U. S. Department of the Interior
Bureau of Land Management

Alaska State Office
222 West 7th, #13
Anchorage, Alaska 99513

BLM-Alaska Open File Report 46
BLM/AK/AE/93/044+3071+985
July 1993

Teshekpuk Lake Special Management Area Oil and Gas Resource Assessment, National Petroleum Reserve–Alaska

Robert J. Bascle

Teshekpuk Lake Special Management Area Oil and Gas Resource Assessment, National Petroleum Reserve–Alaska

Robert J. Bascle

Bureau of Land Management
Alaska State Office
Anchorage, Alaska 99513

Open File Report 46
July 1993

Table of Contents

List of Figures

Summary

The Teshekpuk Lake Special Management Area (TSMA) in the northeastern National Petroleum Reserve in Alaska (NPR-A) has a high potential for having economically recoverable oil and gas resources. Other areas of the NPR-A with a high potential are around the Umiat oil field in the southeastern part of the reserve, the Simpson area just northwest of the TSMA, the Fish Creek area just southeast of the TSMA, and the area in and near the Colville River delta.

The TSMA occupies a large area on the southern flank of the Barrow high. This setting is somewhat analogous to that of the producing oil fields and large, non-producing oil fields on Alaska's North Slope, but details of the geology differ. These differences are significant. For example, erosion at the Lower Cretaceous Unconformity did not expose the Sadlerochit Group to subaerial weathering, and, therefore, this unconformity did not play a role in developing secondary porosity in, or in providing a cap rock for, the Ivishak sandstone.

Several test wells in the vicinity provide subsurface geological data. Promising oil and gas shows exist in some of the wells, but all wells are classified as dry holes and are plugged and abandoned. The drilling data shows that the Teshekpuk Lake area has several potential reservoir rock formations and several potential source rock formations. Some of the wells encounter good porosity, but the potential reservoir sections produced water upon testing. Abundant reflection seismic data, when tied to the well data, allow the identification of potential plays and traps, some of which have not yet been tested or have not been adequately tested, that is, they are large enough that one well drilled into them is insufficient to test the potential play or trap.

The Lisburne Group carbonates, the group which contains the Lisburne Oil Pool of the Prudhoe Bay Field, reach almost 1,400 feet in thickness beneath the TSMA. The Ivishak Formation, the formation which contains the Prudhoe Bay Oil Pool, reaches almost 820 feet in thickness. The J.W. Dalton Test Well No. 1 encounters dead oil and asphalt in the Ivishak Formation. This indicates that oil has been generated and has migrated to or through the TSMA. Whether this oil still exists in producible quantities within the confines of the TSMA is yet to be determined. The Sag River Sandstone, another reservoir formation at Prudhoe Bay, reaches a thickness of almost 160 feet beneath the TSMA.

Only five widely-spaced oil test wells have been drilled within the confines of the TSMA, approximately 1 well per 300 square miles. All are classified as dry holes. Still, these wells leave most of the TSMA unexplored. Given the thicknesses of potential reservoir rock, the shows of oil or gas, or both, in the wells, and the large acreage still unexplored, it is still quite possible for the TSMA to contain economically producible hydrocarbon resources. Only further exploratory drilling can answer the question of whether economically producible hydrocarbon resources exist within the Teshekpuk Lake Special Management Area.

Teshekpuk Lake Special Management Area Oil and Gas Resource Assessment, National Petroleum Reserve–Alaska

I. Introduction

The Teshekpuk Lake Special Management Area (TSMA) has been set aside for special management because of unique environmental values. The TSMA *(Figure 1)* is in the northeastern quadrant of the National Petroleum Reserve-Alaska (NPR-A) around, and including, Teshekpuk Lake, one of the largest lakes within Alaska.

The location of the TSMA places it in an area of high potential for oil and gas resources. The TSMA lies between the producing fields at Prudhoe Bay, Alaska and the Barrow gas fields south of Barrow, Alaska. Oil, although apparently not in economically producible quantities, has been discovered to the northwest of and to the south of the TSMA in the Cape Simpson and Fish Creek areas, respectively.

Several seismic lines cross the TSMA, and five wells have been drilled within the area studied for this report. This exploration data indicates that the area contains potential reservoir rocks, source rocks, and untested structures. Thse scant exploration efforts, however, are not enough to define the oil and gas potential of the area.

2. Surface and Subsurface Data Availability

The U.S. Geological Survey (USGS) has investigated the geology of Alaska's North Slope geologic province since the early 1900s. Investigations began in earnest with the USGS participation in the U.S. Navy's (USN) Naval Petroleum Reserve No. 4 (now National Petroleum Reserve-Alaska, or NPR-A) exploration program of 1944-1953.

Robinson (1959) reports on the test wells *(Figure 2)* and on the core test wells (1964) in the Simpson area. Robinson and Collins (1959) report on the results of the drilling of the Fish Creek Test Well No. 1. Husky Oil NPR Operations, Inc. (1983) and Gryc (1988) report on the wells that Husky drilled for the government's exploration program (Figure 2), including the Atigaru Point Test Well No. 1, Cape Halkett Test Well No. 1, Drew Point Test Well No. 1, East Teshekpuk Test Well No. 1, Ikpikpuk Test Well No. 1, J.W. Dalton Test Well No. 1, South Harrison Bay Test Well No. 1, West Fish Creek Test Well No. 1, and the W.T. Foran Test Well No. 1 (Husky Oil NPR Operations, Inc., 1983a-j). These wells provide subsurface data within and near the Teshekpuk Lake Special Area. Note, however, that the wells drilled within the confines of the study area represent an

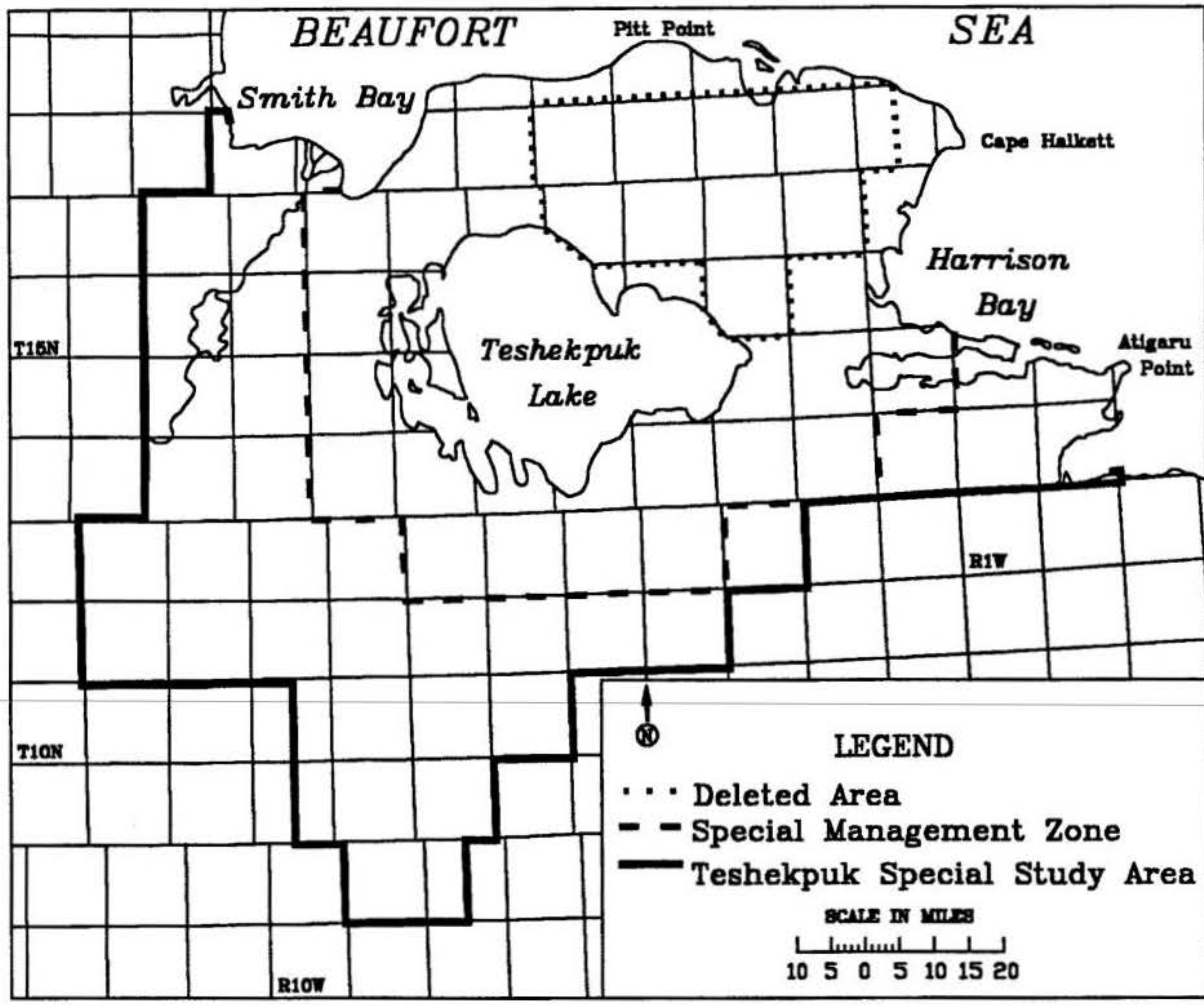

Figure 1 Teshekpuk Lake Special Study Area location map.

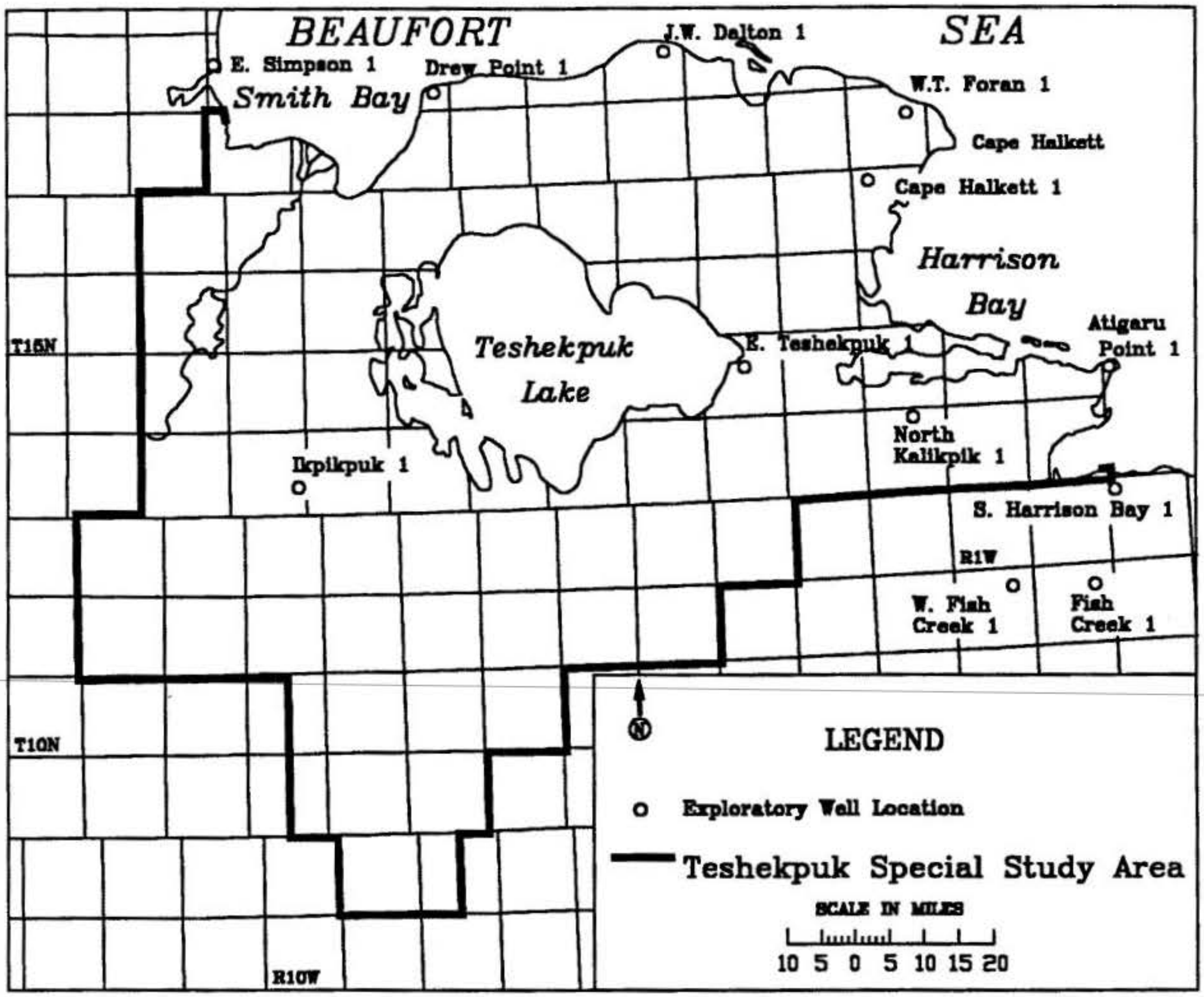

Figure 2 Exploratory test wells in the vicinity of the Teshekpuk Lake Special Study Area.

average of one well per 300 square miles. The direct subsurface geologic data is sparse; it consists of well logs and drill cuttings, mere pinpricks of hard data given the area encompassed within the study area.

Gryc (1988) contains a compilation of reports on the USGS's NPR-A investigations. This professional paper, which supersedes numerous other reports by the USGS on the NPR-A, serves as the main reference for this report and should be consulted for more details.

Reflection seismic surveys, run for the Navy's exploration programs of 1944 through 1953, and 1974 through May 1977, and the USGS's investigations of June 1977 through May 1982, provide a window to the subsurface geology. The seismic surveys are of crucial importance to the assessment of the area and to the identification and selection of drillable prospects.A more closely spaced seismic-exploration pattern, obtainable through infill seismic exploration and modern 3-D seismic methods, would improve the identification and characterization of potential prospects.

3. Structural Geology

The Teshekpuk Lake Special Management Area lies within the Arctic coastal plain physiographic province and above the south flank of the Barrow high *(Figure 3)*, or, as it is often called, the Barrow anticline. The subsurface formations of the Ellesmerian Sequence progressively overstep each other to the north to onlap onto the argillitic basement rocks that form the Barrow high. The sedimentary rocks beneath the TSMA dip gently southward, about one to two degrees, into the Colville trough.

Low-relief, seismically-defined anticlines and synclines gently deform the strata beneath the TSMA. These subtle anticlines are the primary hydrocarbon prospects, but difficult-to-define stratigraphic traps may also exist as potential hydrocarbon prospects. The coarse spacing of the wells drilled in the area provides little help in mapping potential structural and stratigraphic prospects. They do, however, allow for correlation of the geologic data with the geophysical data.

The Fish Creek structure *(Figure 3)*, or disrupted zone, in the southeastern corner of the TSMA may represent an ancient subsea sediment slide within the Torok Formation (Weimer, 1987).

4. Reservoir Potential

The TSMA has several formations that could have good potential reservoir characteristics, i.e., high porosities and permeabilities. Potential reservoir rocks within the TSMA include *(Figure 4)*, in ascending order *(Figures 5 and 6)*: "Argillite Basement"; Endicott Group; Lisburne Group; Sadlerochit Group; Shublik Formation, Sag River Formation, Kingak Formation sandstones, "Kuparuk equivalent" sandstones, Torok Formation sandstones, Nanushuk Group sandstones, and Cretaceous Colville Group/Tertiary sandstones. Of these, the Sadlerochit Group, the Sag River Formation, the Nanushuk Group, and the Colville Group/Tertiary sandstones, and the Lisburne Group carbonates have the highest potential for reservoir-quality rocks.

In the following discussions, keep in mind that measurements of low porosities in non-oil-bearing sections may mislead one into interpreting a formation as having un-

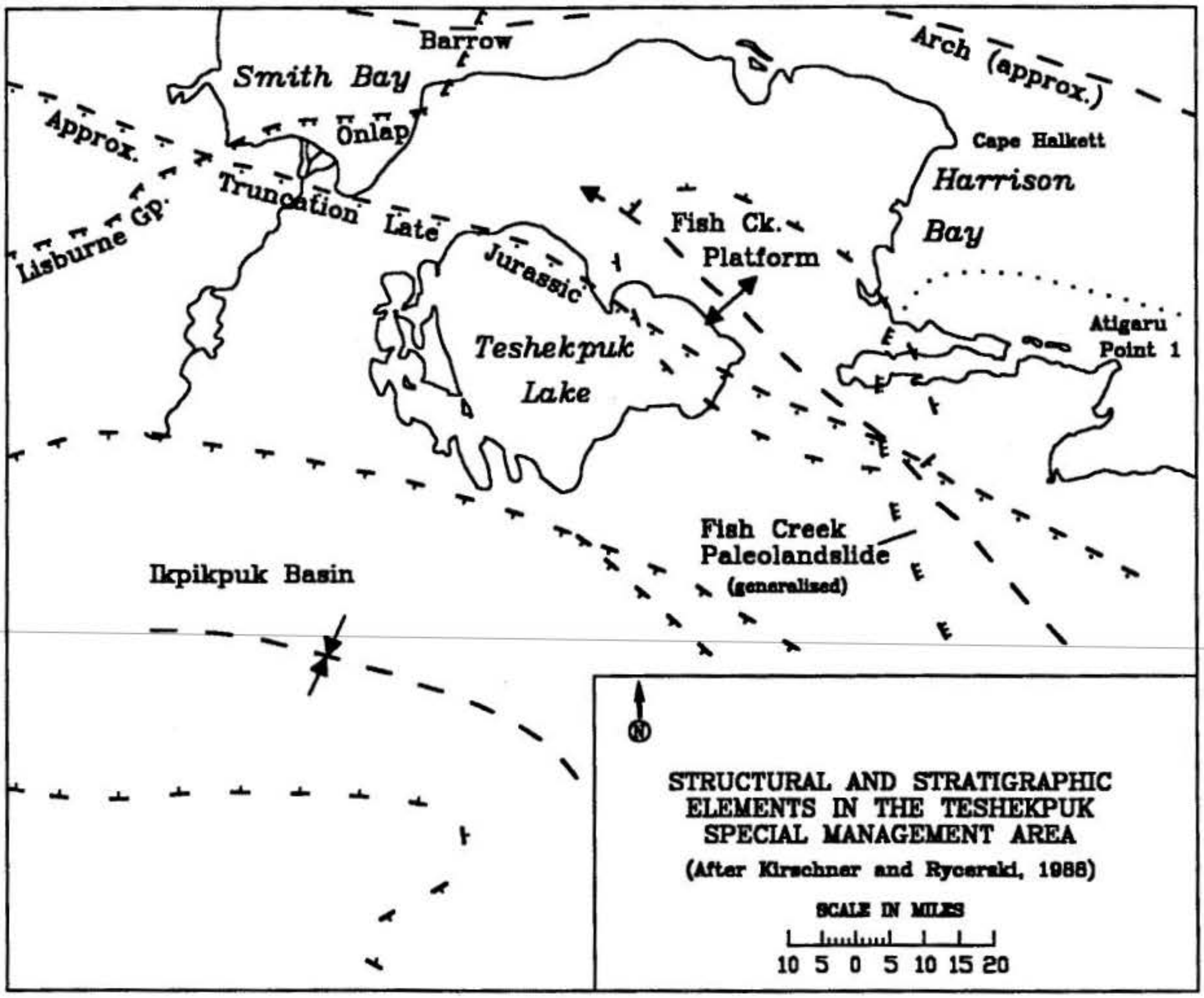

Figure 3 Map of structural and stratigraphic elements in the Teshekpuk area.

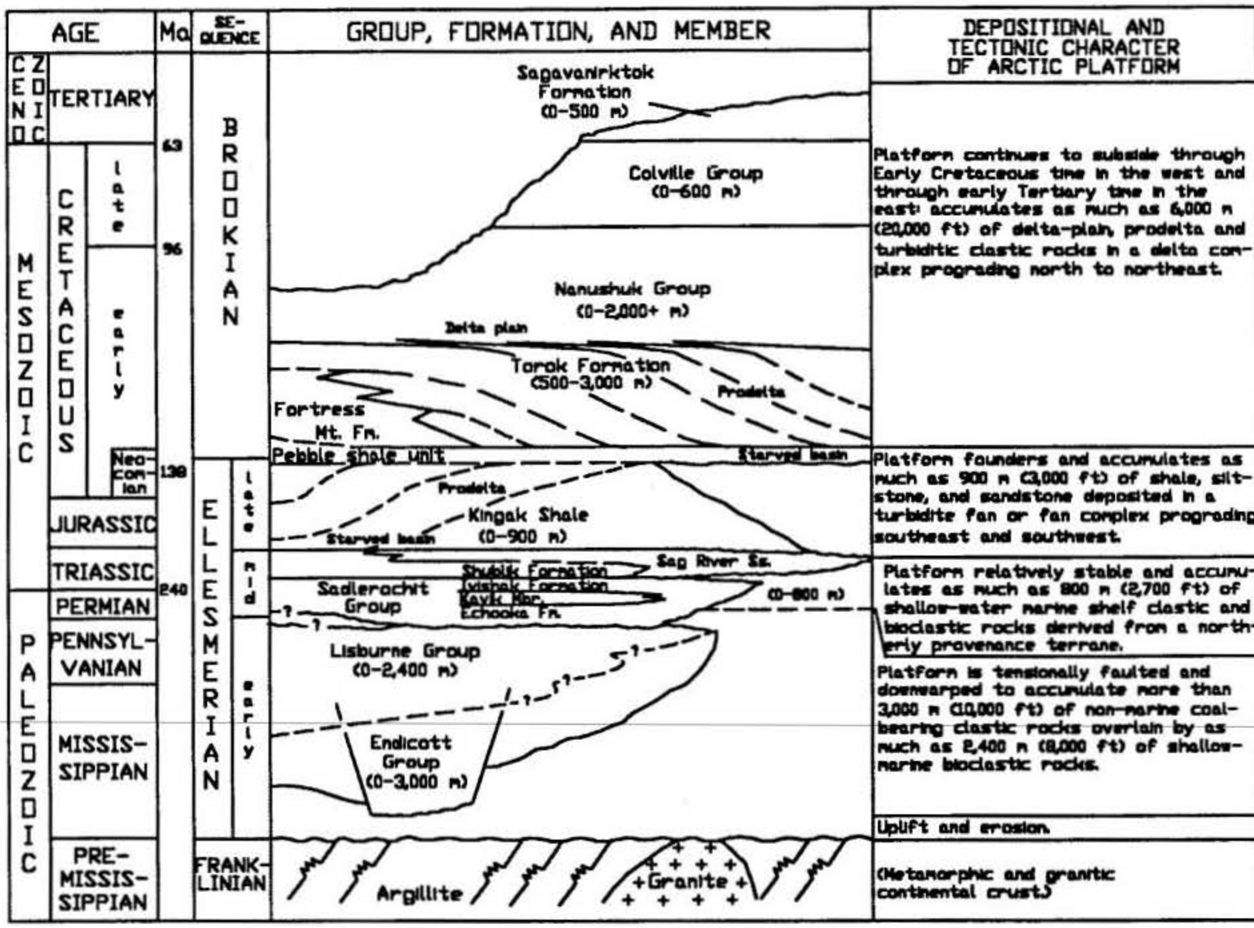

Figure 4 Generalized stratigraphy in National Petroleum Reserve in Alaska. (After Kirschner and Rycerski, 1988.)

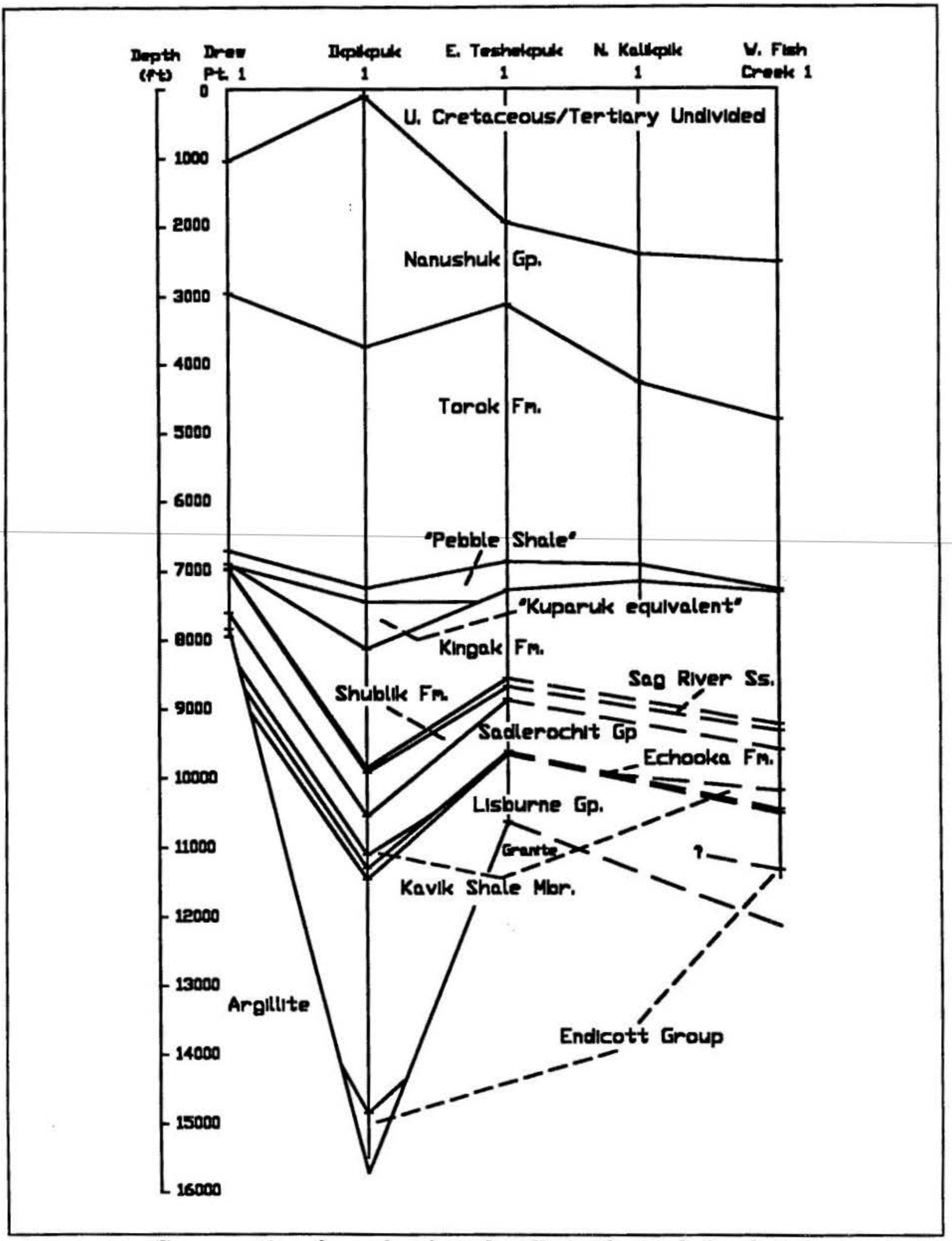

Figure 5 Cross-section through selected wells in the Teshekpuk Lake area. (Note: Distances between wells not to scale.)

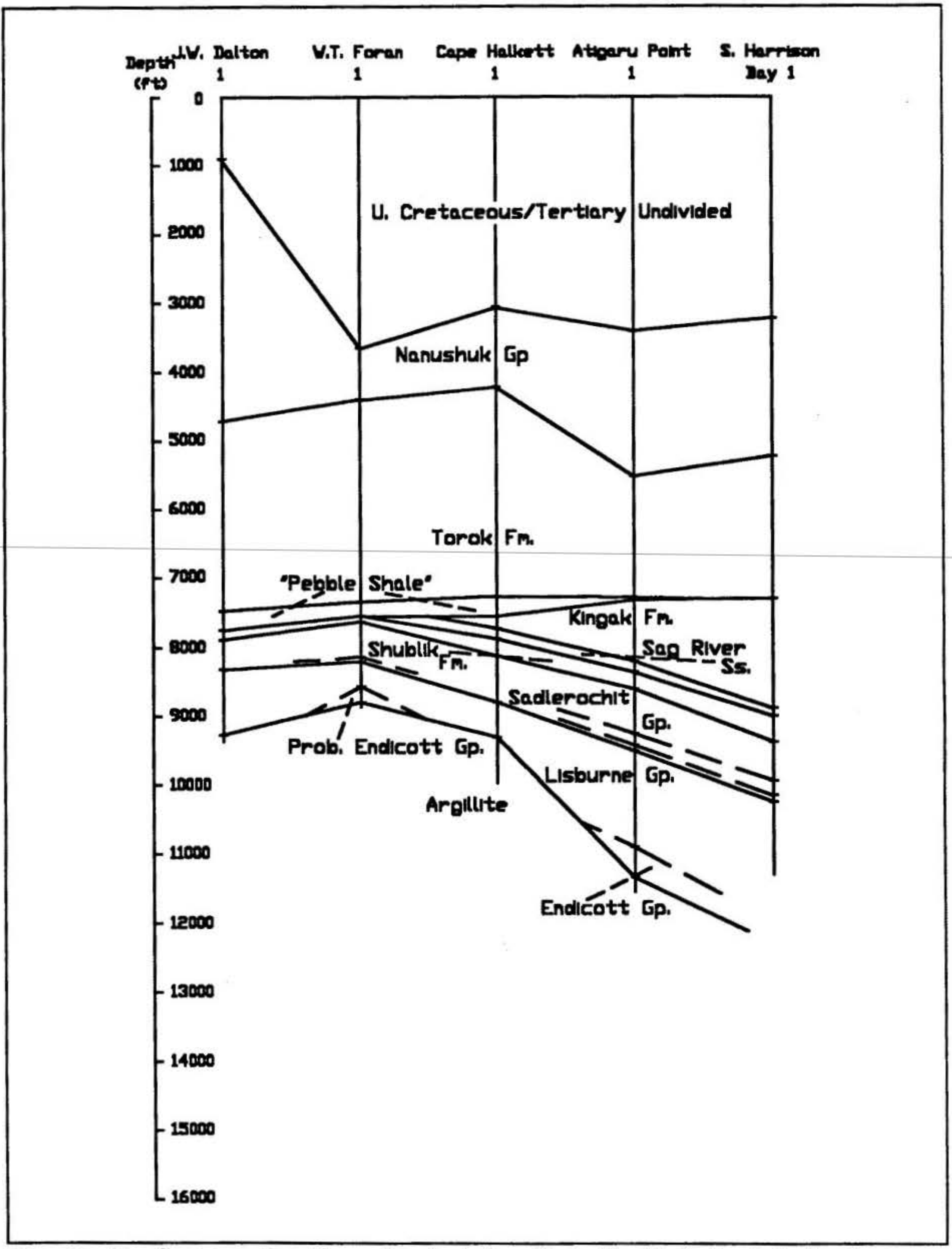

Figure 6 Cross-section through selected wells in the Teshekpuk Lake Area. (Note: Distance between wells not to scale.)

favorable reservoir characteristics throughout its extent. This may not be the case. Good reservoir porosities can be preserved in an otherwise low-porosity formation if hydrocarbon generation and migration occurred early in the diagenetic history of the formation. Alternatively, good secondary porosity may be developed in an otherwise low-porosity formation by leaching at the earth's surface under subaerial conditions or in the subsurface through migration of acidic formation waters. Preservation of primary porosity and development of secondary porosity depend, to a large extent, on the original mineral composition of the formation. They also depend upon the chemical characteristics of formation waters, the burial history and the temperature regimes through which the formations pass.

Argillite Basement

The pre-Mississippian "Argillite basement" consists of a variety of sedimentary and metamorphic rocks and one reported instance of granite. The "Argillite basement" rocks have reservoir quality in limestones at the Pt. Thompson oil field just to the west of the Arctic National Wildlife Refuge (Bird et al., 1987). Determining the ability of the "Argillite basement" to serve as reservoir rock beneath the TSMA is difficult because of the variability inherent in the rocks that form the basement. The "Argillite basement" rocks probably should not be considered as a primary target prior to drilling. Rather, any discovery of economically producible-hydrocarbons within the "Argillite basement" should be considered serendipitous.

5. Endicott Group

Three wells (the W.T. Foran (232 feet), the West Fish Creek (117 feet), and the Atigaru Point (438 feet)) penetrate "probable" Mississippian Endicott Group strata in or near the TSMA. These strata include shale, siltstone, sandstone, limestone, conglomerate, and coal. The sandstone plus conglomerate make up 120 feet, or almost 30 percent of the interval, in the Atigaru Point well. The thickest contiguous interval of sandstone and conglomerate reaches only 60 feet, and the limestone forms a very minor portion of the section. Shale predominates the sections in the West Fish Creek and W.T. Foran wells with sandstone and limestone present as only minor constituents. The prevalence of shale and the paucity of sandstone and limestone severely limits the reservoir potential of the "probable" Endicott Group except possibly in the vicinity of the Atigaru Point well.

6. Lisburne Group

Limestones of the Mississippian Lisburne Group serve as reservoir rocks for the Lisburne Field at Prudhoe Bay. In the wells drilled in the TSMA, the Lisburne Group ranges from zero to nearly 1,400 feet thick. In general, the formation thins from south to north beneath the TSMA by depositional onlap onto the Barrow high, and possibly, by erosional truncation both onshore and offshore.

All of the wells in the area penetrate Lisburne Group strata, except for the Drew Point well which encounters none. The W.T. Foran well penetrates the thinnest section at 366 feet, and the Atigaru Point well penetrates the thickest section at 1,396 feet. The

W.T. Foran well has the highest porosities, but these are all less than 15 percent. The J.W. Dalton has porosities of less than 13 percent, and the other wells have porosities of less than 6 percent. So, the reservoir porosities, at least where tested in the TSMA, tend to be no better than fair and usually are poor. But, low-porosity carbonates can produce hydrocarbons if a hydrocarbon-bearing section is fractured. It is not known whether the Lisburne carbonates are fractured beneath the TSMA, as they are at Prudhoe Bay.

On the positive side, the W.T. Foran produced 11.2 barrels of slightly oil-cut water from the Lisburne Group, and the J.W. Dalton produced 80 barrels of water and 5 barrels of asphalt. Both wells have additional oil staining.

7. Sadlerochit Group

Echooka Formation

Four wells penetrate the Permian Echooka Formation in the study area. The East Teshekpuk well penetrates the thinnest section; it has 38 feet. The West Fish Creek well has 57 feet, the Atigaru Point well has 82 feet, and the South Harrison Bay well has 94 feet. These sections of Echooka Formation consist primarily of sandstone with some siltstone and minor shale. The sandstone are very-fine to fine grained, slightly to very calcareous, argillaceous, and siliceous. Porosity ranges from none observable to very poor.

Ivishak Formation

The Permo-Triassic Ivishak Formation of the Sadlerochit Group occurs in all wells in the TSMA. Its thickness ranges from 238 feet in the Drew Point well to 817 feet in the Atigaru Point well. The Ivishak consists of sandstone, siltstone, shale, and conglomerate. The sandstones range from very-fine-grained to conglomeratic, with the finer-grain sizes predominating. Cements of silica, carbonates, and clay reduce the porosity in most of the wells. Porosity and permeability range from non-existent to fair, but less than 15 percent. In the Prudhoe Bay field, the porosity of the Ivishak runs 20 to 30 percent (Bird et al., 1987).

Note that some investigators interpret the good porosities in the Prudhoe Bay field as having developed under subaerial conditions during exposure at the earth's surface in the Early Cretaceous. These conditions did not prevail in the TSMA as this area remained buried during the Early Cretaceous. Good reservoir porosities in this area then would depend primarily upon the preservation of primary porosity or the subsurface development of secondary porosity.

The J.W. Dalton, Drew Point, W.T. Foran, and Atigaru Point wells have shows of oil and gas, or both. These shows range from a dull gold fluorescence in the Atigaru Point well to good oil staining in the W.T. Foran well to dead oil and asphalt in the J.W. Dalton well. A drill-stem test in the J.W. Dalton well produced water with a small amount of solution gas; a drillstem test in the W.T. Foran well produced 125 barrels of slightly gas-cut water in two hours.

8. Shublik Formation

All wells in the TSMA area penetrate the Triassic Shublik Formation. The thickness ranges from 182 feet in the W.T. Foran well to 624 feet in the Drew Point well. The Shublik consists of a varied lithology of limestones, shales, siltstones and sandstones with the shales and limestones predominating. The limestones of the Shublik range from cryptocrystalline (having very fine crystals), with shell fragments sometimes present, to sandy limestones. The fine-grained sandstones form a minor portion of the sequence in the TSMA area.

The Shublik sections in the South Harrison Bay well and the J.W. Dalton well have poor, patchy porosity of less than 5 percent. Porosity has not been determined for the other wells in the area. The South Harrison Bay well and the East Teshekpuk well have poor gas shows, and the W.T. Foran has oil-impregnated siltstones.

9. Sag River Sandstone

The Sag River Sandstone ranges from zero to 158 feet in the wells in the TSMA area. The J.W. Dalton well and the W.T. Foran well have no Sag River Sandstone, the Drew Point well has 16 feet, the West Fish Creek well has 93 feet, the South Harrison Bay well has 111 feet, the East Teshekpuk well has 124 feet, and the Atigaru Point well has 158 feet.

The Sag River is mainly very fine to fine-grained sandstone with some medium-grained sandstones in the Atigaru Point well. Porosity determinations show porosity consistently below 15 percent. In the West Fish Creek well it runs 9 to 12 percent, in the East Teshekpuk well it averages 8 percent with 12 to 15 percent at the high end, the Atigaru Point well has very poor to poor visible porosity, and the South Harrison Bay well runs 10 to 15 percent porosity on neutron-density crossplots. The Sag River has good shows of oil and gas in the Drew Point well, some poor to fair visible staining in the West Fish Creek well, minor gas shows in the East Teshekpuk well, and some dull gold fluorescence in the Atigaru Point well.

10. Kingak Shale

The Kingak Shale, as its name suggests, consists predominantly of shale. It does, however, have some interbedded sandstones that are thin and very fine to fine-grained. The wells in the TSMA area do not penetrate any potential reservoir sandstones comparable to the Simpson Sand or the Barrow gas sands within the Kingak Shale to the west of the TSMA. Sandstones comparable to these could exist in undrilled areas of the TSMA.

Kuparuk Equivalent Sandstones

"Kuparuk equivalent" sandstones, at about the same stratigraphic interval as the "pebble shale," are penetrated by the J.W. Dalton (poorly developed), the W.T. Foran well (about 33 feet thick), the East Teshekpuk well (17 feet thick), and the Atigaru Point well (thin sandstone). In the J.W. Dalton well, "Kuparuk equivalent" section consists of thin, glauconitic, conglomeratic sandstone and siltstone interbedded with black shale. In the W.T. Foran, it consists of very fine-grained chert and quartz with bentonitic clay and silt matrix, overlying a three-foot thick conglomeratic sandstone. It is poorly consolidated and has poor to fair visible porosity. In the East Teshekpuk well, it consists of fine-grained quartz and chert and has poor to fair reservoir quality. The "Kuparuk equivalent" has oil staining and odor in the W.T. Foran well. Unfortunately, the "Kuparuk equivalent" sands are thin and discontinuous, that is, they are not found in all of the wells, in the area. It is unknown whether "Kuparuk equivalent" sands reach significant thicknesses in undrilled portions of the TSMA.

11. Torok Formation

The Torok Formation, found in all wells in the area, ranges in thicknesses from 1,755 feet to 3,745 feet. It consists mainly of shale with a minor amount of interbedded, thin siltstones and sandstones. The sandstones are very fine- to fine-grained, carbonaceous, silty, shaly, and partly calcareous. They are tight, that is, the poor visible porosity is sometimes choked with clay. The wells in the area encounter scattered oil and gas shows. While the Torok reaches appreciable thicknesses in the TSMA area, its relative paucity of reservoir-quality sandstones virtually eliminates it as a possible reservoir rock.

As mentioned above, the Fish Creek structure, or disrupted zone, lies within the Torok. This structure has been interpreted as a subsea landslide (Weimer, 1987). One well tested this structure and found no hydrocarbons.

12. Nanushuk Group

All wells in the TSMA area penetrate the Nanushuk Group. It ranges from 746 feet thick in the W.T. Foran well to 3,807 feet thick in the J.W. Dalton well and consists of interbedded sandstones, siltstones, shales, and claystones. The finer-grained sediments, that is, siltstones, shales, and claystones, predominate.

The sandstones are mostly very-fine- to fine-grained with some rare, medium- and coarse-grained sandstones. The sandstones are generally thin-bedded and poorly developed. They usually interbed or interlaminate with claystone, shale, or siltstone. Where checked, the sandstones are not reservoir quality because of low porosity and because of the presence of clay or silt in the matrix.

The West Fish Creek well has a few faint shows of oil and a few gas shows. The South Harrison Bay well has traces of hydrocarbon fluorescence in sandstones and siltstones in the upper 1,000 feet of the Nanushuk Group.

So, while the Nanushuk Group may have reservoir quality sandstones, it is unlikely that it contains huge deposits within the TSMA. Simpson core test wells, northeast of the TSMA, produced minor amounts of oil from Nanushuk Group sandstones (Robinson, 1988).

13. Colville Group

Tertiary Sandstones Undivided

All wells in the TSMA area penetrate the sandstones of the Cretaceous Colville Group\Tertiary undivided. The well-site geologists usually subdivide this part of the section, but Claypool and Magoon (1988) lump them together in wells where they recognize both. These sediments consists of claystone, shale, siltstone, sandstone, conglomerates, and their unconsolidated equivalents.

As with the Nanushuk Group sediments, the finer-grained sediments predominate. The sandstones are usually fine grained, but range from very-fine to coarse. The sandstones may be bentonitic, micaceous, calcareous, or glauconitic, and may have silt and clay clogging their pore spaces. The sandstones form thin beds.

Wells which Claypool and Magoon (1988) identify as containing Colville Group/Tertiary undivided usually coarsen upsection. In fact, several of the wells have conglomeratic sections near the top of the Colville/Tertiary undivided. Neither oil nor gas shows are reported from this interval for the wells within the TSMA area. The sandstones of this part of the section could serve as reservoir rocks given sufficient porosity and thickness in the presence of a trapping mechanism. Unfortunately, the sand-rich parts of the section lie at shallow burial depths, are unlikely to have adequate seals, and are likely to lie in or near the permafrost zone. Simpson core test 26, northeast of the TSMA, may have recovered a minor amount of oil from a sandstone in this part of the section (Robinson, 1964).

14. Source Rock Potential and Geochemistry

The potential source rocks beneath the TSMA include: Lisburne Group carbonates; the Kavik Shale member of the Sadlerochit Group, ; Shublik Formation; Kingak Shale; "Pebble Shale"; Torok Formation; and Colville Group shales. Of these, the Shublik Formation, the Kingak Shale, and the "Pebble Shale" probably have the greatest potential as source rock. The numerous oil and gas shows and the few oil and gas fields found in the NPR-A attest that at least one of the potential source rocks has generated oil and gas somewhere in the NPR-A.

This discussion focuses on the stratigraphic units within and near the TSMA. This does not imply that oil and gas within the TSMA had to originate from within its boundaries. Oil and gas could have migrated in from source rocks external to the TSMA, especially since thick sections of potential source rock lie down stratigraphic dip from the TSMA. This discussion, which relies entirely on Claypool and Magoon (1988), just considers the possibilities of these portions of the sedimentary sections acting as hydrocarbon source rocks.

Claypool and Magoon (1988) report on the geochemistry of three wells that are within the confines of the TSMA: the W.T. Foran No. 1, the J.W. Dalton No. 1, and the Drew Point No. 1. They do not discuss the geochemistry of the Cape Halkett No. 1 well because of a meager amount of data, and they make no mention of the East Teshekpuk No. 1 well.

Each of the three wells penetrate the entire sedimentary section and enter the basement complex. The wells penetrate 6,700 to 7,500 feet of Brookian strata and 1,150 to 2,025 feet of Ellesmerian strata *(Figure 4)*.

The rocks in these wells (Claypool and Magoon, 1988) range from thermally immature to mature, according to vitrinite reflectance data (0.3 to 0.75 percent). "The onset of oil generation, based on a C_2-C_4/C_1-C_4 ratio greater than 0.25, mostly agrees with the interpreted trend of vitrinite reflectance." The transition from immature to mature rocks, in the Drew Point well occurs at a depth of about 5,500 feet to 6,000 feet. It occurs at about 6,500 feet in the J.W. Dalton well, and at about 7,200 feet in the W.T. Foran. This makes the lower part of the Torok Formation, the Pebble Shale unit, and the Ellesmerian sequence thermally mature in the TSMA.

The sandstones of the Sagavanirktok Formation and the Colville Group have low organic-carbon content of 0.2 to 0.6 weight percent in the W.T. Foran well, but in the J.W. Dalton well it reaches a maximum of 15 weight percent because of the presence of coal. The Colville shale generally runs about 0.5 weight percent but gets as high as 1.0 weight percent in the Drew Point well. The Nanushuk Group and the Torok Formation have organic-carbon values that run 0.5 to 1.0 weight percent. The Pebble Shale unit has about 2.0 weight percent organic carbon. The rest of the Ellesmerian sequence averages about 0.5 weight percent, except in the J.W. Dalton well where it runs as high as 3.0 weight percent because of oil staining in the Sadlerochit and Lisburne groups.

The J.W. Dalton and Drew Point wells have mainly hydrogen-deficient organic matter, based on H/C ratios. Claypool and Magoon (1988) attribute H/C ratios exceeding 1.0 to the presence of migrated hydrocarbons. The Torok Formation, in the Drew Point well, has a high ratio of volatile hydrocarbons to total hydrocarbons due to migrated oil, as indicated by pyrolysis assays and C_{15+} solvent extraction data.

Claypool and Magoon (1988) report that migrated oil is common throughout the Ellesmerian and Brookian sequences, and they maintain that this situation is not surprising given the location with respect to the Barrow arch. They also speculate, even though the Ellesmerian sequence is thermally mature within the area, that the bulk of the migrated oil originated downdip in the Colville Basin.

15. Conclusions

The Teshekpuk Lake area has the potential to hold economically valuable deposits of hydrocarbons. It lacks for neither potential reservoir rocks nor for potential source rocks. Exploration to the east of NPR-A continues to discover hydrocarbon reservoirs. One of the most recently announced discoveries, ARCO's Fjord discovery in the Colville River delta, lies only about ten miles east of the eastern boundary of NPR-A and along structural strike between the Teshekpuk Lake area and the producing fields at Prudhoe Bay.

A combination of factors (such as, potential reservoir rock, potential source rock, scant exploration, oil and gas discoveries to the east, the Barrow gas fields to the west, and oil discoveries in the Cape Simpson area to the immediate northwest) seem to present a convincing argument for more intense hydrocarbon exploration of the Teshekpuk Lake area.

Whether the area is explored for its hydrocarbon potential or preserved for its environmental values, or used for both activities, is, however, a policy decision. Exploration and preservation are but two possible uses for the area and are not necessarily mutually exclusive.

Bibliography

Bird, K.J., 1988a, The geologic basis for appraising undiscovered hydrocarbon resources in the National Petroleum Reserve of Alaska by the play-appraisal method, *in* Gryc, George, ed., Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 81-116.

Bird, K.J., 1988b, Structure-contour and isopach maps of the National Petroleum Reserve in Alaska, *in* Gryc, George, ed., Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 355-377.

Bird, K.J., S.B. Griscom, S. Bartsch-Winkler, and D.M. Giovanetti, 1987, Petroleum Reservoir Rocks, *in* Bird, K.J. and L.B. Magoon, eds., Petroleum Geology of the Northern Part of the Arctic National Wildlife Refuge, Northeastern Alaska, U.S. Geological Survey Bulletin 1778, p. 79-100.

Claypool, G.E., and Magoon, L.B., 1988, Oil and gas source rocks in the National Petroleum Reserve in Alaska, 1988, *in* Gryc, George, ed., Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 451-482.

Gryc, George, ed., 1988, Geology and exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, 940 p.

Husky Oil NPR Operations, Inc., 1983a, Geological report, Atigaru Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 10 p, Appendices.

Husky Oil NPR Operations, Inc., 1983b, Geological report, Cape Halkett Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska.

Husky Oil NPR Operations, Inc., 1983c, Geological report, Drew Point Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 16 p, Appendices.

Husky Oil NPR Operations, Inc., 1983e, Geological report, East Teshekpuk Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 10 p, Appendices.

Husky Oil NPR Operations, Inc., 1983f, Geological report, Ikpikpuk Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 17 p, Appendices.

Husky Oil NPR Operations, Inc., 1983g, Geological report, J.W. Dalton Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 11 p, Appendices.

Husky Oil NPR Operations, Inc., 1983h, Geological report, South Harrison Bay Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 12 p, Appendices.

Husky Oil NPR Operations, Inc., 1983i, Geological report, West Fish Creek Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 13 p, Appendices.

Husky Oil NPR Operations, Inc., 1983j, Geological report, W.T. Foran Test Well No. 1: Husky Oil NPR Operations, Inc., Anchorage, Alaska, 11 p, Appendices.

Kirschner, C.E. and Rycerski, B.A., 1988, Petroleum potential of representative stratigraphic and structural elements in the National Petroleum Reserve in Alaska, *in* Gryc, George, ed., Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U. S. Geological Survey Professional Paper 1399, p. 191-208.

Magoon, L.B., and Bird, K.J., 1988, Evaluation of petroleum source rocks in the National Petroleum Reserve in Alaska, using organic-carbon content, hydrocarbon content, visual kerogen, and vitrinite reflectance, *in* Gryc, George, ed., Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 381-450.

Magoon, L.B., Bird, K.J., Claypool, G.E., Weitzman, D.E., and Thompson, R.H., 1988, Organic geochemistry, hydrocarbon occurrence, and stratigraphy of government-drilled wells, North Slope, Alaska, *in* Gryc, George, ed., Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 483-487.

Magoon, L.B., and Claypool, G.E., 1988, Geochemistry of oil occurrences, National Petroleum Reserve in Alaska, *in* Gryc, George, ed., Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 519-549.

Robinson, F.M., 1964, Core tests, Simpson Area, Alaska: Exploration of Naval Petroleum Reserve NO. 4 and Adjacent Areas, Northern Alaska, 1944-53: U.S. Geological Survey Professional Paper 305-L, p. 645-730.

Weimer, P., 1987, Seismic stratigraphy of three areas of lower slope failure, Torok Formation, Northern Alaska, *in* Ed. Tailleur, I. and P. Weimer, eds., Alaskan North Slope Geology: The Pacific Section, Society of Economic Paleontologists and Mineralogists, Bakersfield, California and The Alaska Geological Society, Anchorage, Alaska, volume one, p. 481-496.