil and gas fields by the Navy confirmed the belief that the North Slope was an oil province. However, the potential of this province was not fully appreciated until the discovery of the Prudhoe Bay field. This field is an example of an unusual combination of favorable features.

Briefly the Prudhoe Bay field consists of multiple stacked reservoirs, which reach their maximum development near the crest
Diagrammatic cross-section B'-B of eastern Arctic Slope; location is shown on Figure 4. Prudhoe Bay hydrocarbons are trapped beneath unconformity at base of Cretaceous on Barrow arch. Brooks Range thrusts are shown at left.

Reservoir-source rock relations in Prudhoe Bay field depicted on east-west diagrammatic cross section. Oil-source potential of fine-grained rock sequences as determined by amount of total organic carbon (expressed in percent and by size of circle) and amount of C_{18} hydrocarbon content (expressed in parts per million and by size of pie slice). Basal Mississippian shale = 1.1% and 14 ppm; Mississippian red beds = 0.04% and 10 ppm; Lisburne carbonate rocks = 0.3% and 35 ppm; basal Sadlerochit shale = 0.7% and 32 ppm; Jurassic marine shale = 1.9% and 660 ppm; Cretaceous marine shale = 5.4% and 3,000 ppm.

Figure 7. Diagrammatic cross-sections showing reservoir-source-rock relations and geochemical data in the Prudhoe Bay area (modified from Morgridge and Smith, 1972).
Reservoir Rocks

Both clastic and carbonate reservoir rocks are present on the North Slope. The best reservoirs are the pre-Middle Cretaceous clastic and carbonate rocks along the Barrow Arch. However, these reservoirs are of limited thickness and areal extent. In contrast, the Cretaceous rocks in the foothills region are generally poorer quality reservoirs, but they are very thick and areally extensive. Reservoir data have been summarized for outcrop samples and Navy wells (Brosge and Tailleur, 1971), for the Sadlerochit Group at Prudhoe Bay (van Pooien and Associates, Inc., 1974; Jones and Speers, 1976), and for the Lisburne Group (Bird and Jordan, 1976).

The most attractive reservoir rocks are those related to a northern source area. Included are the Lisburne Group, Sadlerochit Group, Shublik Formation, Sag River Sandstone, and Kuparuk River Sandstone. All are productive at Prudhoe Bay and are best developed in the north. The Ellesmerian sequence in NPR-4 has been penetrated by the Topagoruk, Simpson, and Barrow wells and probably by the recent Navy wells, Cape Halkett and East Teshekpuk (table 1). Data from the available wells indicate that nearly all sandstone units at Prudhoe Bay are present in NPR-4. These data are insufficient to determine the most favorable reservoir facies and trends, but they do indicate that the basic stratigraphic pattern is progressive northward onlap onto the Franklinian
Figure 8. Approximate northern limits, Lisburne and Saddlerochit Groups
Adequate seals are expected to be present in most structural and stratigraphic trapping situations.

The potential for structural traps is greatest in the foothills belt in folds associated with thrusting. These traps may be of limited areal extent and difficult to explore for, especially in the more geologically complex southern foothills. Accumulations in structural traps include the oil field at Umiat and the Gubik, Kemik, and Kavik gas fields. Structural traps related to broad gentle folding and associated normal faulting may also be present on the Barrow Arch. The South Barrow gas field may be an example of this type of trap.

Stratigraphic traps may be related to updip pinch-outs and truncations in the pre-Lower Cretaceous rocks along the Barrow Arch. However, the extremely favorable source-to-reservoir relationships at Prudhoe Bay may not be present. An additional trapping mechanism may be updip shaling-out of sands deposited on the foreset and bottomset beds in Cretaceous clastic wedges. Thin isolated sands within the thick Torok Shale may be an example of this type.

Combination structural and stratigraphic traps such as Prudhoe Bay may be present. They may be small, however, compared to Prudhoe Bay because of less favorable combinations of reservoir, source, and structure.
Regionally in northern Alaska, hydrocarbon reservoir horizons have been found in the Ellesmerian sequence, consisting of Mississippian to Middle Pennsylvanian shallow water carbonates (Lisburne Group), a major Early Triassic sandstone and conglomerate horizon (Sadlerochit Group), thin carbonates in the Late Triassic (Shublik Formation), a thin late Triassic sandstone (Sag River Sandstone), and Early Cretaceous and/or Jurassic sandstone (Kuparuk River Sandstone) (fig. 6). All these horizons are related to the northern platform area. In addition, Early Cretaceous sandstones (Brookian sequence) derived from the south are reservoir horizons in some areas. Late Cretaceous and Tertiary beds are also potential reservoirs on the Arctic Slope, but available information indicates that rocks of this age are very thin or absent from most of the Reserve. With the exception of limited areas along the northern coastline, and the eastern boundary, Late Cretaceous and Tertiary rocks may be precluded from consideration as exploration objectives in NPR-4.

The Prudhoe Bay hydrocarbon accumulation is contained in reservoirs of the Lisburne Group, the Sadlerochit Group, the Shublik Formation, the Sag River Sandstone, and Kuparuk River Sandstone. The major reservoir is the Lower Triassic Ivishak Formation of the Sadlerochit Group. Published geochemical data, in combination with the structural and stratigraphic relationships (Morgridge and Smith, 1972)
oral commun., 1976; Gold and Lachenbruch, 1973). In either case, regardless of the cause of the high gradient, the result may be higher than average temperatures affecting the sedimentary section and the organic matter contained within the sediments. Older rocks with longer burial histories may thus have had greater residence times at elevated temperatures and therefore may have been more greatly affected by eometamorphic processes while younger beds may only be reaching the point of optimum oil generation and migration. At Prudhoe Bay, the Sadlerochit reservoir temperature ranges from 192° to 216°F at a depth of 8,650 feet, and an average of 200°F is being used in reservoir calculations (van Poolen and others, 1974, p. 15). Calculations by Bird and Jordan (1976) on burial history and geothermal gradient indicate that Mississippian coals in the Prudhoe Bay area are probably within the gas generating regime below 13,000 feet.

In summary, the supergiant Prudhoe Bay oil and gas accumulation appears to be the result of the fortuitous juxtaposition of organically rich, thermally mature, Cretaceous source beds with older reservoir beds containing good to excellent porosity and permeability. The importance of these geological, geochemical, and thermal history relationships cannot be overemphasized in an analysis of the hydrocarbon potential of any part of northern Alaska.
4. As a result of the above factors, the probability of juxtaposition of Cretaceous source beds with late Paleozoic and early Mesozoic reservoir horizons in most of NPR-4 is slight. Long distance hydrocarbon migration from Cretaceous source beds into these horizons appears unlikely.

Substantiation of the Prudhoe Bay area geochemical data seems to be found in the results of some of the Navy well data from the PET-4 program of exploration, and from industry drilling in northern Alaska other than in the Prudhoe Bay area. Discoveries of gas and some oil have been made from thin Jurassic and Upper Triassic beds in the Barrow area. An active oil seep and shows in wells in the Cape Simpson area are probably derived from Upper Cretaceous beds. Varying small amounts of oil and gas were recovered from Lower Cretaceous rocks at various locations in NPR-4. Almost every well that has penetrated Cretaceous beds on the Arctic Slope has had some hydrocarbon shows. In contrast, Permian and probable Lower Triassic and Mississippian beds had no reported shows in the only publicly available well (Topagoruk #1) that penetrated them in NPR-4. East of Prudhoe Bay, only gas has been recovered from Triassic reservoir beds in two areas distantly removed from communication with the rich Cretaceous source beds (Kemik and Kavik fields, fig. 1).
comparison with the similar Rocky Mountain Cretaceous section suggests that the play will be dominantly a gas play with small oil accumulations. This is somewhat substantiated by the numerous gas shows in many of the Navy wells in NPR-4. One of the main controlling factors in the play may be reservoir quality; although many of the sediments are medium- to coarse-grained sandstones, a pervasive clay matrix inhibits porosity and permeability. This clay probably consists of primary depositional material plus clays from diagenetic alteration of mafic igneous detritus derived from an extensive source terrain in the Brooks Range. As a result, one of the major problems in the Albian play will be prediction of porosity trends. One of the major controls on distribution of clay matrix and therefore porosity may be the environments of deposition. Winnowing of the clays may be much more efficient in some environments, whereas diagenetic alterations of igneous detritus may have a greater inhibiting effect in other environments. Only limited study has been devoted to these relationships in northern Alaska.

The southernmost trend, the Southern Foothills sub-province, is believed prospective for gas in complex structural traps. Possible objectives are carbonate reservoirs in the Mississippian (Lisburne Group) and Triassic (Shublik Formation) and sandstone reservoirs in the Cretaceous (Okpikruak, Fortress Mountain, and Ipewik Formations).
1966; Chapman and others, 1964), and on carbonate facies studies (Armstrong, 1970). The Lisburne Group in the area of Lisburne Ridge, near the Etivluk River at the southeastern corner of NPR-4 (fig. 9), contains approximately 500 feet of dolomite with observable intergranular and vugular porosity, some of which contains pyrobitumen. Although allochthonous, and tightly folded, the rocks dip northward into the basin. The possibility of a drilling objective to this allochthonous horizon should be studied by additional field work and seismic studies.

Hydrocarbon play analysis

Current experience on the Arctic Slope suggests that several types of plays should be considered in assessing the hydrocarbon potential of NPR-4. These plays are summarized in table 4 in approximate order of relative importance. It should be emphasized, however, that this relative ranking is somewhat subjective; one of the purposes of an evaluation program should be to provide data for a more accurate assessment of the relative potential of these plays. The list of play types is not intended to be all-inclusive; it includes only those play types and major controls that have been observed or can be inferred as likely to be present.

Evaluation of the tabulated play parameters (table 4) suggests that the likelihood of Prudhoe Bay type fields of wide areal extent in NPR-4 is slight. Several stacked reservoirs on a structure are not likely. Stratigraphic
<table>
<thead>
<tr>
<th>Formation/Stratigraphic Unit</th>
<th>Play Type</th>
<th>Logs/Cores</th>
<th>Hydrocarbons</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permian-Lower Triassic clastics</td>
<td>do</td>
<td>do</td>
<td>Thick, possibly up to 400', fair to excellent porosity and permeability</td>
<td>Gas do</td>
</tr>
<tr>
<td>Upper Triassic sandstones and dirty carbonates</td>
<td>do</td>
<td>Structural</td>
<td>Thin, less than 50', probably very fine grained sandstone with good to excellent porosity and permeability, low rate of lateral facies change</td>
<td>Gas do</td>
</tr>
<tr>
<td>Lower Cretaceous (Albian) sandstones derived from a southern source (Nanushuk Group, Umiat type play)</td>
<td>do</td>
<td>Stratigraphic and/or Structural</td>
<td>Thin, probably less than 100' net sandstone with fair to good porosity and permeability, fair lateral facies continuity</td>
<td>Gas do</td>
</tr>
<tr>
<td>Conventional Jurassic and Lower Cretaceous sands from a coeval age northern source</td>
<td>do</td>
<td>do</td>
<td>Thin, probably less than 100' net sandstone with fair to good porosity and permeability, fairly widespread</td>
<td>Gas do</td>
</tr>
</tbody>
</table>

Possible play in a narrow east-west band south of Barrow. Indigenous hydrocarbons probably quite over-mature and limited to dry gas.

Probably present in a broad band from the Barrow area to the Colville River. Indigenous hydrocarbons probably zone what over-mature and somewhat gas prone, but with some oil. This play probably represents the most prospective oil play in NPR-A. Other oil plays have greater oil potential but are likely to be present only in a limited area.

Present over a wide geographic area of the entire central portion of NPR-A. Sands are part of a broad northward prograding coal-bearing clastic wedge. Dominantly a gas play because of the abundant associated coal. Some oil potential in lower portion of sandstone interval in zone of interfingering with underlying marine shales, and toward distal end of wedge where sands become marine. Total reserves may be large but likely to be in numerous small stratigraphically controlled fields. Largest play on NPR-A in terms of total hydrocarbon potential, second to coastal plain Jurassic-Lower Cretaceous play in oil potential.
controls are likely to play a major role in any hydrocarbon accumulation. Present knowledge of the potential reservoir horizons suggest that facies variations may occur rapidly. Fields may be of small areal extent and exploration will require detailed seismic facies interpretations closely integrated with micropaleontologic studies, and with geologic studies that include the latest concepts of clastic and carbonate deposition and their control on reservoir porosity and permeability.


Morgridge, D. L., and Smith, W. B., 1972, Geology and discovery of Prudhoe Bay field, eastern Arctic Slope, Alaska, in King, R. E., ed.,


