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Krass, V.A., and Amoco Oil Co.

GMC DATA REPORT 459A

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GEOLOGIC MATERIALS CENTER

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Denver Region Northern Division
Geological Report NO-14-86R
1986 Alaska Field Work:
Lisburne Peninsula and Western
De Long Mountains
Part II: Analytical Results

PART II

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INTRODUCTION

This is the second part of a two-part report on fieldwork done in the Lisburne Peninsula and De Long Mountains, northwestern Alaska during the 1986 summer field season. Part I of this report summarizes stratigraphic and structural field observations. Part II documents the results of source rock and paleontological analyses. The primary purpose of the sampling and analytical program was twofold:

1. To characterize the source rock potential of the late Paleozoic and Mesozoic marine shale sections of the western Brooks Range which will constrain the framework for SUBSIDE modelling in support of offshore OCS Sales 109 and 97.

   In the western portion of the North Slope, available data on kerogen type and organic richness of the Shublik, Kingak and Pebble shales is limited to well control in the vicinity of the Barrow Arch. Here, the overlying Cretaceous section is relatively thin and older rocks are within reasonable drilling depths. This area, however, represents the more proximal portions of the Ellesmerian basin (provenance direction to the north) and does not adequately characterize the full range of medial and distal source rock facies which are expected to provide richer oil kerogen. In the central and southern NPRA, these more distal facies are currently buried under thick Cretaceous clastics of the Colville Basin and have not been penetrated by the drill bit. The most distal portions of the Permian to Neocomian source rock interval do outcrop in the northern part of the western Brooks Range. Analysis of these outcrop samples will provide us with kerogen type (oil versus gas), organic richness data and possibly convertibilities for the distal end members of the Ellesmerian source basin. The thermal maturity of these outcrop units is the result of burial by Brookian thrust sheets, as well as depositional burial, and will not give a direct correlation to the burial history of equivalent source rocks beneath the Colville Trough.

2. To add to the knowledge base for the Regional North Slope source rock/oil correlation study.

   For the past few years Amoco's Tulsa Research Center Geochemistry Group has been compiling and analyzing GCMS data (gas chromatography/mass spectrometer) on northern Alaska source rocks and oil samples. The goal of this study is to understand the regional changes in oil types, their relation to regional variability in the character of source rocks and to document migration history. To date, most of this work has concentrated on well data from the northern part of the coastal plain and outcrop data from the northeastern Brooks Range. Due to a lack of samples, Tulsa has not been able to document the full east to west variation in the character of the primary source horizons (Pebble, Kingak and Shublik shales) in the distal portion of the Ellesmerian Basin. These distal facies outcrop in the western Brooks Range (De Long Mountains and Lisburne Peninsula). Geochemical analysis of these rocks will provide additional data on regional changes in source rock character and should aid in our understanding of the east to west change in oil types across the North Slope.

CONCLUSIONS

1. The distal basin facies of the upper Ellesmerian section (Triassic to Neocomian) contains good to excellent oil sources and has primary potential for generation of a significant volume of oil. The lower Ellesmerian (Mississippian to Permian) and Brookian (Neocomian to Albian) sections are gas-prone. Results on source rock richness and kerogen type from all distal shales in the western Brooks Range will help constrain the regional source model used as an input for SUBSIDE for the OCS 109 and 97 Sales.

2. The high-level thermal maturity of the outcrops exposed to the Lisburne Peninsula and in the western De Long Mountains is the result of burial by Brookian thrust sheets, as well as depositional burial. This tectonic burial and uplift has placed these rocks outside of the main generation basin from which hydrocarbons migrated to fill traps on the North Slope. Study of the maturity of these outcrops does not give a correlation to the burial or thermal history of equivalent source rocks to the north and west beneath the Colville-Hanna Trough.

3. Thermal maturity of the Triassic to Neocomian source rock interval is high in the Lisburne Peninsula area (Tmax generally 450-550 degrees centigrade, peak gas to advanced). These thermal conditions make determination of original kerogen distribution, original TOC, and convertibility difficult. Thermal maturities are slightly lower in the western De Long Mountains (peak oil to peak gas), where some of the thrust sheets have apparently undergone less tectonic burial. These samples (7-23) are more useful for source rock analysis and for GCMS typing.

4. Mississippian Endicott coal and non-marine to marine shale are fair to excellent gas sources (coal 78 percent TOC, shale 0.5 to 4.5 percent TOC).

5. Black marine shales interbedded with the Lisburne Group carbonates analyzed as poor to fair sources (0.78 to 0.84 percent TOC). Kerogen type is indeterminate.

6. The late Triassic Otuk Formation of the Etivluk Group ranges from non-source to excellent source for oil or oil and gas (0.3 to 6.6 percent TOC, av. 2.4 percent TOC). The Otuk is the distal basin equivalent to the Shublik formation, a major source for oil on the North Slope.

7. The late Jurassic to early Cretaceous (Neocomian) Ipewik Formation contains marine black shales with excellent source potential for oil (2.7 to 11.0 percent TOC). The Ipewik Formation is equivalent to the Kingak Shale and possibly to the Pebble Shale, and indicates this interval continues to be an excellent oil source in the western North Slope. To the north, in the western NPRA, the Pebble Shale is dominantly gas prone. If the Ipewik Formation is indeed equivalent to the Pebble Shale, the results of this study indicate this Neocomian shale unit

becomes oil prone somewhere beneath the western Colville Trough and may provide an oil source for the Chukchi Sea OCS 109 and 97 areas.

8. All of the Brookian turbidite units, including the Ogotorok, Okpikruak, Kisimilok, Telavirak and Fortress Mountain formations, are early Cretaceous in age and were derived, at least in part, from erosion of thrust sheets of basinal Triassic rocks. These units are fair to good sources for gas and gas condensate (0.2 to 1.7 percent TOC, av. 1.0 percent TOC), at immature to peak gas thermal stage.

9. The Albian Nanushuk Group delta facies contains thermally immature interbedded marginal marine shales and coal with good to excellent potential for gas and gas condensate (coal 71 to 79 percent TOC, shale 1.5 percent TOC).

10. The gas chromatogram signature of some of the bitumens from the Otuk and Ipewik Formations resemble those of North Slope oils. However, any substantive correlations between these source rocks and North Slope oils, as well as documentation of regional variations in source rock character, will have to wait until more in depth GCMS analyses are performed on the samples.

11. No datable fossils were recovered from the Franklinian Iviagik Formation. Thus we were unable to confirm the Siluro-Ordovician age data published by the USGS from the same outcrop area.

12. Potential reservoir facies exist in the Franklinian Iviagik greywacke, Mississippian Endicott sandstone, Mississippian to Pennsylvanian carbonates, and Cretaceous turbidite and delta sandstones. None of these intervals showed well developed porosity in outcrop. Thin-sections have not yet been prepared for these samples. Analysis of these rocks is expected to be included in the 1987 Western Brooks Range field report (Krass and Muller).

13. A thick section of late Mississippian to early Pennsylvanian Lisburne Group dolomites, equivalent in age to the Alapah Formation, is present on the Lisburne Peninsula. This is the westernmost occurrence of Alapah dolomites and suggests this unit, which is an excellent reservoir in some areas of the North Slope, may be present in the Chukchi Sea OCS 109 area.

RECOMMENDATIONS

1. The results of the 1986 field study suggest that the De Long Mountains section may contain Otuk and Ipewik shales with lower levels of thermal maturity than that found on the Lisburne Peninsula. Additional source rock collection should be made in the De Long Mountains area to provide higher quality and more statistically valid source rock data on the Ellesmerian and Brookian section. This work was planned for the 1987 field season. Collection of these samples was completed in August, 1987, and sample analysis is in progress.

2. Source rock samples of the Triassic Otuk and Jurassic-Neocomian Ipewik formations should be high-graded for

richness and low thermal maturity and analyzed by GCMS at Tulsa. Results of these analyses should be integrated by Tulsa Research and the Denver Region into the North Slope Geochemical Study. Source rock character changes from east to west should be documented and correlations between the western Brooks Ranges source rocks and North Slope oils should be investigated. On the recommendation of Tulsa Research, this work is being held up until more outcrop samples from this area have been analyzed (1987 field samples) and source rock relationships are better defined.

3. Source rock richness (TOC) and kerogen type data from this study, as well as additional data from the 1987 fieldwork, should be incorporated into a regional source rock basin model for the western North Slope. This work will serve as a primary input for regional SUBSIDE modelling in support of OCS 109 and 97.

4. Age assessment for many of the shales studied by the Denver Region Paleontology Staff was indeterminate due to barren samples. In the future, samples should also be collected from adjacent chert beds in hope of dating these intervals by radiolaria.

ENCLOSURES

26. Foraminiferal Biostratigraphic Analysis Upper Paleozoic Outcrop Samples Western Brooks Range, Alaska
27. Palynology and Visual Kerogen Assessment Western Brooks Range 1986 Outcrop Samples
28. Summary Table - Palynology, Visual Kerogen and TAI Analyses
29. Source Rock Analysis - Brown and Ruth
30. Technical Service Report 865233CR Amoco Research Center Source Rock Evaluation Outcrop Samples, Northwestern Alaska
31. Government Report Compliance Documentation

DISCUSSION

Paleontological Analyses

The Denver Regional Paleontological staff analyzed all shale and carbonate samples collected during the field program for age assessment. The results of their work is given in Enclosure 26 (Foraminifera study), and Enclosures 27 and 28 (Palynology study).

Paleozoic

Foraminifera analyzed from Lisburne Group skeletal packstones collected on the Lisburne Peninsula document a late Mississippian to early Pennsylvanian age (Meramecian-Atokan). This assemblage of limestones and dolomites records the westernmost occurrence of carbonates equivalent in age to the Alapah Formation of the Lisburne Group. In a regional sense, the

Alapah Formation contains the thickest section of dolomites within the Lisburne and may have the highest potential for good reservoir development. Well and seismic control show that the Alapah is absent in the northwestern portion of the NPRA and initially suggested that this potential reservoir horizon might not be present in the offshore Chukchi Sea. The occurrence of a thick section of Alapah-equivalent dolomites in the Point Hope region shows the unit was deposited far to the west and may be present as a reservoir target within the OCS 109 area.

The only other upper Paleozoic section which contained diagnostic fossils was the marine facies of the Endicott Group. A partially silicified echinoderm/bryozoan packstone from a section of interbedded shale and limestone yielded late Mississippian (Chesterian or younger) foraminifera and Mississippian palynology age dates. The marine facies possibly represents a transitional phase between the Endicott and Lisburne. No datable fossils were found in the Iviagik Formation. Thus, we are unable to confirm the USGS Siluro-Ordovician graptolite age for this formation.

Mesozoic

Palynologic analysis was performed on sixty-eight shale samples from both the Lisburne Peninsula and De Long Mountains. About thirty-one of the rocks examined contained sufficient palynomorphs to make an age interpretation. The following is a summary of the age dates obtained:

FORMATION	AGE DATE
Otuk	Late Triassic, to (?) Early Jurassic
Ipewik	Jurassic; Late Jurassic or Early Cretaceous
Ogotoruk	Early Cretaceous, Neocomian, Triassic recycled
Okpikruak	Early Cretaceous
Kisimilok	Early Cretaceous, Triassic recycled
Telavirak	Early Cretaceous
Fortress Mountain	Early Cretaceous, Late Neocomian
Nanushuk	Early Cretaceous, Albian

All of the age determinations made are in agreement with the published, though not always documented, ages for these formations. The late Triassic Otuk Formation correlates with the Shublik Formation north of the Brooks Range. The possible early Jurassic range of this unit suggests the upper part of the section may represent the distal equivalent of the lower Kingak Formation. The late Jurassic to (?) early Cretaceous Ipewik Formation was found at both the Lisburne Peninsula (7-21-04A) and in the western De Long Mountains (7-23-5A, 7-23-12B). This formation is a rich oil source (see source rock discussion below) and correlates with the upper Kingak or Pebble Shales. All of the various Brookian turbidite units (including the Okpikruak, Ogotoruk, Kisimilok, Telavirak and Fortress Mountain Formations) were dated as early Cretaceous, probably Neocomian. Most of these samples also contained recycled Triassic palynomorphs, attesting to their partial derivation from erosion of Triassic rocks during Brooks Range thrusting. The youngest unit which outcrops in the study area is the deltaic Nanushuk Group, dated as early Cretaceous (Albian).

Source Rock Analyses

Brown and Ruth Labs (Englewood, Colorado) analyzed fifty-seven shale and limestone potential source rock samples for Total Organic Carbon content (TOC). All samples with a TOC of 0.5 percent or higher were also run for Rock Eval Pyrolysis. Over 70 percent of the rocks analyzed contained greater than 1.0 percent TOC and are considered fair to excellent source rocks. The maximum TOC level exceeded 11 percent (excluding coals). In general, the samples are thermally mature to over-mature, making original kerogen type and accurate convertibility determinations difficult. TMAX (degrees centigrade) ranged from 438 (peak oil) to 548 (advanced). Samples collected in the Lisburne Peninsula area showed the highest thermal maturities. Here, all of the samples except the Albian Nanushuk and a few early Cretaceous Ogotoruk shales are at peak or past peak gas. In the De Long Mountains the thermal maturity was slightly lower, generally in the peak oil to peak gas range. Eight samples with the lowest thermal degradation and high TOC content were sent to Tulsa Research for more in-depth source rock analysis. Table I summarizes the samples analyzed and the results obtained from Brown and Ruth (see Enclosure 29 for detailed report). Visual kerogen results are taken from Amoco Denver palynology study (Dave Wall; Enclosure 28).

TABLE I: SOURCE ROCK SUMMARY

AGE	NO. OF SAMPLES	TOC % / LITH	KEROGEN (VISUAL)
Miss. Endicott	11	0.54-4.51 shale 77.79 coal	herbaceous-woody, fusinitic (coaly)
Miss. Lisburne	2	0.78-0.84 shale	no data
Triassic to Perm? Etivluk	14	0.29-6.61 shale 1.21-2.60 ls	altered amorphous, mixed (amorph-woody), less- sapropelic, humic, bituminous
Jurassic to E. Cret. Ipewik	3	2.65-11.04 shale	amorphous-bituminous, mixed (amorph-woody)
E. Cret. Turbidites	23	0.20-1.70 shale	dominantly woody and woody-herbaceous, 30% mixed (woody-amorphous)
Albian Nanushuk Deltaic	2	1.52 shale 71.22 coal	herbaceous to woody

Paleozoic

Eleven samples of Mississippian Endicott Group shales and coal were analyzed. As expected, the non-marine to marginal marine coal and shale facies are fair to excellent sources for gas (shale 1.4 to 4.5 percent TOC, coal 77.79 percent TOC). An open marine shelf facies of the Endicott (?) containing thinly interbedded black shale and limestone was sampled at a major cliff outcrop south of Pt. Hope (27-T32N-R32W). The two shale samples taken (7-17-1, 7-17-6) analyzed as poor to fair sources (0.5 to 0.9 TOC), suggesting even a marine facies of the Endicott may not provide a good source for oil.

It must be remembered, however, that these Endicott shale samples are probably thermally mature to over-mature (TMax unavailable), and original TOC content may have been reduced by as much as 50 percent by generation and expulsion. Shales interbedded with the Lisburne limestone and dolomite are not expected to be volumetrically important in this area due to low total organic carbon content (0.78 and 0.84 percent) and low composite thickness. Thicker black shale facies within the Lisburne are reported from areas not yet visited in the western De Long Mountains. These units (Kuna Formation) will be visited in the 1987 field season.

Ellesmerian Mesozoic

The primary source rocks for the known North Slope oil accumulations are contained within the basinal facies of the Ellesmerian Atlantic style margin and include the late Triassic Shublik Shale, Jurassic to Neocomian Kingak Shale and the Neocomian Pebble Shale. The distal equivalents to these units which outcrop on the Lisburne Peninsula and western Brooks Range are as follows:

Late Triassic	Shublik Fm	Otuk Fm (Etivluk Group)
Jurassic to Neocomian	Kingak Fm	Otuk Fm to Ipewik Fm
Neocomian	Pebble Fm	Ipewik Fm

The Permian to Triassic to (?) lower Jurassic Etivluk group consists of thick chert and siliceous shale with more thinly interbedded non-siliceous shale. All of the datable samples from this group were interpreted as Triassic to late Triassic and are equivalent to the Shublik Formation to the north. Twelve shale and two limestone samples were analyzed. The shales ranged from non-source to excellent source (0.25 to 6.61 percent TOC, average 2.35 percent TOC). Samples with 5 to 6 percent TOC were found at both the Lisburne Peninsula and in the De Long Mountains. The black limestones found at Spiney Ridge (1-T33N-R23W and 20-T33N-R23W) are fair sources (1.21 to 2.60 percent TOC). All of the Etivluk/Otuk samples show moderate to high levels of thermal maturity with TMAX values ranging from 438 to 548 degrees centigrade and TAI values of 5 to 6. Tulsa Research analysis gives a vitrinite reflectance range of 0.81 to 1.67 percent Ro, interpreted as peak oil to peak gas. Preserved kerogen within these thermally degraded rocks is mixed, with some samples dominantly altered amorphous and others dominantly woody-herbaceous. Considering the preferential destruction of amorphous kerogen with increasing thermal maturity, these results suggest the Etivuluk is an oil to mixed oil and gas source.

The Ipewik Formation, dated as late Jurassic to early Cretaceous, was found at Spiney Ridge in the western De Long Mountains (6-T33N-R22W and 16-R12S-R50W) and in a drainage cut in the northern Lisburne Peninsula (18-T8S-R58W). All three samples tested analyzed as excellent oil sources. Total organic carbon content measured by Brown and Ruth ranged from 2.65 to 11.04 percent. Two of the shale samples were rerun by Tulsa Research and yielded 3.5 to 4.9 percent TOC. The discrepancy in TOC values is attributed to variable weathering of the outcrop samples as well as original sample inhomogeneity. Thermal maturity indicators including vitrinite reflectance (0.88 to 0.93 percent Ro), TMAX (451 to 541) and TAI (5 to 6), are in general agreement and indicate a range from peak oil (Spiney Ridge area) to peak gas (Lisburne Peninsula sample). Visual kerogen assessment shows amorphous to mixed amorphous-woody-herbaceous kerogen. FTIR versus elemental analysis plots also demonstrate the oil prone nature of the Ipewik. This formation is the distal equivalent of the upper Kingak to Pebble Shales and these analyses indicate this interval is still an excellent oil source in the western part of the North Slope.

Brookian Early Cretaceous

Twenty-three samples of early Cretaceous (presumably mid to late Neocomian) turbidite shale samples were analyzed. Formations tested include the Okpikruak, Ogotoruk, Kisimilok, Telavirak and Fortress Mountain. All of these units had abundant plant debris fossils in outcrop and were expected to be gas sources. Source rock analysis bears out this conclusion, indicating the turbidite facies is a fair to good source for gas and gas condensate. Total organic carbon content ranges from 0.20 to 1.70 percent TOC, with an average of 1.00 percent. Visual kerogen is dominantly woody and woody-herbaceous, with approximately 30 percent of the samples containing mixed woody-amorphous kerogen. TMAX values range from 362 to 500 degrees centigrade, interpreted as immature to peak or past peak gas (?).

The youngest rocks analyzed for source potential were an early Cretaceous (Albian) coal and shale from the Nanushuk Group deltaic clastic section. The coal sample is rated an immature excellent gas and gas condensate source with 71-79 percent TOC, 423 degrees centigrade TMAX and 0.6 percent Ro vitrinite reflectance. Woody kerogen indicates a gas source, with FTIR/elemental analysis suggesting some potential for gas condensate. The shale sample is also an immature good source for gas with 1.52 percent TOC, 446 degrees centigrade TMAX and herbaceous kerogen. To the north, where the Nanushuk Group clastics are more deeply buried in the Colville Trough, these rocks have generated gas and minor amounts of condensate as evidenced by shows in NPRA wells.

Source Rock Exploration Potential

The lower Ellesmerian section, including the marine facies of the Endicott and shales within the Lisburne Group carbonates contain fair to good potential for gas generation. The very limited analyses run in this study suggest these older rocks will not provide a secondary source for oil for North Slope prospects. The early Cretaceous Brookian turbidite and delta sequences are also dominantly gas prone, with only minor potential for liquid generation. Rotary core data from the Chukchi Sea (Fugro, 1985) and outcrop data from the NPRA (TRC geochemical database) show the Brookian clastics continue to be dominated by gas kerogen to the north and west and provide little potential for oil generation. It is possible that the more distal part of the Torok shales in the Beaufort Sea and North Chukchi Basin may contain amorphous kerogen and some potential for oil.

The primary potential for major generation of significant quantities of oil is found in the basinal facies of the Triassic to Neocomian Ellesmerian section. These rocks are known to be the major source for the oil at Prudhoe Bay and adjacent fields, as well as for most of the oil shows across the northern coast of Alaska. Data from this study confirms that these units continue to be good to excellent sources for oil in the southwestern part of the North Slope, and provides encouragement for oil potential in the Chukchi Sea. Well control from the northwestern NPRA suggests that the Neocomian Pebble Shale, which is an excellent oil source in the central North Slope, becomes more gas prone to the west and its potential for oil generation deteriorates. If part of the Neocomian

Ipewik Formation is indeed equivalent to the Pebble Shale, analyses from this study show that the unit grades from a gas or mixed source near the coast southward into an oil prone kerogen facies somewhere beneath the Colville Trough. With appropriate timing of generation and long distance migration, the Pebble Shale may still provide a source for oil for the Chukchi Sea. Data from this study combined with well control from the northern NPRA provide information on source richness and kerogen type from the proximal and distal portions of the Ellesmerian basin. This knowledge will provide input for source modelling and SUBSIDE profiling of the Chukchi Sea and western NPRA.

The Tulsa Research technical service report on these source rocks (Enclosure 30) states that chromatograms of some of the bitumens resemble those of North Slope oils. However, GCMS analysis is necessary for valid correlation on the North Slope. A more extensive source rock collection program is planned for the De Long Mountains in the summer 1987 season. Tulsa has recommended waiting until a more statistically valid definition of source rock relationships from this area is available before doing a GCMS source rock and source/oil correlation study. Thus, rich oil sources with low thermal maturity will be chosen from both the 1986 and 1987 western Brooks Range programs for GCMS analysis to provide regional character variations in Triassic to Neocomian source rocks and source rock/oil correlations for the North Slope Regional Geochemistry Project. These results should be available by early 1988 and will be documented in the vault report on the 1987 Western Brooks Range Field Study (Krass and Muller).

Reservoir Rock Analyses

A secondary objective of the 1986 field season was to collect representative samples of any potential reservoir units for thin section preparation and descriptive petrographic analysis in support of the regional evaluation of the Chukchi Sea OCS 109 Sale. Although examination of these rocks will give some insight into the reservoir potential of equivalent units buried to the north and west, the diagenetic history of the two areas is expected to be quite different. The outcrop samples have been involved in the Brookian Orogeny, resulting in a different burial and thermal history than that of the various prospect corridors within the Chukchi Sea, which are primarily outside of this zone of deformation. Rocks collected in the 1986 season will be processed along with the 1987 De Long Mountains samples, and descriptions and interpretations included with the 1987 field report (Krass and Muller, 1987). In 1986, lithology samples were collected from sandstone and carbonate facies from the Franklinian, Ellesmerian and Brookian sequences (see Appendix III C, Part I of report as follows):

TABLE II: POTENTIAL RESERVOIR ROCK SAMPLES

AGE	GROUP OR FORMATION	LITHOLOGY
E. Cretaceous	Ogotoruk	Sandstone
	Okpikruak	Sandstone
	Telavirak	Sandstone
	Kisimilok	Sandstone
	Fortress Mountain	Sandstone
	Nanushuk	Sandstone
(?) Permo-Triassic	Etivluk (?)	Sandstone
Mississippian	Lisburne	Dolomite and Limestone
Mississippian	Endicott	Sandstone and Limestone
(?) Siluro-Ordovician	Iviagik	Coarse Greywacke

The Franklinian Iviagik Formation consists of a thick pile of turbidite greywackes and slates. Although some of the greywackes are coarse grained, the rocks appear clay-rich and have undergone deep burial. They have no apparent porosity in hand specimen. Reservoir potential within the Paleozoic lower Ellesmerian units includes fine to medium grained non-marine to marine quartz-rich sandstone within the Endicott Group and carbonates within the Lisburne Group. The Endicott at the Lisburne Peninsula, which represents the westernmost occurrence of this unit, is thought to have been derived from the north and possibly the west (Mayfield and others, 1983, see Part I references). The quartz rich nature of these sands gives encouragement for a possible quartzose provenance within the western Chukchi. The Lisburne limestone and dolomite sequence lacked porosity in outcrop, but the presence of thick sections of dolomite within this unit suggest it could be an important prospective reservoir target in the Chukchi Sea under more favorable diagenetic conditions.

The upper Ellesmerian Permian to Neocomian section present in the Lisburne Peninsula and western De Long Mountains represents a distal basin facies, dominated by siliciclastic chert and shale deposition. The lack of potential reservoir horizons seen in outcrop reflects this basinal setting and good clastic reservoir facies are documented in the NPRA to the north and are expected to the west in the Chukchi Sea.

The Brookian thick turbidite and delta facies contain a variety of sandstone units ranging from thin rhythmically interbedded fine grained immature sands to thicker more coarse grained sands. Little work has been done on the thin turbidite sand facies since these rocks have marginal exploration potential on the western North Slope. In the field area studied, the turbidite sands are very fine grained and appear to be poorly sorted and clay-rich, suggesting poor reservoir quality. Regional work has shown that the delta sands within the western Nanushuk Formation (Corwin Delta) are also clay-rich and generally poor reservoirs. Comparative thin sections of all Brookian sandstones collected will detail the character of each of these facies.

ENCL. 26
NO-14-86R

Amoco Production Company
Denver, Colorado

October 17, 1986

D. T. Bauer
1256 AB

Attn: V. A. Krass

re: Foraminiferal Biostratigraphic Analysis of Upper <u>Paleozoic Outcrop Samples, Western Brooks Range, Alaska</u>

Twenty-two outcrop samples were examined for contained calcareous microfossils (foraminifers and skeletal algae). Brief sample-by-sample petrographic descriptions and fossil checklists are recorded on attached pages.

In general, the sampled lithologies do not contain well developed calcareous microfossil assemblages. Only four of the 22 samples yielded biostratigraphically diagnostic recoveries, whereas the remaining 18 were barren or contained unidentifiable fragments. Two samples (7-18-14C and 14D) are assigned an undifferentiated Meramecian-Atokan age on the basis of the problematicum <u>Asphaltina</u> <u>cordillerensis</u>. Sample 7-17-1C is regarded as Chesterian or younger on the basis of Biseriamminidae. And sample 7-21-5A is Morrowan or younger on the basis of <u>Globivalvulina</u> <u>bulloides</u>.

John R. Groves

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JRG/mmm

cc: J. W. Parks
R. W. Pierce

Spl. 7-17-1A

Lithology: partly calcitic, dolomitized and silicified limestone (precurser lithology is presumed to be limestone).
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-17-1B

Lithology: sparsely fossiliferous, argillaceous quartz siltstone to mudstone.
Biota: No calcareous microfossils.
Age: indet.

Spl. 7-17-1C

Lithology: partly silicified echinoderm/bryozoan packstone.
Biota: indet. Biseriamminidae
indet. Endothyridae
Tetrataxis sp.
Age: Chesterian or younger.

Spl. 7-17-1D

Lithology: partly calcitic, dolomitized spiculitic packstone, with patches of probable barite cement.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-17-6A

Lithology: highly argillaceous quartz siltstone.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-17-6B

Lithology: extensively dolomitized mixed skeletal packstone, with patches of probable barite cement.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-18-12B

Lithology: shale.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-18-14C

Lithology: quartz silty mixed skeletal packstone.
Biota: *Asphaltina cordillerensis*
cf. *Berestovia* sp.
Age: Meramecian-Atokan?

Spl. 7-18-14D

Lithology: quartz silty mixed skeletal packstone.
Biota: *Asphaltina cordillerensis*
Age: Meramecian-Atokan?

Spl. 7-18-15A

Lithology: shale.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-19-2B

Lithology: indet. (sample was destroyed in thin sectioning).
Biota: indet.
Age: indet.

Spl. 7-19-2C

Lithology: shale.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-19-9A

Lithology: partly silicified coral megafossil embedded in mixed skeletal/pelletoidal/spiculitic wackestone.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-19-11A

Lithology: impure, texturally immature quartz fine sandstone to siltstone.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-21-1J

Lithology: calcitic dolomite.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-21-2A

Lithology: extensively silicified echinoderm/bryozoan packstone.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-21-2C

Lithology: calcitic dolomite.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-21-5A

Lithology: partly cherty and dolomitic echinoderm/ bryozoan packstone.
Biota: indet. Biseriamminidae
Tetrataxis sp.
Neoarchaediscus sp.
indet. Eostaffellidae
Globivalvulina bulloides
Neoarchaediscus incertus
Asteroarchaediscus rugosus
Age: Morrowan or younger.

Spl. 7-21-1I

Lithology: dolomite.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-22-1B

Lithology: slightly calcitic dolomite.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-22-1C

Lithology: coral megafossil.
Biota: no calcareous microfossils.
Age: indet.

Spl. 7-22-2A

Lithology: calcitic dolomite.
Biota: no calcareous microfossils.
Age: indet.

ENCL. 27
NO-14-86R

AMOCO

Amoco Production Company
Denver, Colorado

July 9, 1987

D.T.Bauer
AB 1256

Attn: Valerie A. Krass

Western Brooks Range, Alaska
<u>1986 Outcrop Samples</u>

Seventy-four samples from the 1986 Field Party were examined for palynology, including age-determinations where possible and visual kerogens (type present and thermal alteration color index or TAI). The results of this work have been given to Valerie Krass in the form of tables and single page descriptions per sample for her use in geologic reports and to meet some permit requirements.

This memo. summarizes those results. Previous reports on the foram. work by John Groves and Jim Parks have been dispatched and this memo. on the palynology completes our work on the 1986 collection.

David Wall DW

27.

WESTERN BROOKS RANGE 1986 FIELD SAMPLES

VISUAL KEROGEN ANALYSIS

Kerogen types

The majority of the samples contain woody and herbaceous ("structured") organic material. This kerogen is terrestrial by origin and normally considered suitable only for gas generation at appropriately high levels of thermal alteration. However, four samples from the Shublik/Siksikpuk Formation had a significant amount by proportion of amorphous kerogen and could be significant as oil-generating source rock. These were samples 7/17-04a, 7/19-08a, 7/23-04a, 7/23-10a. A single sample from the Ogotoruk Fm. also had good amorphous kerogen: this was sample 7/22-05a.

Eleven other samples had some proportion of amorphous kerogen and therefore some potential for oil generation, but they appeared less likely to be good potential sources from visual inspection. These were from the Shublik/Siksikpuk (7/17-02g, 7/23-01a, 7/23-09a), Ogotoruk (7/17-02j, 7/22-04a, 7/22-03a, 7/22-06a), Okpikruak (7/23-02a, 7/23-06a), Fortress Mountain (7/20-01c) and ?Ipewik (7/23-12b).

Thermal Maturation (TAI)

Almost all the collection samples had high TAI values of 5, 6 or 7 (on a scale of 1-7, with 7 representing complete carbonization). These values are resultant from deep burial and/or tectonic influences. Two samples from the Nanushuk had the only relatively low values (3 to 4) indicating a different thermal history. A few samples from the Shublik/Siksikpuk Fm., which had amorphous rather than structured kerogen, also had slightly lower than normal TAI values for this collection. These were 7/23-01b, 7/23-04a, 7/23-08a and 7/23-10a.

AGE DETERMINATIONS

General

About thirty out of the seventy-four samples examined had sufficient palynomorphs to make some age interpretations. For summary purposes, they are treated as listed by field party formation identification (list attached and numbered as per below).

1) Formation unknown (Mississippian or Silurian/Ordovician)

One sample, 7/19-01b, had a few spores of probable Mississippian age which precluded the alternate possibility of Silurian/Ordovician. The others from this group (see list atttached) contained only highly carbonized kerogen.

2) Iviagik or ?Iviagik (Silurian/Ordovician or older)

All samples from this group were barren.

3) Endicott (Mississippian)

Sample 7/19-02b was barren, but two others were dated as Mississippian by their spores. One was 7/19-01b (see above),while the other, 7/24-09b, had a strong representation of spores comparable to those normally found in the coastal plain subsurface Kekiktuk Conglomerate Fm. (This latter sample is the final one on the sample list).

4) Shublik/Siksikpuk (Permo-Triassic)

Twenty seven samples were examined and five had sufficient spore, pollen and acritarchs present to confirm a Triassic age. The remainder were barren and usually had very high TAI values near 6 or 7. Samples 7/23-08a and 7/23-09a had palynomorphs that compared well with those from the Shublik Formation on the North Slope. Sample 7/23-10a also had the same general appearance but was almost barren.

Triassic spores and pollen also were isolated from samples 7/17-02a, 7/17-02b and 7/19-08a. Samples 7/20-02a, 7/23-01a and 7/23-01b had rare marine scolecodonts but no age-diagnostic palynomorphs.

5) Formation unknown (Permo-Triassic and/or Jurassic-Cretaceous

One sample from this group, 7/21-04a, was dated as probably Neocomian based on a marine dinoflagellate often seen in the North Slope Pebble Shale Fm. The remaining four samples were barren for palynology but JWP reported possibly Early Cretaceous radiolarians in 7/21-05d.

6) Ipewik or ?Ipewik (?Jurassic)

Sample 7/23-05a had a tasmanite alga which suggested a possible Early Jurassic age. The other sample in the group did not appear to be Jurassic: it resembled 7/21-04a which was more likely to be Early Cretaceous (Neocomian).

7) Formation unknown (Early Cretaceous or Jurassic)

Sample 7/13-03a was barren and 7/17-02m had palynomorphs of possibly Early Cretaceous age.

8) Okpikruak or ?Okpikruak (Early Cretaceous)

Three samples in this group (7/23-02a, 7/23-05c and 7/23-11a) had Early Cretaceous marine dinoflagellates of probable Neocomian age and sample 7/23-06a was barren.

9) Ogotoruk or ?Ogotoruk (Early Cretaceous)

Of fourteen samples examined, seven had palynologic recovery. Sample 7/22-05a resembled samples noted above from the Okpikruak Fm. The remaining six had very few or even no age-diagnostic Cretaceous palynomorphs, but did contain a moderately high number of Triassic specimens. These latter are apparently recycled into the Cretaceous because in some instances there are bona fide Cretaceous specimens in the sample, including foraminifera. Sometimes however, the Cretaceous element is so weak that at least superficially, the samples appear to be Late Triassic-Early Jurassic.

10) Kisimilok (Early Cretaceous)

Four samples were examined from the Kisimilok. As with the Ogotoruk samples described above, an apparently recycled Triassic element often was the most conspicuous one. There was little or nothing seen which would provide an Early Cretaceous age call, but by analogy with the Ogotoruk samples, the true age well may be Early Cretaceous.

11) <u>Telavirak (Early Cretaceous)</u>

The single sample examined from the Telavirak falls into the same category. It had one marine acritarch which perhaps supports a Cretaceous age call, but most of the spores apparently were recycled from the Triassic.

12) <u>Fortress Mountain or ?Fortress Mtn. (Early Cretaceous)</u>

Four samples from this group also contained some Triassic palynomorphs, but three (7/18-06b, 7/20-01d and 7/20-01e)also contained at least a few indigenous Early Cretaceous marine dinoflagellates. Again they duplicate the circumstances noted for many other Cretaceous samples in this collection.

13) <u>Nanushuk (Early Cretaceous)</u>

Two samples from the Nanushuk had Albian palynomorphs comparable to ones seen in the Nanushuk of the NPRA, Alaska. A third sample was a coal (7/20-08a) and it was barren. The two samples with recoveries had noticeably lower TAI values than the bulk of the collection.

Paleontology Samples, Lisburne Peninsula- West De Long Mountains, Alaska

	Sample No.	Formation	Tentative Age	Lithology
Gp.1	7/19-01b	?	Miss or Sil/Ord	shale
	7/19-01c	?	Miss or Sil/Ord	shale w/ graptolite
	7/19-01d	?	Miss or Sil/Ord	shale
	7/19-01e	?	Miss or Sil/Ord	dolomite
Gp.2	7/19-03b	Iviagik?	Sil/Ord or older	slate/phyllite
	7/19-05a	Iviagik?	Sil/Ord or older	mica. coaly shale?
	7/19-07a	Iviagik?	Sil/Ord or older	slate
	7/22-11a	Iviagik	Sil/Ord or older	slate
	7/23-07a	Baird	Devonian	coral megafossil
Gp.3	7/19-02b	Endicott	Early Miss	shale
	7/19-02c	Endicott	Early Miss	shale
	7/17-01a	?	Early Miss	mudstone
	7/17-01b	?	Early Miss	shale
	7/17-01c	?	Early Miss	limestone
	7/17-01d	?	Early Miss	shale
	7/17-06a	?	Early Miss	shale
	7/17-06b	?	Early Miss	limestone
	7/19-11a	?	Early Miss ?	shale
	7/18-12b	Lisburne	Mississippian	shale
	7/18-14c	Lisburne	Mississippian	dol. limestone
	7/18-14d	Lisburne	Mississippian	macrofossil sample
	7/18-15a	Lisburne	Mississippian	shale
	7/19-09a	Lisburne	Mississippian	limestone
	7/21-01i	Lisburne	Mississippian	dolomite
	7/21-01j	Lisburne	Mississippian	dolomite
	7/21-02a	Lisburne	Mississippian	limestone
	7/21-02c	Lisburne	Mississippian	limestone
	7/21-05a	Lisburne	Mississippian	limestone
	7/22-01b	Lisburne	Mississippian	dolomite
	7/22-01c	Lisburne	Mississippian	macrofossils
	7/22-02a	Lisburne	Mississippian	dolimite
Gp.4	7/17-02a	Shub/Sik	Permo-Triassic	shale
	7/17-02b	Shub/Sik	Permo-Triassic	shale
	7/17-02c	Shub/Sik	Permo-Triassic	silc. mudstone
	7/17-02d	Shub/Sik	Permo-Triassic	silc. micrite
	7/17-02e	Shub/Sik	Permo-Triassic	bivalve sample
	7/17-02f	Shub/Sik	Permo-Triassic	?coaly shale
	7/17-02g	Shub/Sik	Permo-Triassic	silc. shale
	7/17-02h	Shub/Sik	Permo-Triassic	silc. mudstone
	7/17-02i	Shub/Sik	Permo-Triassic	silc. mudstone
	7/17-02n	Shub/Sik	Permo-Triassic	bivalve sample
	7/17-04a	Shub/Sik	Permo-Triassic	shale
	7/18-01a	Shub/Sik	Permo-Triassic	silc. shale
	7/18-01b	Shub/Sik	Permo-Triassic	shale

	7/18-01c	Shub/Sik	Permo-Triassic	silc. shale
	7/19-08a	Shub/Sik	Permo-Triassic	shale
	7/20-02a	Shub/Sik	Permo-Triassic	bivalve sample
	7/20-03a	Shub/Sik	Permo-Triassic	shale
	7/20-06a	Shub/Sik	Permo-Triassic	shale
	7/20-06c	Shub/Sik	Permo-Triassic	shale
	7/21-03a	Shub/Sik	Permo-Triassic	shale
	7/21-05b	Shub/Sik	Permo-Triassic	silc. mudstone
	7/21-05c	Shub/Sik	Permo-Triassic	silty shale
	7/23-01a	Shub/Sik	Permo-Triassic	shale
	7/23-03a	Shub/Sik	Permo-Triassic	shale
	7/23-08a	Shub/Sik	Permo-Triassic	slate
	7/23-09a	Shub/Sik	Permo-Triassic	shale
	7/23-10a	Shub/Sik	Permo-Triassic	shale
Gp.5	7/24-05a	?	Permo-Triassic	claystone
	7/24-06a	?	Permo-Triassic	mudstone
	7/21-04a	?	Pr/Tr or Jur/K	shale
	7/21-04c	?	Pr/Tr or Jur/K	shale
	7/21-05d	?	Pr/Tr or Jur/K	shale
Gp.6	7/23-05a	Ipewik	Jurassic?	shale
	7/23-12b	Ipewik?	Jurassic	shale
Gp.7	7/17-02m	?	E. Cret or Jur.	shale
	7/17-03a	?	E. Cret or Jur.	shale
Gp.8	7/23-02a	Okpikruak?	Early Cretaceous	shale
	7/23-05c	Okpikruak?	Early Cretaceous	silty shale
	7/23-06a	Okpikruak	Early Cretaceous	shale
	7/23-11a	Okpikruak	Early Cretaceous	shale
Gp.9	7/17-02j	Ogotoruk?	Early Cretaceous	shale
	7/17-05a	Ogotoruk?	E. Cret or Jur.	shale
	7/18-01d	Ogotoruk?	Early Cretaceous	shale
	7/18-09a	Ogotoruk	Early Cretaceous	shale
	7/18-10b	Ogotoruk	Early Cretaceous	shale
	7/18-12a	Ogotoruk?	Early Cretaceous	shale
	7/20-02b	Ogotoruk?	Early Cretaceous	shale
	7/21-03b	Ogotoruk?	Early Cretaceous	shale
	7/21-06a	Ogotoruk	Early Cretaceous	shale
	7/22-03a	Ogotoruk	Early Cretaceous	shale
	7/22-04a	Ogotoruk	Early Cretaceous	shale
	7/22-05a	Ogotoruk	Early Cretaceous	shale
	7/22-06a	Ogotoruk	Early Cretaceous	silty shale
	7/22-07a	Ogotoruk	Early Cretaceous	shale
Gp.10	7/18-04b	Kisimilok	Early Cretaceous	shale
	7/18-05a	Kisimilok	Early Cretaceous	shale
	7/18-07a	Kisimilok	Early Cretaceous	shale
	7/18-08b	Kisimilok	Early Cretaceous	shale
Gp.11	7/18-02b	Telavirak	Early Cretaceous	shale

Gp.12	7/18-06b	Fort. Mtn.	Early Cretaceous	silty shale
	7/20-01c	Fort.Mtn?	Early Cretaceous	shale
	7/20-01d	Fort.Mtn?	Early Cretaceous	shale
	7/20-01e	Fort.Mtn?	Early Cretaceous	shale
Gp.13	7/20-07a	Nanushuk	Early Cretaceous	shale
	7/20-07b	Nanushuk	Early Cretaceous	shale
	7/24-09b	?	?	shale

OUTCR.Samples

==

Sample Number: 7/17-02a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Late Triassic

Evidence: Moderately rich assemblage of Late Triassic spores and pollen, plus rare acritarchs (marine)

Kerogen type: Woody with minor amorphous component

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

===

Sample Number: 7/17-02b
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Probably Late Triassic

Evidence: Late Triassic spores and pollen. Very rare Jurassic dinoflagellates in sample were disregarded as accidental contaminants of unknown source

Kerogen type: Woody with minor amorphous component

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

===

OUTCR.Samples

==

Sample Number: 7/17-02c
Lithology: Silc.mudstne
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: ?Altered amorphous material

Thermal stage (1-7): 5-6
Generation potential: ?Peak generation for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-02e
Lithology: Bivalve smpl
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Indeterminate

Thermal stage (1-7): Indet
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-02f
Lithology: Coaly shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of fossils

Kerogen type: ?Altered amorphous/humic material

Thermal stage (1-7): 6
Generation potential: Past-peak generation for oil

Sort: 0

==

Batch 1. (19)

OUTCR.Samples

==

Sample Number: 7/17-02g
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Possibly altered amorphous

Thermal stage (1-7): 5-6
Generation potential: Peak generation for gas
Past-peak for oil
Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-02i
Lithology: Mudstone
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Herbaceous-woody, partly bituminous

Thermal stage (1-7): 5-6
Generation potential: Peak genration for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-02j
Lithology: Shale
Formation: Ogotoruk?
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Rare Cretaceous dinoflagellates but Late Triassic present as spores,pollen and rare dinoflagellate,interpretted as recycle. (Albian forams. reported by JWP)

Kerogen type: Mixed,woody and amorphous

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-02m
Lithology: Shale
Formation: Unknown
Field age: ?Early Cretaceous or Jurassic

Palynology age: Possibly Early Cretaceous

Evidence: Only non-age diagnostic pollen and spores of
Mesozoic type

Kerogen type: Woody

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-02n
Lithology: Bivalve smpl
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: ?Woody

Thermal stage (1-7): 5-6
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-03a
Lithology: Shale
Formation: Unknown
Field age: ?Early Cretaceous or Jurassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Woody,very sparse recovery

Thermal stage (1-7): Indet
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-04a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Trias

Palynology age: Indeterminate

Evidence: No fossils present

Kerogen type: Amorphous with minor woody component

Thermal stage (1-7): 5
Generation potential: Peak generation for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/17-05a
Lithology: Shale
Formation: Kisimilok
Field age: Early Cretaceous

Palynology age: Early Cretaceous

Evidence: Early Cretaceous dinoflagellates:also Albian forams. reported (JWP)

Kerogen type: Wood-herbaceous

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples .

==

Sample Number: 7/18-01a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: No fossils recovered:extensive soil contamination from outcrop

Kerogen type: Indeterminate

Thermal stage (1-7): Indet
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-01b
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of fossils:extensive soil contamination from outcrop

Kerogen type: Possibly amorphous to 30 percent

Thermal stage (1-7): 5
Generation potential: ?Peak generation for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-01c
Lithology: Silc.shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of fossils:extensive soil contamination from outcrop

Kerogen type: ?Woody

Thermal stage (1-7): Indet
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-01d
Lithology: Shale
Formation: Ogotoruk?
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Similar to sample 7/18-04b: some possibly Triassic dinoflagellates observed but considered to be recycled

Kerogen type: Woody

Thermal stage (1-7): 5-6
Generation potential: Peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-02b
Lithology: Shale
Formation: Telavirak
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Rare marine acritarch Pterospermopsis alongside apparent
Late Triassic recycled spores and pollen

Kerogen type: Herbaceous-woody

Thermal stage (1-7): 5-6
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-04b
Lithology: Shale
Formation: Kisimilok
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Similar to sample 7/18-01d; some possible Triassic spores and rare dinoflagellates observed but considered to be recycled

Kerogen type: Woody with minor gray amorphous

Thermal stage (1-7): 6
Generation potential: Peak or past-peak for gas

Sort: 0

==

OUTCR.Samples

===

Sample Number: 7/18-05a
Lithology: Shale
Formation: Kisimilok
Field age: Early Cretaceous

Palynology age: Uncertain

Evidence: Possibly Early Cretaceous with some Late Triassic recycled pollen and spores:some soil contamination from outcrop

Kerogen type: Woody

Thermal stage (1-7): 5
Generation potential: Peak generation for gas

Sort: 0

===

OUTCR.Samples

==

Sample Number: 7/18-06b
Lithology: Silty shale
Formation: Fortress Mountain
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous with recycle

Evidence: Possible Early Cretaceous acritarch Pterospermopsis mixed with Late Triassic spores and pollen

Kerogen type: Woody

Thermal stage (1-7): 5-6
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-07a
Lithology: Shale
Formation: Kisimilok
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Only non-age diagnostic Mesozoic spores and pollen:some soil contamination from outcrop

Kerogen type: Woody

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-08b
Lithology: Shale
Formation: Kisimilok
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Only non-age diagnostic Mesozoic pollen and spores seen;
possible Late Triassic recycle

Kerogen type: Woody

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-09a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Barren for palynomorphs;few Cretaceous forams. reported by JWP

Kerogen type: Woody

Thermal stage (1-7): 5-6
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-10b
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Barren for palynomorphs

Kerogen type: Woody

Thermal stage (1-7): 5-6
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/18-12a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Woody, sparse

Thermal stage (1-7): 5-6
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/19-01b
Lithology: Shale
Formation: Unknown
Field age: Mississippian or Silurian/Ordovician

Palynology age: Possibly Mississippian

Evidence: Rare spores comparable with North Slope Kekiktuk Fm.

Kerogen type: Herbaceous-wwody

Thermal stage (1-7): 5
Generation potential: Peak for gas only

Sort: 1

==

OUTCR.Samples

==

Sample Number: 7/19-01c
Lithology: Shale(grapt)
Formation: Unknown
Field age: Mississippian or Silurian/Ordovician

Palynology age: Indeterminate

Evidence: Barren samples

Kerogen type: ?Graphitic

Thermal stage (1-7): 6-7
Generation potential: None

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/19-01d
Lithology: Shale
Formation: Unknown
Field age: Mississippian or Silurian/Ordovician

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Graphitic

Thermal stage (1-7): 7
Generation potential: None

Sort: 0

==

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Sample Number: 7/19-02h
Lithology: Shale
Formation: Endicott
Field age: Early Mississippian

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Fusinitic (coaly)-opaque

Thermal stage (1-7): Indet
Generation potential: Indeterminate

Sort: 0

==

OUTCR.Samples

OUTCR.Samples
==

Sample Number: 7/19-05a
Lithology: Shale
Formation: Iviagik?
Field age: Silurian/Ordovician or older

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Graphitic

Thermal stage (1-7): 6-7
Generation potential: None

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/19-08a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Possibly Late Trias-Early \Jurassic

Evidence: Few opaque spores and two possible Early Jurassic marine dinoflagellates. Poor.

Kerogen type: Amorphous to bituminous

Thermal stage (1-7): 5+
Generation potential: Peak to past-peak for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-01c
Lithology: Shale
Formation: Fortress Mountain?
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Only non-age diagnostic Mesozoic spores and pollen

Kerogen type: Mixed with 30 percent amorphous

Thermal stage (1-7): 4-5
Generation potential: Early generation for oil/gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-01d
Lithology: Shale
Formation: Fortress Mountain
Field age: Early Cretaceous

Palynology age: Early Cretaceous

Evidence: Rare Cretaceous dinoflagellates

Kerogen type: Herbaceous, minor amorphous component

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-01e
Lithology: Shale
Formation: Fortress Mountain?
Field age: Early Cretaceous

Palynology age: Late Neocomian

Evidence: Neocomian marine dinoflagellates

Kerogen type: Mixed, with minor amorphous only

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-02a
Lithology: Bivalve smpl
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren for palynomorphs;rare scolecodont (marine)

Kerogen type: Woody

Thermal stage (1-7): 6
Generation potential: None

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-02b
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Non age-diagnostic Mesozoic pollen and spores;does include some apparently recycled Late Triassic

Kerogen type: Woody-herbaceous

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-03a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: ?Woody

Thermal stage (1-7): 6-7
Generation potential: None

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-06a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: ?Altered amorphous material

Thermal stage (1-7): 6
Generation potential: ?Past peak for oil generation

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-06c
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Possibly altered amorphous-bituminous

Thermal stage (1-7): 5-6
Generation potential: Past peak for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/20-07a
Lithology: Shale
Formation: Nanushuk
Field age: Early Cretaceous

Palynology age: Early Cretaceous

Evidence: Few Cretaceous dinoflagellates:not narrowly age-diagnostic

Kerogen type: Herbaceous,organic-rich sample

Thermal stage (1-7): 4
Generation potential: Early generation for gas

Sort: 0

==

OUTCR.Samples

===

Sample Number: 7/20-07b
Lithology: Shale
Formation: Nanushuk
Field age: Early Cretaceous

Palynology age: Albian

Evidence: Presence of Albian dinoflagellates

Kerogen type: Herbaceous with abundant sporomorphs

Thermal stage (1-7): 3-4
Generation potential: Immature
Early generation of oil & gas
Sort: 0

===

OUTCR.Samples

==

Sample Number: 7/20-08a
Lithology: Coal
Formation: Nanushuk
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Woody

Thermal stage (1-7): Indet
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-03a
Lithology: Shale
Formation: Shublik//Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: ?Woody

Thermal stage (1-7): 6
Generation potential: None

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-03b
Lithology: Shale
Formation: Ogotoruk?
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: ?Woody,sparse

Thermal stage (1-7): 6
Generation potential: None

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-04a
Lithology: Shale
Formation: Unknown
Field age: Permo-Triassic or Jurassic/Cretaceous

Palynology age: Early Cretaceous or Late Jurassic

Evidence: Rare marine dinoflagellates of type known to occur in Pebble Shale and Upper Kingak of North Slope.

Kerogen type: Amorphous to bituminous

Thermal stage (1-7): ?5+
Generation potential: Past-peak for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-04c
Lithology: Shale
Formation: Unknown
Field age: Permo-Triassic or Jurassic/Cretaceous

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: ?Altered amorphous or herbaceous

Thermal stage (1-7): 6-7
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-05b
Lithology: Silc.mudstne
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: ?Woody

Thermal stage (1-7): 6
Generation potential: Possibly peak generation gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-05c
Lithology: Silty shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Woody,?some bituminous material

Thermal stage (1-7): ?6
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-05d
Lithology: Shale
Formation: Unknown
Field age: Permo-Triassic or Jurassic/Cretaceous

Palynology age: Indeterminate

Evidence: Barren of palynomorphs:possibly Cretaceous radiolarians

Kerogen type: Altered woody-humic

Thermal stage (1-7): 6
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/21-06a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Woody opaque only

Thermal stage (1-7): 5-6
Generation potential: Unknown

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/22-03a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence:

Kerogen type: Mixed,bituminous amorphous and woody

Thermal stage (1-7): 5
Generation potential: Possibly peak generation oil
or condensate
Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/22-04a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Single dinoflagellate plus some non-age diagnostic spores and pollen

Kerogen type: Woody-herbaceous,minor amorphous

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

===

Sample Number: 7/22-05a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Early Cretaceous (Neocomian)

Evidence: Neocomian marine dinoflagellates

Kerogen type: Amorphous to bituminous,minor woody-herb.

Thermal stage (1-7): 5
Generation potential: Peak generation for oil

Sort: 0

===

OUTCR.Samples

==

Sample Number: 7/22-06a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Few non-age diagnostic spores,pollen and fungal bodies

Kerogen type: Woody,minor amorphous

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/22-07a
Lithology: Shale
Formation: Ogotoruk
Field age: Early Cretaceous

Palynology age: Possibly Early Cretaceous

Evidence: Few non-age diagnostic spores and pollen

Kerogen type: Woody-humic,some soil contamination

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/22-11a
Lithology: Slate
Formation: Iviagik
Field age: Ordovician/Silurian?

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Graphitic

Thermal stage (1-7): 7
Generation potential: None

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-01a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Possibly Triassic

Evidence: Possible Triassic dinoflagellate and single scolecodont (marine)

Kerogen type: Humic-sapropelic,some amorphous

Thermal stage (1-7): 5
Generation potential: Possibly peak generation oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-01b
Lithology: Limestone
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample
Rare scolecodonts,lycopodiacean spore

Kerogen type: Woody-herbaceous

Thermal stage (1-7): 4
Generation potential: Early generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-02a
Lithology: Shale
Formation: Okpikruak
Field age: Early Cretaceous

Palynology age: Early Cretaceous

Evidence: Abundant marine Neocomian (Pebble Shale) dinoflagellates

Kerogen type: Mixed,herbaceous-woody and micritic amorphous

Thermal stage (1-7): 4-5
Generation potential: Peak for oil
Early generation for gas
Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-03a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Humic and some amorphous-bituminous

Thermal stage (1-7): 5
Generation potential: Possibly peak generation oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-04a
Lithology: Limestone
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren sample

Kerogen type: Amorphous-sapropelic

Thermal stage (1-7): 4-5
Generation potential: Peak generation for oil
Early generation for gas
Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-05a
Lithology: Shale
Formation: Ipewik
Field age: ?Jurassic

Palynology age: Jurassic

Evidence: Presence of Tytthodiscus sp.cf hexagonalis (tasmanite alga)

Kerogen type: Mixed, possibly amorphous with woody tissue

Thermal stage (1-7): 5-6
Generation potential: Peak for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-05c
Lithology: Shale
Formation: Okpikruak
Field age: Early Cretaceous

Palynology age: Early Cretaceous

Evidence: Several species of Early Cretaceous dinoflagellates and few spores and pollen.

Kerogen type: Woody

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-06a
Lithology: Shale
Formation: Okpikruak
Field age: Early Cretaceous

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Mixed,herbaceous and amorphous

Thermal stage (1-7): 5-6
Generation potential: ?Early peak for condensate

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-08a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Late Triassic

Evidence: Spores and pollen plus a few acritarchs comparable to the North Slope Shublik Formation assemblages

Kerogen type: Mixed with 50 percent amorphous;oil globules

Thermal stage (1-7): 4
Generation potential: Early peak generation for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-09a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Trias

Palynology age: Possibly Late Triassic (Shublik)

Evidence: Few marine acritarchs including good /Veryhachium trispinosum

Kerogen type: Mixed,woody-herbaceous plus minor amorphous

Thermal stage (1-7): 5-6
Generation potential: Peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-10a
Lithology: Shale
Formation: Shublik/Siksikpuk
Field age: Permo-Triassic

Palynology age: Possibly Triassic, uncertain

Evidence: Single acritarch

Kerogen type: Amorphous,similar to 7/23-08a

Thermal stage (1-7): 4
Generation potential: Early peak generation for oil

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-11a
Lithology: Shale
Formation: Opikruak
Field age: Early Cretaceous

Palynology age: Early Cretaceous

Evidence: Several Early Cretaceous dinoflagellates

Kerogen type: Woody-opaque

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/23-12b
Lithology: Shale
Formation: ?Ipewik
Field age: Jurassic

Palynology age: Questionably Early Cretaceous/Late Jur.

Evidence: Rare and poorly preserved dinoflagellates of a type known to occur in the Pebble Shale and Upper Kingak (similar to sample 7/21-04a)

Kerogen type: ?Altered amorphous and herbaceous, mixed

Thermal stage (1-7): 5-6
Generation potential: Peak to past peak for oil
Early generation for gas
Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/24-05a
Lithology: Claystone
Formation: Unknown
Field age: ?Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Woody with minor amorphous-bituminous

Thermal stage (1-7): 5
Generation potential: Unknown,very sparse

Sort: 0

==

OUTCR.Samples

==

Sample Number: 7/24-06a
Lithology: Mudstone
Formation: Unknown
Field age: ?Permo-Triassic

Palynology age: Indeterminate

Evidence: Barren of palynomorphs

Kerogen type: Coaly to graphitic

Thermal stage (1-7): 6
Generation potential: Probably none

Sort: 0

==

Batch 2.

OUTCR.Samples

===

Sample Number: 7/24-09b
Lithology: Shale
Formation: Unknown
Field age: Unknown

Palynology age: Mississippian

Evidence: Good assemblage of spores comparable with those found in the North Slope Kekiktuk Conglomerate Fm.

Kerogen type: Herbaceous-woody

Thermal stage (1-7): 5
Generation potential: Early peak generation for gas

Sort: 0

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VALERIE KRASS OUTCROPS-WESTERN BROOKS RANGE 1986 FIELD PARTY

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*Sample No.	Formation	Field age	Palynology age	Kerogen type	TAI	Generation potential scale	
7/17-02a	Shublik/Siksikpuk	Permo-Triassic	Late Triassic	Woody with minor amorphous component	5	Early peak generation for gas	
7/17-02b	Shublik/Siksikpuk	Permo-Triassic	Probably Late Triassic	Woody with minor amorphous component	5	Early peak generation for gas	
7/17-02c	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	?Altered amorphous material	5-6	?Peak generation for oil	
7/17-02e	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Indeterminate	Indet	Unknown	
7/17-02f	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	?Altered amorphous/humic material	6	Past-peak generation for oil	
7/17-02g	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Possibly altered amorphous	5-6	Peak generation for gas	Past-peak for oil
7/17-02i	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Herbaceous-woody, partly bituminous	5-6	Peak generation for gas	
7/17-02j	Ogotoruk?	Early Cretaceous	Possibly Early Cretaceous	Mixed,woody and amorphous	5	Early peak generation for gas	
7/17-02m	Unknown	?Early Cretaceous or Jurassic	Possibly Early Cretaceous	Woody	5	Early peak generation for gas	
7/17-02n	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	?Woody	5-6	Early peak generation for gas	
7/17-03a	Unknown	?Early Cretaceous or Jurassic	Indeterminate	Woody,very sparse recovery	Indet	Unknown	
7/17-04a	Shublik/Siksikpuk	Permo-Trias	Indeterminate	Amorphous with minor woody component	5	Peak generation for oil	
7/17-05a	Kisimilok	Early Cretaceous	Early Cretaceous	Wood-herbaceous	5	Early peak generation for gas	
7/18-01a	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Indeterminate	Indet	Unknown	
7/18-01b	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Possibly amorphous to 30 percent	5	?Peak generation for oil	
7/18-01c	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	?Woody	Indet	Unknown	
7/18-01d	Ogotoruk?	Early Cretaceous	Late Triassic	Woody	5-6	Peak generation for gas	
7/18-02b	Telavirak	Early Cretaceous	Possibly Early Cretaceous	Herbaceous-woody	5-6	Early peak generation for gas	
7/18-04b	Kisimilok	Early Cretaceous	Possibly Late Triassic (uncertain)	Woody with minor gray amorphous	6	Peak or past-peak for gas	

Palynology samples run by David Wall, April-July,1987

7/18-05a	Kisimilok	Early Cretaceous	Uncertain	Woody	5 Peak generation for gas
7/18-06b	Fortress Mountain	Early Cretaceous	Possibly Early Cretaceous with recycle	Woody	5-6 Early peak generation for gas
7/18-07a	Kisimilok	Early Cretaceous	Possibly Early Cretaceous	Woody	5 Early peak generation for gas
7/18-08b	Kisimilok	Early Cretaceous	Possibly Early Cretaceous	Woody	5 Early peak generation for gas
7/18-09a	Ogotoruk	Early Cretaceous	Indeterminate	Woody	5-6 Early peak generation for gas
7/18-10b	Ogotoruk	Early Cretaceous	Indeterminate	Woody	5-6 Early peak generation for gas
7/18-12a	Ogotoruk	Early Cretaceous	Indeterminate	Woody, sparse	5-6 Early peak generation for gas
7/19-01b	Unknown	Mississippian or Silurian/Ordovician	Possibly Mississippian	Herbaceous-woody	5 Peak for gas only
7/19-01c	Unknown	Mississippian or Silurian/Ordovician	Indeterminate	?Graphitic	6-7 None
7/19-01d	Unknown	Mississippian or Silurian/Ordovician	Indeterminate	Graphitic	7 None
7/19-02h	Endicott	Early Mississippian	Indeterminate	Fusinitic (coaly)-opaque	Indet Indeterminate
7/19-05a	Iviagik?	Silurian/Ordovician or older	Indeterminate	Graphitic	6-7 None
7/19-08a	Shublik/Siksikpuk	Permo-Triassic	Possibly Late Trias-Early Jurassic	Amorphous to bituminous	5+ Peak to past-peak for oil
7/20-01c	Fortress Mountain?	Early Cretaceous	Possibly Early Cretaceous	Mixed with 30 percent amorphous	4-5 Early generation for oil/gas
7/20-01d	Fortress Mountain	Early Cretaceous	Early Cretaceous	Herbaceous, minor amorphous component	5 Early peak generation for gas
7/20-01e	Fortress Mountain?	Early Cretaceous	Late Neocomian	Mixed, with minor amorphous only	5 Early peak generation for gas
7/20-02a	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Woody	6 None
7/20-02b	Ogotoruk	Early Cretaceous	Possibly Early Cretaceous	Woody-herbaceous	5 Early peak generation for gas
7/20-03a	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	?Woody	6-7 None
7/20-06a	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	?Altered amorphous material	6 ?Past peak for oil generation

Palynology samples run by David Wall, April-July,1987

7/20-06c	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Possibly altered amorphous-bituminous	5-6	Past peak for oil
7/20-07a	Nanushuk	Early Cretaceous	Early Cretaceous	Herbaceous,organic-rich sample	4	Early generation for gas
7/20-07b	Nanushuk	Early Cretaceous	Albian	Herbaceous with abundant sporomorphs	3-4	Early generation of oil & gas
7/20-08a	Nanushuk	Early Cretaceous	Indeterminate	Woody	Indet	Unknown
7/21-03a	Shublik//Siksikpuk	Permo-Triassic	Indeterminate	?Woody	6	None
7/21-03b	Ogotoruk?	Early Cretaceous	Indeterminate	?Woody,sparse	6	None
7/21-04a	Unknown	Permo-Triassic or Jurassic/Cretaceous	Early Cretaceous or Late Jurassic	Amorphous to bituminous	?5+	Past-peak for oil
7/21-04c	Unknown	Permo-Triassic or Jurassic/Cretaceous	Indeterminate	?Altered amorphous or herbaceous	6-7	Unknown
7/21-05b	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	?Woody	6	Possibly peak generation gas
7/21-05c	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Woody,?some bituminous material	?6	Unknown
7/21-05d	Unknown	Permo-Triassic or Jurassic/Cretaceous	Indeterminate	Altered woody-humic	6	Unknown
7/21-06a	Ogotoruk	Early Cretaceous	Indeterminate	Woody opaque only	5-6	Unknown
7/22-03a	Ogotoruk	Early Cretaceous	Indeterminate	Mixed,bituminous amorphous and woody	5	Possibly peak generation oil or condensate
7/22-04a	Ogotoruk	Early Cretaceous	Possibly Early Cretaceous	Woody-herbaceous,minor amorphous	5	Early peak generation for gas
7/22-05a	Ogotoruk	Early Cretaceous	Early Cretaceous (Neocomian)	Amorphous to bituminous,minor woody-herb.	5	Peak generation for oil
7/22-06a	Ogotoruk	Early Cretaceous	Indeterminate	Woody,minor amorphous	5	Early peak generation for gas
7/22-07a	Ogotoruk	Early Cretaceous	Possibly Early Cretaceous	Woody-humic,some soil contamination	5	Early peak generation for gas
7/22-11a	Iviagik	Ordovician/Silurian?	Indeterminate	Graphitic	7	None
7/23-01a	Shublik/Siksikpuk	Permo-Triassic	Possibly Triassic	Humic-sapropelic,some amorphous	5	Possibly peak generation oil
7/23-01b	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Woody-herbaceous	4	Early generation for gas

Palynology samples run by David Wall, April-July,1987

VALERIE KRASS OUTCROPS-WESTERN BROOKS RANGE 1986 FIELD PARTY

7/23-02a	Okpikruak	Early Cretaceous	Early Cretaceous	Mixed,herbaceous-woody and micritic amorphous	4-5	Peak for oil	Early generation for gas
7/23-03a	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Humic and some amorphous-bituminous	5	Possibly peak generation oil	
7/23-04a	Shublik/Siksikpuk	Permo-Triassic	Indeterminate	Amorphous-sapropelic	4-5	Peak generation for oil	Early generation for gas
7/23-05a	Ipewik	?Jurassic	Jurassic	Mixed, possibly amorphous with woody tissue	5-6	Peak for gas	
7/23-05c	Okpikruak	Early Cretaceous	Early Cretaceous	Woody	5	Early peak generation for gas	
7/23-06a	Okpikruak	Early Cretaceous	Indeterminate	Mixed,herbaceous and amorphous	5-6	?Early peak for condensate	
7/23-08a	Shublik/Siksikpuk	Permo-Triassic	Late Triassic	Mixed with 50 percent amorphous;oil globules	4	Early peak generation for oil	
7/23-09a	Shublik/Siksikpuk	Permo-Trias	Possibly Late Triassic (Shublik)	Mixed,woody-herbaceous plus minor amorphous	5-6	Peak generation for gas	
7/23-10a	Shublik/Siksikpuk	Permo-Triassic	Possibly Triassic, uncertain	Amorphous,similar to 7/23-08a	4	Early peak generation for oil	
7/23-11a	Opikruak	Early Cretaceous	Early Cretaceous	Woody-opaque	5	Early peak generation for gas	
7/23-12b	Ipewik?	Jurassic	Possibly Early Cretaceous/Late Jurassic	?Altered amorphous and herbaceous, mixed	5-6	Peak to past peak for oil	Early generation for gas
7/24-05a	Unknown	?Permo-Triassic	Indeterminate	Woody with minor amorphous-bituminous	5	Unknown,very sparse	
7/24-06a	Unknown	?Permo-Triassic	Indeterminate	Coaly to graphitic	6	Probably none	
7/24-09b	Unknown	Unknown	Mississippian	Herbaceous-woody	5	Early peak generation for gas	

ENCL. 29
NO-14-86R

EXLOG/BROWN & RUTH LABORATORIES, INC.
8985 EAST NICHOLS AVENUE, SUITE 300, ENGLEWOOD, COLORADO 80112

September 10, 1986

Amoco Production Company
1670 Broadway
P.O. Box 800
Denver, Colorado 80201

Attention: Ms. Valerie A. Krass

Dear Ms. Krass:

The total organic carbon (TOC) and Rock-Eval data enclosed were obtained on fifty-seven (57) outcrop samples recently supplied to our laboratory for routine source-rock screening analysis. Those samples with a TOC content of 0.5% or higher were pyrolyzed.

Low pyrolysis S2 yields irrespective of organic content, and elevated Tmax values suggest that many of the sediments are overmature. It is possible that those organic-lean samples which did not produce a measureable Tmax because of their negligible S2 yields contain very oxidized organic matter at various maturity levels.

A number of exceptions are present, however. Samples -047, -048, -051, -054, and -056 have some residual source-rock potential and are probably still within the oil window; the organic matter is these samples is gas-prone at present. Samples -029 and -038 are coals; the former appears to be very overmature although it has some remaining potential to generate gas, the latter has very high potential to generate gas and appears to be immature.

Please advise us should you require further analyses to be performed. We will hold the samples pending your instructions.

We appreciate the opportunity to be of service to Amoco Production Company. If you have any questions regarding these data, please contact us.

Very truly yours,

EXLOG/BROWN & RUTH LABORATORIES, INC.

Alan Daly

Alan Daly

AD/pmg

CVMS
92-00064319-030

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TABLE I

Results of Total Organic Carbon Analysis and Rock-Eval Pyrolysis

Sample Number	Depth (ft)	TOC (Wt.%)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	Production Index	Hydrogen Index	Oxygen Index
6165-001	7/17-01B	0.54	<0.10	<0.10	0.30	**	--	--	55
6165-002	7/17-02A	0.95	<0.10	<0.10	0.63	**	--	--	66
6165-003	7/17-02F	3.42	<0.10	<0.10	2.18	**	--	--	64
6165-004	7/17-02G	4.88	<0.10	<0.10	1.24	**	--	--	25
6165-005	7/17-02J	1.07	<0.10	<0.10	0.20	**	--	--	20
6165-006	7/17-02L	1.06	<0.10	<0.10	0.55	**	--	--	52
6165-007	7/17-02M	1.06	<0.10	<0.10	0.45	**	--	--	43
6165-008	7/17-03A	0.20/ 0.21							
6165-009	7/17-05A	1.04	<0.10	<0.10	0.29	**	--	--	27
6165-010	7/17-06A	0.92	<0.10	<0.10	0.18	**	--	--	20
6165-011	7/18-01B	0.29	--	--	--	--	--	--	--
6165-012	7/18-01C	0.25	--	--	--	--	--	--	--
6165-013	7/18-01D	1.70	<0.10	<0.10	0.29	**	--	--	17
6165-014	7/18-02B	1.09	<0.10	<0.10	0.26	**	--	--	24
6165-015	7/18-04B	1.13	<0.10	<0.10	0.11	**	--	--	10
6165-016	7/18-05A	0.71	<0.10	<0.10	0.12	**	--	--	17
6165-017	7/18-06B	0.81	<0.10	<0.10	0.38	**	--	--	48
6165-018	7/18-07A	0.75	<0.10	<0.10	0.15	**	--	--	20
6165-019	7/18-08B	0.87	<0.10	<0.10	0.17	**	--	--	20
6165-020	7/18-09A	0.93	<0.10	<0.10	0.09	**	--	--	10
6165-021	7/18-12B	0.84	<0.10	0.41	0.41	**	--	--	49
6165-022	7/18-15A	0.78	<0.10	<0.10	0.29	**	--	--	37
6165-023	7/19-01B	4.51	<0.10	<0.10	0.65	**	--	--	14
6165-024	7/19-01C	3.96	<0.10	<0.10	0.45	**	--	--	11
6165-025	7/19-01D	1.43	<0.10	<0.10	0.29	**	--	--	21
6165-026	7/19-02A	3.10	<0.10	0.14	0.70	363	--	4	23
6165-027	7/19-02B	3.78	<0.10	<0.10	0.68	**	--	--	18
6165-028	7/19-02C	2.27	<0.10	<0.10	0.56	**	--	--	25
6165-029	7/19-02H	77.79	0.38	22.53	4.48	523	--	29	6
6165-030	7/19-08A	1.39	<0.10	0.31	0.97	492	--	23	69
6165-031	7/19-11A	1.21	<0.10	<0.10	0.25	**	--	--	21
6165-032	7/20-01E	1.65	<0.10	0.25	0.25	493	--	15	15
6165-033	7/20-02B	0.92	<0.10	<0.10	0.27	**	--	--	30
6165-034	7/20-03A	0.29	--	--	--	--	--	--	--
6165-035	7/20-06A	1.25	<0.10	0.14	0.69	495	--	11	55
6165-036	7/20-06C	6.61	<0.10	0.57	1.45	548	--	9	22
6165-037	7/20-07B	1.52	<0.10	0.43	1.53	446	--	28	101
6165-038	7/20-08A	71.22	1.78	136.54	1.83	422	0.01	192	3
6165-039	7/21-03B	0.79	<0.10	0.19	1.10	476	--	24	140
6165-040	7/21-04A	2.65	0.19	0.16	0.97	541	0.54	6	37
6165-041	7/21-05D	2.39	<0.10	0.10	1.08	539	--	4	45
6165-042	7/21-06A	1.08	<0.10	<0.10	0.36	**	--	--	34
6165-043	7/22-03A	1.05	<0.10	0.12	0.46	362	--	11	43
6165-044	7/22-04A	1.51	<0.10	<0.10	0.62	**	--	--	41

TABLE I

Results of Total Organic Carbon Analysis and Rock-Eval Pyrolysis

Sample Number	Depth (ft)	TOC (Wt.%)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	Production Index	Hydrogen Index	Oxygen Index
6165-045	7/22-05A	1.48	<0.10	0.37	0.54	493	--	25	37
6165-046	7/22-07A	1.17	<0.10	0.13	0.37	500	--	11	31
6165-047	7/23-01A	2.25	0.57	2.58	0.40	447	0.18	115	18
6165-048	7/23-01B	2.60	0.54	4.05	0.19	443	0.12	156	7
6165-049	7/23-02A	1.28	<0.10	0.21	0.56	481	--	17	44
6165-050	7/23-04A	1.21	0.26	0.71	0.34	458	0.27	59	28
6165-051	7/23-05A	11.04	0.49	14.00	0.35	452	0.03	127	3
6165-052	7/23-06A	--	--	--	--	--	--	--	--
6165-053	7/23-06A	1.42	0.10	<0.10	0.23	**	--	--	16
6165-054	7/23-09A	5.19	0.19	3.07	0.35	438	0.06	59	7
6165-055	7/23-10A	1.37	<0.10	0.43	0.33	467	--	31	24
6165-056	7/23-12B	4.01	0.30	2.82	0.15	451	0.13	70	4
6165-057	7/24-09B	1.34	<0.10	0.14	0.33	510	--	10	25

ENCL. 30
NO-14-86R

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AMOCO PRODUCTION COMPANY
RESEARCH CENTER

SOURCE ROCK EVALUATION

Mississippian to Cretaceous Age Outcrops, Northwestern Alaska

Geochemistry Services Group

R. J. Harwood

Technical Service 865233CR
Requested by V. A. Krass
DENVER NORTHERN

Larry M Ross
2-June 1987

Distribution: M. R. Short, Denver
K. F. Arleth, Denver
H. A. Baker, Denver
V. A. Krass, Denver
P. K. H. Groth, Denver

Ipewik J-K
Ipewik J
Nanushuk coal UK
Endicott coal Miss
Etivluk sh - 4 PR.

30.

Subject: Mississippian to Cretaceous Age Outcrops, Northwestern Alaska (Figure 1)

INTRODUCTION

Eight outcrops from northwestern Alaska were submitted to help determine the potential for oil in this area. The samples are reported by Denver to be from the Cretaceous Nanushuk, Jurassic-Cretaceous Ipewik, Permian-Triassic Etivluk, and lower Mississippian Endicott. These beds were deposited prior to the great outwash of sediments from the Brooks Range (telecon with Valerie Krass).

All of these samples received initial total organic carbon and Rock-Eval pyrolysis screening by both Brown and Ruth Laboratories and Amoco. Because of some discrepancies between Amoco and Brown and Ruth data from these analyses, Amoco repeated the screening analyses in addition to performing the comprehensive source rock analyses.

CONCLUSIONS

(1) The Cretaceous Nanushuk coal is an excellent, but immature source for gas and condensate, and is in the early stage of gas generation.

(2) The Jurassic-Cretaceous Ipewik samples are excellent sources for oil and are in the peak stage of oil generation.

(3) The Permian-Triassic Etivluk samples range from nonsource to excellent in rating, contain gas and oil type kerogens, and range from peak oil to peak gas stages of generation.

(4) The lower Mississippian Endicott coal is rated excellent and is in the late peak stage of gas generation; this sample is too mature to determine the original kerogen type.

(5) The results from this outcrop study suggest that Permian to Cretaceous beds in this area are at favorable levels of maturity for petroleum generation and expulsion

(6) Variations among the Amoco and Brown and Ruth screening data probably are caused by sample inhomogeneity.

RECOMMENDATION

More outcrop samples from this area should be collected and analyzed to adequately evaluate the petroleum potential of the area.

SOURCE ROCK EVALUATION

Cretaceous Nanushuk

The one coal sample from this formation is rated as an excellent source for gas condensate, but is thermally immature and in the early stage of gas generation. The excellent rating is based on the 79.3% total organic carbon content and the 165,710 ppm generated hydrocarbons on Rock-Eval pyrolysis (Tables 1 and 2). A gas-condensate type of the kerogen is interpreted from the 0.75 H/C ratio on elemental analysis, and the FTIR (infrared) versus elemental analysis ratio plots (Table 5, Figure 3, Enclosure 2). The moderately high convertibility on pyrolysis (0.21), which often occurs with coals, usually does not correspond with a high hydrogen content or oil generating ability. Variations in composition of this and other samples on TOC and Rock-Eval analyses by Amoco and by Brown and Ruth are attributed to sample inhomogeneity. The early stage of gas generation is interpreted from the 0.60% vitrinite reflectance value, 423 ^{0}C Tmax from pyrolysis, and poorly developed normal paraffin peaks on the bitumen chromatogram (Tables 2 and 5, Figure 2, Enclosure 1).

Jurassic-Cretceous Ipewik

The two samples from this formation are rated as excellent oil sources in the peak oil stage of generation. Excellent ratings are based on the 4.9% and 3.5% TOC contents; even though the amounts of generated hydrocarbons on pyrolysis cannot be used for this rating because hydrocarbon generation is partially completed, the pyrolysis response is supportive of a rich source sequence. An oil generating type for this kerogen is interpreted from the position of data on the FTIR versus elemental analysis ratio plots. A peak stage of oil generation is based on the 0.93% and 0.88% vitrinite reflectance values and the mature and oil-like development of normal paraffin peaks on the bitumen chromatograms. These bitumen chromatograms have a general similarity to whole oil chromatograms for North Slope oils, but a detailed gas chromatography-mass spectrometry (GC-MS) study would be required to establish a correlation.

Permian-Triassic Etivluk

These samples range from nonsource to excellent in rating, have both gas and oil type kerogens, and range from peak oil to peak gas stages of generation. Much variation was noted on reanalysis of these samples. The two samples from the 1B location are rated respectively as excellent and marginal on the basis of the 2.0% and 0.5% TOC values; however, analysis of the second sample by Brown and Ruth found 2.6% TOC. The sample from the 9A location is rated as good from the 1.2% TOC value, but Brown and Ruth found 5.2% TOC. The single sample from the 4A location is rated as nonsource from the 0.4% TOC, but reanalysis by Amoco found 1.1% TOC and analysis by Brown and Ruth found 1.2% TOC.

Both oil and gas type kerogens are noted among these samples. The first sample from the 1B location appears to contain oil type kerogen on the basis of the FTIR-elemental analysis plots; the second sample from this location was not evaluated because of low TOC on Amoco's analysis. The sample from the 9A location appears to contain gas type kerogen on the basis of FTIR-elemental analysis data. The sample from the 4A location did not receive FTIR analysis because of the low TOC on initial analysis. However, 0.03 convertibility on Amoco's Rock-Eval and 0.06 on the Brown and Ruth Rock-Eval suggest gas type kerogen.

Thermal maturities of these samples range from peak oil to peak gas stages of generation. A peak stage of oil generation for the first sample from the 1B location is interpreted from the 0.81 vitrinite reflectance, 455 ^{0}C Tmax on Rock-Eval, and well developed normal paraffin peaks on the bitumen chromatogram. A peak stage of gas generation for the sample from the 9A location is based on the 1.67% vitrinite reflectance and lesser amounts of C_{26} to C_{30} normal paraffins on the bitumen chromatogram possibly because of thermal cracking. The sample from the 4A location may be in the early peak stage of gas generation based on the 458 ^{0}C Tmax from the Brown and Ruth analysis.

Lower Mississippian Endicott

This coal sample has an excellent rating and is in the late stage of gas generation. The excellent rating is based on the 52.2% TOC. Because of high maturity the kerogen type could not be determined with Rock-Eval pyrolysis, elemental analysis, or FTIR analysis, but often Mississippian coals are gas and condensate generating. A late peak stage of gas generation is interpreted from the 1.90% vitrinite reflectance value, 0.48 H/C ratio on elemental analysis, and 530 ^{0}C Tmax.

Exploration Significance

These results have shown the presence of excellent rated sources with oil type kerogens in the peak stage of oil generation at the surface in the Etivluk and Ipewik; higher levels of maturity can be expected in the subsurface. The data suggest a favorable petroleum potential of this area, but more samples are needed to obtain a statistically valid estimation of the source rock capabilities. These results suggest that younger Cretaceous beds are thermally immature at least at the surface, and older Paleozoic bads are over-mature in this area.

Chromatograms of some of the bitumens resemble those for some North Slope oils. However, experience has shown that the GC-MS comparisons are needed for correlation in the North Slope area. When more outcrop samples from this area have been analyzed and the source rock relationships have been more fully defined, a GC-MS comparison with North Slope oils may be warranted.

Robert J. Harwood by cmR
R. J. Harwood

RJH

AMOCO PRODUCTION COMPANY
RESEARCH CENTER

OFFICE DENVER DISTRICT NORTHERN
AUTHORIZED BY V. KRASS
TECHNICAL SERVICE NUMBER 865233

SOURCE ROCK SUMMARY
TABLE 1.
DATE 05/28/87

SAMPLE NUMBER	SMPL TYPE	FORMATION	AGE	LITHOLOGY	FIELD NO. OR DEPTH FEET TOP***BOTTOM	PETROLEUM GENERATION CAPABILITY	TYPE	STAGE
STATE ALASKA OPERATOR			COUNTY POINT HOPE	LEASE	SAMP. 7-20-08A	WELL LOCATION	SEC: 36 T: 6S R: 56W	
R-4278	OT	NANUSHUK	CRETACEOUS	COAL		EXCELLENT	GAS-COND.	EARLY GAS
R-4278A	OT	NANUSHUK	CRETACEOUS	COAL		EXCELLENT	GAS-COND.	EARLY GAS
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE	SAMP. 7-23-01A/7-23-01B	WELL LOCATION	SEC: 20 T: 33N R: 23W	
R-4279	OT	ETIVLUK	PERM-TRIA	SH		EXCELLENT	OIL	PEAK OIL
R-4279A	OT	ETIVLUK	PERM-TRIA	SH		EXCELLENT	OIL	PEAK OIL
R-4280	OT	ETIVLUK	PERM-TRIA	SH		MARGINAL	NOT KNOWN	NOT KNOWN
R-4280A	OT	ETIVLUK	PERM-TRIA	SH		MARGINAL	NOT KNOWN	NOT KNOWN
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE	SAMP. 7-23-05A	WELL LOCATION	SEC: 6 T: 33N R: 22W	
R-4282	OT	IPEWIK	JUR-CRET	SH		EXCELLENT	OIL	PEAK OIL
R-4282B	OT	IPEWIK	JUR-CRET	SH		EXCELLENT	OIL	PEAK OIL
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE	SAMP. 7-23-09A	WELL LOCATION	SEC: 3 T: 12S R: 49W	
R-4283	OT	ETIVLUK	PERM-TRIA	SH		GOOD	GAS	PEAK GAS
R-4283B	OT	ETIVLUK	PERM-TRIA	SH		GOOD	GAS	PEAK GAS
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE	SAMP. 7-23-12B	WELL LOCATION	SEC: 16 T: 12S R: 50W	
R-4284	OT	IPEWIK	JUR-CRET	SH		EXCELLENT	OIL	PEAK OIL
R-4284B	OT	IPEWIK	JUR-CRET	SH		EXCELLENT	OIL	PEAK OIL
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE	SAMP.7-23-04A	WELL LOCATION	SEC: 1 T: 33N R: 23W	
R-4285	OT	ETIVLUK	PERM-TRIA	SH		NON SOURCE		
R-4285B	OT	ETIVLUK	PERM-TRIA	SH		GOOD	GAS?	EARLY PEAK GAS?
STATE ALASKA OPERATOR			COUNTY POINT HOPE	LEASE	SAMP. 7-19-02H	WELL LOCATION	SEC: 28 T: 9S R: 61W	
R-4286	OT	ENDICOTT	L MISS	COAL		EXCELLENT	GAS?	LATE GAS
R-4286A	OT	ENDICOTT	L MISS	COAL		EXCELLENT	GAS?	LATE GAS

[redacted]

AMOCO PRODUCTION COMPANY
RESEARCH CENTER

OFFICE DENVER DISTRICT NORTHERN
TECHNICAL SERVICE NUMBER 865233

ROCKEVAL PYROLYSIS DATA
TABLE 2A.
DATE 05/28/87

SAMPLE NUMBER	TOP OF INTERVAL FEET	FORMATION	TOTAL ORGANIC CARBON WT% ROCKEVAL TOC	PPM VOLATILE HYDROCARBONS (S1 X 1000)	VOL/ TOC	PPM GENERATED HYDROCARBONS (S2 X 1000)	GEN/ TOC	TEMP OF MAX GEN	VOL/ VOL + GEN	WEATHERING CHARACTERISTICS
STATE ALASKA OPERATOR			COUNTY POINT HOPE	LEASE SAMP. 7-20-08A	WELL LOCATION		SEC: 36 T: 6S R: 56W			
R-4278		NANUSHUK	79.3	710	< 0.01	165710	0.21	423	< 0.01	BLOCKY
R-4278A		NANUSHUK	73.4	620	< 0.01	98120	0.13	427	0.01	
B&R*			71.2	1780	< 0.01	136540	0.19	422	0.01	
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE SAMP. 7-23-01A/7-23-01B	WELL LOCATION		SEC: 20 T: 33N R: 23W			
R-4279		ETIVLUK	2.0	650	0.03	2430	0.12	455	0.21	SLABBY
R-4279A		ETIVLUK	2.3	570	0.02	2360	0.10	456	0.19	
B&R*			2.3	570	0.02	2580	0.12	447	0.18	
R-4280		ETIVLUK	0.5	190	0.04	260	0.05	NR	0.42	BLOCKY
R-4280A		ETIVLUK	0.7	220	0.03	440	0.06	NR	0.33	
B&R*			2.6	540	0.02	4050	0.16	443	0.12	
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE SAMP. 7-23-05A	WELL LOCATION		SEC: 6 T: 33N R: 22W			
R-4282		IPEWIK	4.9	200	< 0.01	4660	0.10	458	0.04	SLABBY
R-4282B		IPEWIK	8.2	390	< 0.01	6660	0.08	479	0.06	
B&R*			11.0	490	< 0.01	14000	0.13	452	0.03	
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE SAMP. 7-23-09A	WELL LOCATION		SEC: 3 T: 12S R: 49W			
R-4283		ETIVLUK	1.2	60	< 0.01	110	0.01	NR	0.35	SLABBY
R-4283B		ETIVLUK	1.4	110	0.01	< 10	< 0.01	NR	1.00	
B&R*			5.2	190	< 0.01	3070	0.06	438	0.06	

* BROWN AND RUTH SCREENING DATA

NR indicates "not reliable"

[redacted]

AMOCO PRODUCTION COMPANY
RESEARCH CENTER

OFFICE DENVER DISTRICT NORTHERN
TECHNICAL SERVICE NUMBER 865233

ROCKEVAL PYROLYSIS DATA
TABLE 2B.
DATE 05/28/87

SAMPLE NUMBER	TOP OF INTERVAL FEET	FORMATION	TOTAL ORGANIC CARBON WT% ROCKEVAL TOC	PPM VOLATILE HYDROCARBONS (S1 X 1000)	VOL/ TOC	PPM GENERATED HYDROCARBONS (S2 X 1000)	GEN/ TOC	TEMP OF MAX GEN	VOL/ VOL + GEN	WEATHERING CHARACTERISTICS
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE SAMP. 7-23-12B		WELL LOCATION		SEC: 16 T: 12S R: 50W		
R-4284		IPEWIK	3.5	140	< 0.01	2240	0.06	447	0.06	SLABBY
R-4284B		IPEWIK	3.3	220	0.01	1790	0.05	477	0.11	
B&R*			4.0	300	< 0.01	2820	0.07	451	0.13	
STATE ALASKA OPERATOR			COUNTY DE LONG MTS	LEASE SAMP.7-23-04A		WELL LOCATION		SEC: 1 T: 33N R: 23W		
R-4285		ETIVLUK	0.4	60	0.01	70	0.02	NR	0.46	BLOCKY
R-4285B		ETIVLUK	1.1	230	0.02	350	0.03	NR	0.40	
B&R*			1.2	260	0.02	710	0.06	458	0.27	
STATE ALASKA OPERATOR			COUNTY POINT HOPE	LEASE SAMP. 7-19-02H		WELL LOCATION		SEC: 28 T: 9S R: 61W		
R-4286		ENDICOTT	52.2	< 10	< 0.01	10180	0.02	530	< 0.01	BLOCKY
R-4286A		ENDICOTT	84.4	340	< 0.01	5680	0.01	495	0.06	
B&R*			77.8	380	< 0.01	22530	0.03	523	0.02	

* BROWN AND RUTH SCREENING DATA

NR indicates "not reliable"

A M O C O P R O D U C T I O N C O M P A N Y
R E S E A R C H C E N T E R

OFFICE DENVER DISTRICT NORTHERN
TECHNICAL SERVICE NUMBER 865233

SOURCE ROCK DATA
TABLE 3.
DATE 05/28/87

SAMPLE NUMBER	FIELD NO. OR DEPTH FEET TOP***BOTTOM	FORMATION	TOTAL ORG C WT%	BITUMEN BBL/AF	BITUMEN PPM	SAT HC BBL/AF	SAT HC PPM	SAT HC/ BITUMEN	BIT/ TOC	NC17/ PR	NC18/ PH	CPI BITUMEN	PR/ PH
STATE ALASKA COUNTY POINT HOPE WELL LOCATION SEC: 36 T: 6S R: 56W OPERATOR LEASE SAMP. 7-20-08A													
R-4278		NANUSHUK	79.3	116	6436				0.01	0.40	3.85	2.12	10.46?
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 20 T: 33N R: 23W OPERATOR LEASE SAMP. 7-23-01A/7-23-01B													
R-4279		ETIVLUK	2.0	33	1838				0.09	3.78	4.42	1.04	1.29
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 6 T: 33N R: 22W OPERATOR LEASE SAMP. 7-23-05A													
R-4282		IPEWIK	4.9	17	922				0.02	3.43	4.82	1.08	1.76
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 3 T: 12S R: 49W OPERATOR LEASE SAMP. 7-23-09A													
R-4283		ETIVLUK	1.2	1	72				0.01	2.53	3.35	1.04	1.59
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 16 T: 12S R: 50W OPERATOR LEASE SAMP. 7-23-12B													
R-4284		IPEWIK	3.5	5	278				0.01	3.87	5.87	1.03	1.77
STATE ALASKA COUNTY POINT HOPE WELL LOCATION SEC: 28 T: 9S R: 61W OPERATOR LEASE SAMP. 7-19-02H													
R-4286		ENDICOTT	52.2	22	1235				< 0.01				

AMOCO PRODUCTION COMPANY
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OFFICE DENVER DISTRICT NORTHERN
TECHNICAL SERVICE NUMBER 865233

VISUAL AND VITRINITE REFLECTANCE
TABLE 4.
DATE 05/28/87

SAMPLE NUMBER	FIELD NO. OR DEPTH FEET TOP***BOTTOM	FORMATION	VIT REFLECTANCE %RO	VIT REFLECTANCE COUNTS	VISUAL SCALE	KEROGEN DESCRIPTION	DENVER % VIT. REFL.
STATE ALASKA COUNTY POINT HOPE WELL LOCATION SEC: 36 T: 6S R: 56W; OPERATOR LEASE SAMP. 7-20-08A							
R-4278		NANUSHUK	0.60	30		STRUCTURED	
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 20 T: 33N R: 23W; OPERATOR LEASE SAMP. 7-23-01A/7-23-01B							
R-4279		ETIVLUK	0.81	50		AMORPHOUS	
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 6 T: 33N R: 22W; OPERATOR LEASE SAMP. 7-23-05A							
R-4282		IPEWIK	0.93	50		STRUCTURED	1.30
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 3 T: 12S R: 49W; OPERATOR LEASE SAMP. 7-23-09A							
R-4283		ETIVLUK	1.67	50		MIXED	1.61
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 16 T: 12S R: 50W; OPERATOR LEASE SAMP. 7-23-12B							
R-4284		IPEWIK	0.88	50		STRUCTURED	1.00
STATE ALASKA COUNTY POINT HOPE WELL LOCATION SEC: 28 T: 9S R: 61W; OPERATOR LEASE SAMP. 7-19-02H							
R-4286		ENDICOTT	1.90	50		STRUCTURED	

AMOCO PRODUCTION COMPANY
RESEARCH CENTER

OFFICE DENVER DISTRICT NORTHERN
TECHNICAL SERVICE NUMBER 865233

KEROGEN DATA
TABLE 5.
DATE 05/28/87

LAB SAMPLE NUMBER	FIELD NO. OR DEPTH FEET TOP***BOTTOM	FORMATION	NORM. ELEMENTAL ANALYSIS, WT. % CARBON	HYDROGEN	OXYGEN	NITROGEN	% REC	SULFUR WT. %	ASH WT. %	ATOMIC RATIO O/C	ATOMIC RATIO H/C	CARBON ISOTOPE KEROGEN
STATE ALASKA COUNTY POINT HOPE WELL LOCATION SEC: 36 T: 6S R: 56W OPERATOR LEASE SAMP. 7-20-08A												
R-4278		NANUSHUK	81	5.1	12.8	1.6	86			0.12	0.75	
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 20 T: 33N R: 23W OPERATOR LEASE SAMP. 7-23-01A/7-23-01B												
R-4279		ETIVLUK	87	5.1	5.2	2.4	81			0.04	0.70	
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 6 T: 33N R: 22W OPERATOR LEASE SAMP. 7-23-05A												
R-4282		IPEWIK	88	4.9	4.7	2.0	95			0.04	0.66	
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 3 T: 12S R: 49W OPERATOR LEASE SAMP. 7-23-09A												
R-4283		ETIVLUK	80	4.1*	14.4	1.8	76			0.14	0.61	
STATE ALASKA COUNTY DE LONG MTS WELL LOCATION SEC: 16 T: 12S R: 50W OPERATOR LEASE SAMP. 7-23-12B												
R-4284		IPEWIK	86	4.9	6.6	2.7	92			0.06	0.67	
STATE ALASKA COUNTY POINT HOPE WELL LOCATION SEC: 28 T: 9S R: 61W OPERATOR LEASE SAMP. 7-19-02H												
R-4286		ENDICOTT	90	3.6	5.1	1.3	90			0.04	0.48	

* MAY BE SOMEWHAT HIGH BECAUSE OF SOME RALSTONITE IN THE KEROGEN

[redacted]

AMOCO PRODUCTION COMPANY
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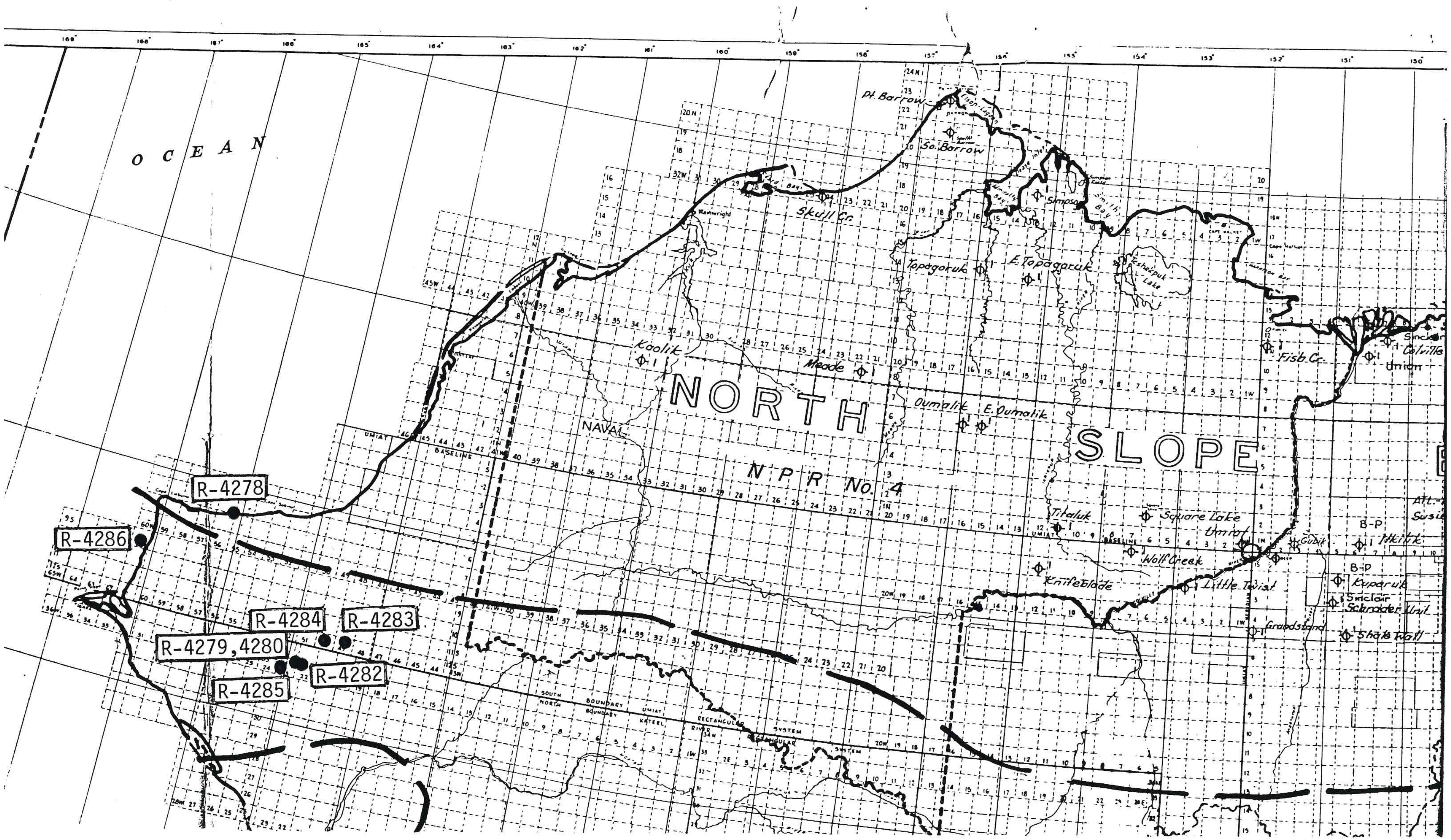
OFFICE DENVER DISTRICT NORTHERN
TECHNICAL SERVICE NUMBER 865233

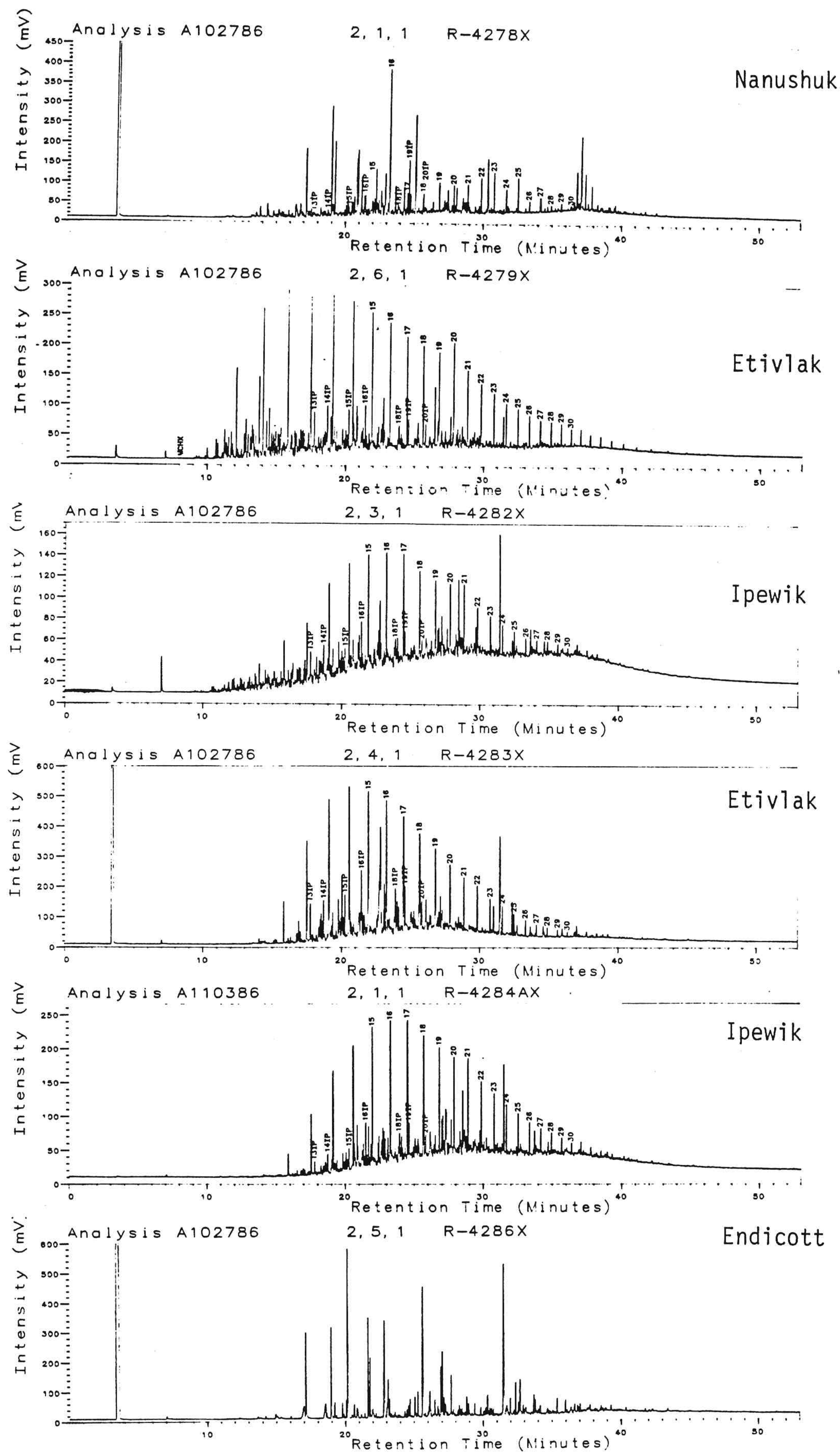
ROCK-TO-OIL CORRELATION
TABLE 6.
DATE 05/28/87

SAMPLE NUMBER	FIELD NO. OR DEPTH FEET TOP***BOTTOM	FORMATION	CARBON ISOTOPES OF EXTRACT SAT	AROM	BIT	OPT ROT	IR	PR/PH	SULFUR WT. %
STATE ALASKA OPERATOR		COUNTY POINT HOPE LEASE SAMP. 7-20-08A				WELL LOCATION	SEC: 36 T: 6S R: 56W		
R-4278		NANUSHUK						10.46	
STATE ALASKA OPERATOR		COUNTY DE LONG MTS LEASE SAMP. 7-23-01A/7-23-01B				WELL LOCATION	SEC: 20 T: 33N R: 23W		
R-4279		ETIVLUK						1.29	
STATE ALASKA OPERATOR		COUNTY DE LONG MTS LEASE SAMP. 7-23-05A				WELL LOCATION	SEC: 6 T: 33N R: 22W		
R-4282		IPEWIK						1.76	
STATE ALASKA OPERATOR		COUNTY DE LONG MTS LEASE SAMP. 7-23-09A				WELL LOCATION	SEC: 3 T: 12S R: 49W		
R-4283		ETIVLUK						1.59	
STATE ALASKA OPERATOR		COUNTY DE LONG MTS LEASE SAMP. 7-23-12B				WELL LOCATION	SEC: 16 T: 12S R: 50W		
R-4284		IPEWIK						1.77	
STATE ALASKA OPERATOR		COUNTY POINT HOPE LEASE SAMP. 7-19-02H				WELL LOCATION	SEC: 28 T: 9S R: 61W		
R-4286		ENDICOTT						4.69	



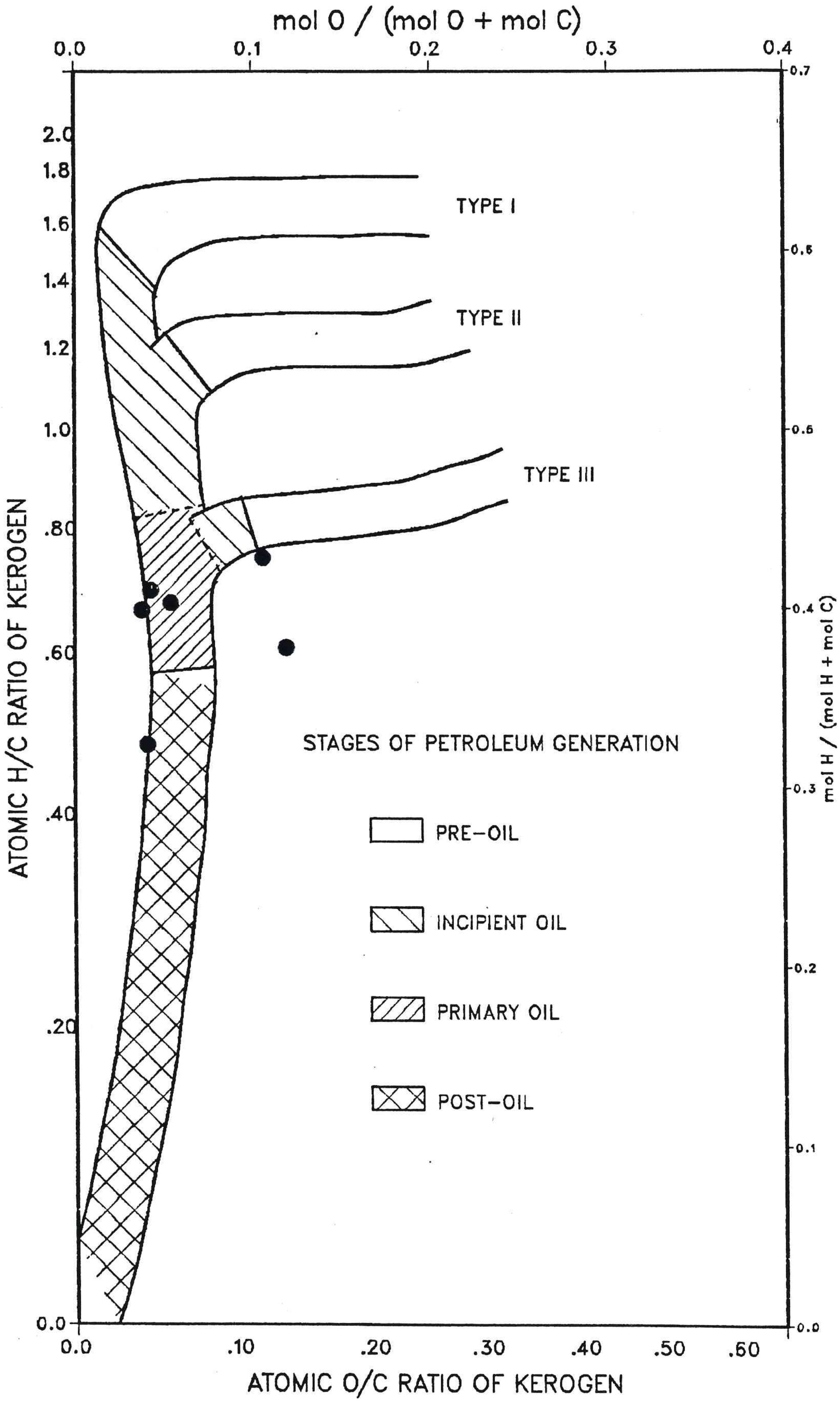
TS 865233
Figure 1

[redacted] Confidence
[redacted]



Bitumen Chromatograms

TS 865233
Figure 2



TS 865233

FIGURE 3

[redacted]

OF 12/3/86
WW

December 3, 1986

Amoco Production Company
Research Center
Tulsa, Oklahoma

3 Dec
Larry M. Ross

Attn: Mr. Larry Ross

Requisition No. 86GL0065
T. S. No. 865233
Samples R-4278, R-4279, R-4282,
R-4283, R-4284 and R-4286

Attached find the Visual analyses and the Vitrinite Reflectance analyses of the 6 samples on which this service was requested. It is my understanding that these are outcrop samples from different localities in Alaska.

Summary

R-4278 is a coal with excellent vitrinite. The distinct vitrinite population has a mean of 0.60% Ro and is interpreted as gas source kerogen in the early gas generation stage.

R-4279 contains an abundance of amorphous kerogen which should be good source material for oil generation. The reflectivity analysis gives a population mean of 0.81% Ro indicating that it is in the peak stage of liquid generation.

R-4282 is composed primarily of structured kerogen which is considered to be gas source. The mean of the vitrinite population is 0.93% Ro indicating that it is in the early peak stage for gas generation.

R-4283 contains a mixture of structured and amorphous kerogen. The vitrinite population mean of 1.67% Ro indicates that the kerogen is at a relatively advanced degree of diagenesis. The kerogen is near the end of the peak gas generation stage and is past the generating stage for liquids.

R-4284 contains primarily structured kerogen but it has an amorphous component. With a vitrinite population mean of 0.88% Ro, the kerogen is primarily gas source in the early generation stage. The amorphous component is oil source in the peak generation stage.

R-4286 is a coal with excellent vitrinite. The distinct vitrinite population has a mean of 1.90% Ro and is interpreted as gas source kerogen near the end of the gas generation stage.

All of the slides sent to me with this service request are being returned with this report.

John F. Grayson
John F. Grayson

TS 865233
Enclosure 1

[redacted]

. S. No. 865233 Sample No. R-4278

ORGANIC PETROLOGY ANALYSIS

VISUAL ANALYSIS OF KEROGEN: STRUCTURED. Size range, from fine debris to large particles; mostly larger particles, black; relatively little fine debris; smaller particles, brown. No cells or tissues observed from which a judgement of diagenetic level can be made.

VITRINITE RELECTANCE ANALYSIS: There were 30 reflectivity measurements made on this sample. The measurements, in increasing magnitude, are the following: 0.50, 0.50, 0.54, 0.55, 0.56, 0.57, 0.57, 0.58, 0.58, 0.58, 0.59, 0.59, 0.59, 0.60, 0.61, 0.61, 0.62, 0.62, 0.62, 0.63, 0.63, 0.63, 0.64, 0.64, 0.67, 0.72, 0.77, 1.01, 1.60, 1.73

HISTOGRAM OF V. R. DATA:

```
                     X
      20-|           X
      19-|           X
      18-|           X
      17-|           X
      16-|           X
      15-|           X
      14-|           X
      13-|           X
      12-|           X
      11-|           X
      10-|           X
       9-|           X
       8-|           X
       7-|           X
       6-|           X
       5-|           X
       4-|           X
       3-|         X X
       2-|         X X X
       1-|         X X X X   X           X X
           . . . . | . . . . | . . . . | . . . . | . . . . | . . . . |
                  .5        1.0       1.5       2.0       2.5       3.0
```

The primary population is interpreted between 0.50 and 0.77 with a mean of 0.60% Ro. This indicates that the kerogen is diagenetically at an equivalent stage to high volatile bituminous coals and is in the early gas generating stage.

Amoco Production Company - Research Center - Req. No. 86GL0065
John F. Grayson Report, December 3, 1986

ı. S. No. 865233 Sample No. R-4279

ORGANIC PETROLOGY ANALYSIS

VISUAL ANALYSIS OF KEROGEN: AMORPHOUS. Mostly fine amorphous debris (Type C) but with a substantial component of clustered amorphous kerogen (Type A); light brown to dark brown. Structured component, about 25%, various sized particles, mostly black. Interpreted to be good liquid source kerogen in the peak generation stage.

VITRINITE RELECTANCE ANALYSIS: There were 50 reflectivity measurements made on this sample. The measurements, in increasing magnitude, are the following: 0.49, 0.51, 0.51, 0.54, 0.56, 0.62, 0.66, 0.66, 0.67, 0.71, 0.74, 0.76, 0.77, 0.78, 0.78, 0.79, 0.80, 0.81, 0.81, 0.83, 0.85, 0.86, 0.86, 0.88, 0.88, 0.89, 0.90, 0.90, 0.91, 0.91, 0.96, 0.96, 0.96, 0.98, 0.99, 1.01, 1.01, 1.02, 1.04, 1.32, 1.39, 1.41, 1.48, 1.48, 1.51, 1.52, 1.53, 1.65, 1.68, 2.30

HISTOGRAM OF V. R. DATA:

```
20-|
19-|
18-|
17-|
16-|
15-|
14-|
13-|
12-|
11-|
10-|                 X
 9-|               X X X
 8-|               X X X
 7-|               X X X
 6-|               X X X
 5-|             X X X X         X
 4-|         X   X X X X         X
 3-|         X   X X X X         X
 2-|         X X X X X X       X X   X
 1-|         X X X X X X     X X X   X           X
     ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' |
            .5        1.0       1.5       2.0       2.5       3.0
```

The primary population is interpreted between 0.49 and 1.04 with a mean of 0.81% Ro. This indicates that the kerogen is diagenetically at an equivalent stage to high volatile bituminous coals and is in the peak generation stage for liquids.

Amoco Production Company - Research Center - Req. No. 86GL0065
John F. Grayson Report, December 3, 1986

[redacted]

I. S. No. 865233 Sample No. R-4282

ORGANIC PETROLOGY ANALYSIS

VISUAL ANALYSIS OF KEROGEN: STRUCTURED. Size range, from fine debris to large particles; larger particles, black; smaller particles and fine debris, dark brown. A substantial amount of fine debris, much of which appears to be fine , broken fragments of structured particles. Some of the fine debris, however, may be fine amorphous material (Type C).

VITRINITE RELECTANCE ANALYSIS: There were 50 reflectivity measurements made on this sample. The measurements, in increasing magnitude, are the following: 0.67, 0.69, 0.70, 0.73, 0.74, 0.75, 0.77, 0.77, 0.78, 0.78, 0.79, 0.80, 0.80, 0.83, 0.83, 0.84, 0.85, 0.85, 0.86, 0.87, 0.89, 0.91, 0.91, 0.92, 0.92, 0.93, 0.94, 0.96, 0.96, 0.97, 0.97, 0.98, 0.98, 1.02, 1.02, 1.03, 1.04, 1.07, 1.09, 1.10, 1.12, 1.17, 1.18, 1.19, 1.19, 1.20, 1.22, 1.22, 1.55, 1.82

HISTOGRAM OF V. R. DATA:

```
20-|
19-|
18-|
17-|
16-|
15-|
14-|
13-|
12-|
11-|               X X
10-|               X X X
 9-|               X X X
 8-|               X X X
 7-|               X X X   X
 6-|               X X X   X
 5-|             X X X X   X
 4-|             X X X X X X
 3-|             X X X X X X
 2-|             X X X X X X
 1-|             X X X X X X       X   X
     ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' |
            .5        1.0       1.5       2.0       2.5       3.0
```

The primary population is interpreted between 0.67 and 1.22 with a mean of 0.93% Ro. This indicates that the kerogen is diagenetically at an equivalent stage to high volatile bituminous coals and is in the early peak gas generating stage.

Amoco Production Company - Research Center - Req. No. 86GL0065
John F. Grayson Report, December 3, 1986

[redacted]

I. S. No. 865233 Sample No. R-4283

ORGANIC PETROLOGY ANALYSIS

VISUAL ANALYSIS OF KEROGEN: MIXED. Structured particles, size range from medium to fine, mostly black, some brown. Majority of kerogen is fine debris; appears to be fine amorphous kerogen (Type C) with fine structured particles embedded. Dark color of the amorphous kerogen suggests that it is at an advanced degree of diagenesis.

VITRINITE RELECTANCE ANALYSIS: There were 50 reflectivity measurements made on this sample. The measurements, in increasing magnitude, are the following: 1.18, 1.20, 1.22, 1.23, 1.24, 1.26, 1.28, 1.33, 1.41, 1.43, 1.44, 1.47, 1.48, 1.49, 1.50, 1.58, 1.59, 1.62, 1.64, 1.68, 1.70, 1.70, 1.72, 1.76, 1.78, 1.79, 1.81, 1.81, 1.82, 1.83, 1.86, 1.88, 1.89, 1.90, 1.92, 1.93, 1.97, 2.00, 2.04, 2.04, 2.08, 2.10, 2.10, 2.31, 2.36, 2.67, 2.74, 2.83, 2.84, 3.66

HISTOGRAM OF V. R. DATA:

```
20-¦
19-¦
18-¦
17-¦
16-¦
15-¦
14-¦
13-¦
12-¦
11-¦
10-¦
 9-¦
 8-¦
 7-¦                                   X
 6-¦                                   X X
 5-¦                       X           X X
 4-¦                       X     X X X X X X
 3-¦                       X X X X X X X X X X
 2-¦                       X X X X X X X X X X             X
 1-¦                       X X X X X X X X X X   X X     X X
     ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦
            .5        1.0       1.5       2.0       2.5       3.0
```

The primary population is interpreted between 1.18 and 2.10 with a mean of 1.67% Ro. This indicates that the kerogen is diagenetically at an equivalent stage to low volatile bituminous coals and is in the peak gas and past peak oil generating stage.

Amoco Production Company - Research Center - Req. No. 86GL0065
John F. Grayson Report, December 3, 1986

T. S. No. 865233 Sample No. R-4284

ORGANIC PETROLOGY ANALYSIS

VISUAL ANALYSIS OF KEROGEN: STRUCTURED. Size range, from fine debris to large particles; larger particles, black; smaller particles and fine debris, black and brown. An amorphous component is present; the fine debris appears to be a mixture of fine, broken fragments of structured particles embedded in a matrix of fine amorphous kerogen.

VITRINITE RELECTANCE ANALYSIS: There were 50 reflectivity measurements made on this sample. The measurements, in increasing magnitude, are the following: 0.60, 0.62, 0.62, 0.64, 0.65, 0.66, 0.68, 0.70, 0.73, 0.75, 0.76, 0.76, 0.77, 0.78, 0.80, 0.80, 0.82, 0.82, 0.83, 0.83, 0.85, 0.85, 0.86, 0.86, 0.89, 0.90, 0.90, 0.91, 0.91, 0.92, 0.92, 0.93, 0.93, 0.94, 0.96, 0.97, 0.99, 1.00, 1.03, 1.06, 1.09, 1.11, 1.16, 1.18, 1.18, 1.22, 1.23, 1.36, 1.61, 1.71

HISTOGRAM OF V. R. DATA:

```
        20-¦
        19-¦
        18-¦
        17-¦
        16-¦
        15-¦
        14-¦                 X
        13-¦                 X
        12-¦                 X
        11-¦               X X
        10-¦               X X
         9-¦               X X
         8-¦               X X
         7-¦               X X
         6-¦               X X
         5-¦             X X X X   X
         4-¦           X X X X X   X
         3-¦           X X X X X X X
         2-¦           X X X X X X X
         1-¦           X X X X X X X   X   X X
             . . . . ¦ . . . . ¦ . . . . ¦ . . . . ¦ . . . . ¦ . . . . ¦
                    .5        1.0       1.5       2.0       2.5       3.0
```

The primary population is interpreted between 0.60 and 1.23 with a mean of 0.88% Ro. This indicates that the kerogen is diagenetically at an equivalent stage to high volatile bituminous coals; it is in the early gas and peak oil generating stage.

Amoco Production Company - Research Center - Req. No. 86GL0065
John F. Grayson Report. December 3. 1986

[redacted]

I. D. No. 865233 Sample No. R-4286

ORGANIC PETROLOGY ANALYSIS

VISUAL ANALYSIS OF KEROGEN: STRUCTURED. Size range, from fine debris to large particles; larger particles, black; smaller particles, black and dark brown. No cells or tissues observed on which a judgement of diagenetic level can be made.

VITRINITE RELECTANCE ANALYSIS: There were 50 reflectivity measurements made on this sample. The measurements, in increasing magnitude, are the following: 1.46, 1.51, 1.53, 1.56, 1.58, 1.60, 1.61, 1.63, 1.67, 1.69, 1.70, 1.71, 1.72, 1.73, 1.76, 1.77, 1.78, 1.80, 1.81, 1.81, 1.82, 1.83, 1.83, 1.86, 1.88, 1.88, 1.92, 1.93, 1.93, 1.95, 1.96, 1.98, 2.02, 2.02, 2.06, 2.07, 2.08, 2.10, 2.10, 2.11, 2.14, 2.17, 2.19, 2.20, 2.24, 2.28, 2.30, 2.34, 2.34, 3.04

HISTOGRAM OF V. R. DATA:

```
        20-¦
        19-¦
        18-¦
        17-¦
        16-¦
        15-¦
        14-¦
        13-¦
        12-¦
        11-¦
        10-¦
         9-¦                                   X
         8-¦                                   X
         7-¦                                   X     X
         6-¦                                 X X X   X
         5-¦                               X X X X X X
         4-¦                               X X X X X X X X
         3-¦                             X X X X X X X X X
         2-¦                             X X X X X X X X X
         1-¦                             X X X X X X X X X             X
             ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦ ' ' ' ' ¦
                    .5        1.0       1.5       2.0       2.5       3.0
```

The primary population is interpreted between 1.46 and 2.34 with a mean of 1.90% Ro. This indicates that the kerogen is diagenetically at an equivalent stage to low volatile bituminous or semi-anthracite coals and is near the past peak gas generating stage.

Amoco Production Company - Research Center - Req. No. 86GL0065
John F. Grayson Report, December 3, 1986

[redacted]

AMOCO PRODUCTION COMPANY
Tulsa, Oklahoma
December 17, 1986

86351ART0079

TO: R. J. Harwood

SUBJECT: TS 865233 Alaska Outcrop Samples - FTIR

FTIR analysis was done on six outcrop samples from De Long Mountains and Point Hope Counties, Alaska to help establish kerogen type and maturity. Figure FTIR-1 is a plot of the Aromatic Fraction determined from FTIR data vs elemental O/C. This plot is effective for distinguishing Type II from Type III kerogens up to a vitrinite reflectance value of about 2.0. Figure FTIR-2 plots the Aliphatic Fraction from FTIR vs elemental H/C. This also can differentiate between Types II and III in some cases, and the H/C value is useful for determining oil generation stage.

Each sample is discussed separately below.

R-4278 is a Type III kerogen as shown on Figure FTIR-1. The H/C value indicates an incipient, pre-expulsion stage of generation. The Type III classification is consistent with the external service laboratory visual interpretation.

R-4279 plots in the Type II regions on Figures FTIR-1 and FTIR-2. Elemental data suggests a primary oil generation stage. The visual description by the external service laboratory as amorphous agrees with the FTIR designation of Type II.

R-4282 is a Type II kerogen according to the attached figures. This kerogen is slightly more mature than R-4279 and is in the primary oil generation stage. This interpretation is not consistent with the service laboratory visual description of primarily structured. Reexamination under both transmitted and reflected light showed that this kerogen is, in fact, mostly amorphous with a small amount of structured material present (M. D. Lewan, personal communication). This interpretation is more favorable for liquid generating capability.

R-4283 plots in the Type III region. This kerogen contains some Ralstonite contamination which will increase the measured oxygen content yielding an O/C value that is too high. Thus, the point on Figure FTIR-1 should be moved to the left. There is insufficient contamination to move the point into the Type II region, however. Hence, a Type III designation stands. Also, the H/C values should be good, leading to the conclusion that the sample is near the end of the primary generation stage.

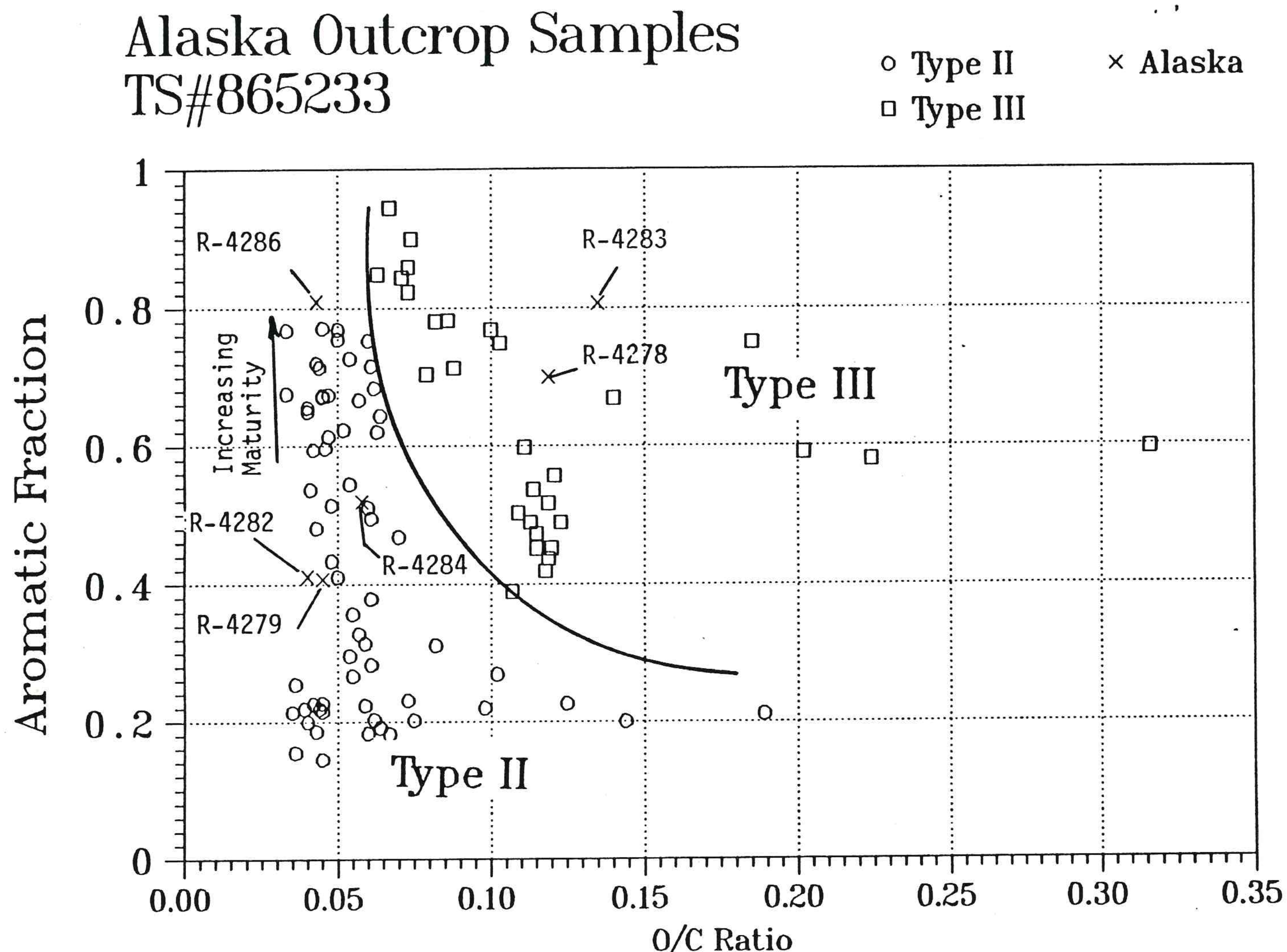
R-4284 is a Type II kerogen according to the points in FTIR-1 and FTIR-2. Elemental data indicates the sample is in the middle of the primary oil generating window. Like sample R-4282, this one was stated by the external service laboratory visual analysis to be mainly structured with an amorphous component; an interpretation that is at odds with the FTIR results. Reexamination of this sample, as before, showed primarily amorphous kerogen with a structured component (M. D. Lewan). The FTIR data and the visual reexamination give a much more optimistic view of the original oil generating potential of this sample.

R-4286 is described as a coal at an advanced stage of diagenesis. No FTIR data for coals at such advanced stages are available for comparison. Thus, the fact that this sample plots in the very mature Type II region on the FTIR may or may not have any significance.

Marwin K. Kemp

MKK:mkk
Attachments

Figure FTIR-1

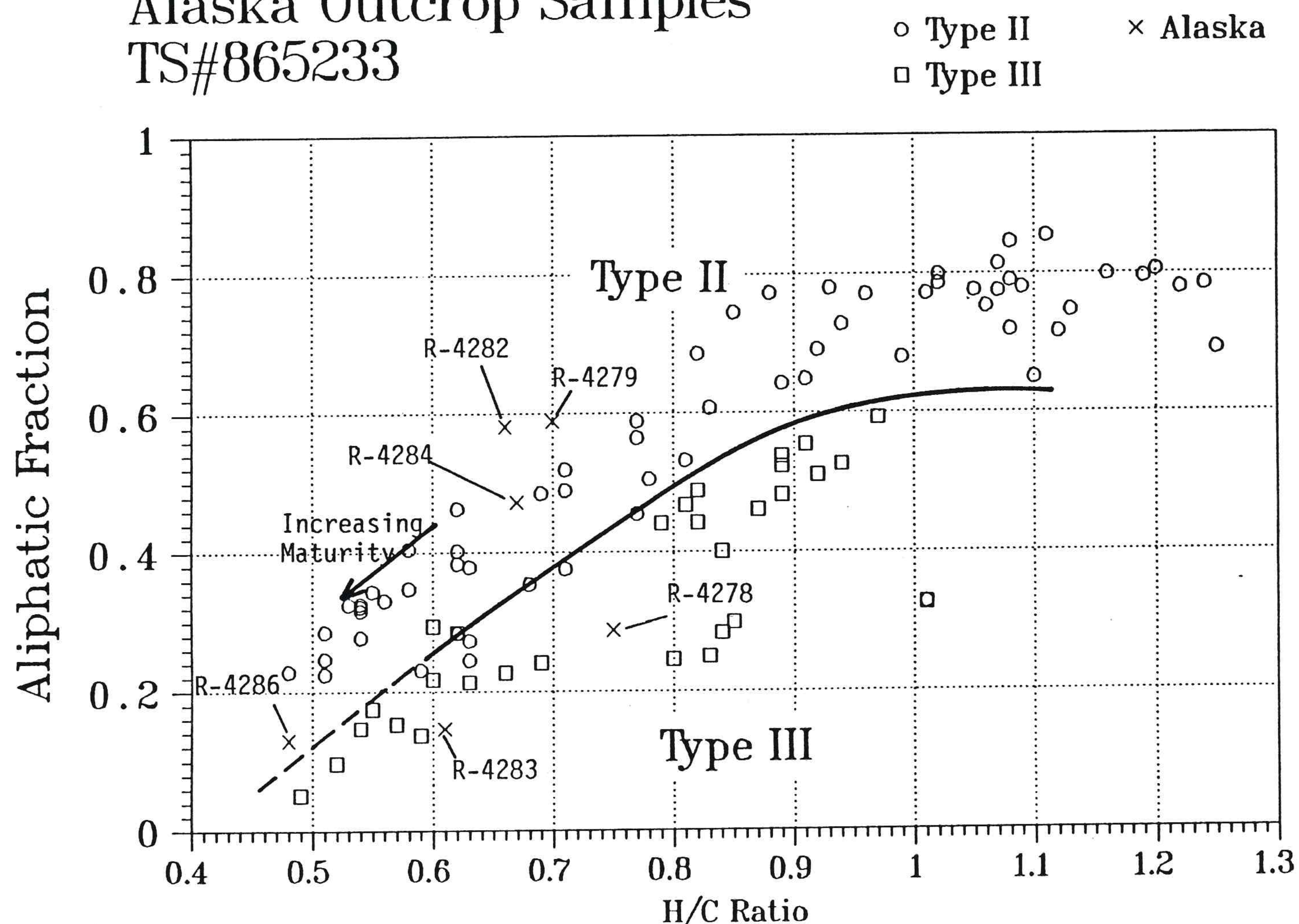


12/15/86

[redacted]

Figure FTIR-2

Alaska Outcrop Samples
TS#865233



12/15/86

[redacted]