GEOLOGICAL AND GEOCHEMICAL ANALYSIS OF THE AURORA WELL, OFFSHORE OF THE ARCTIC NATIONAL WILDLIFE REFUGE 1002 AREA

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ABSTRACT

The Aurora 890 #1 OCS Y-0943 well is the deepest well drilled in the Beaufort Sea. It is immediately offshore of the Arctic National Wildlife Refuge 1002 area and is strategically located between more intensely explored areas of the U.S. and Canadian Beaufort Seas. This is the most recent available data for the oil and gas assessment of northeast Alaska.

Geophysical logs record 5,585 m of clastic section at Aurora. Log and cuttings analysis assigns the basal three units to the locally derived Breakup sequence (5,585 to 4,858 m). These are unconformably overlain by 10 units of middle Brookian depositional sequence (4,858 to 283 m). Unconformities separate the middle and upper Brookian sediments. A veneer of Tuktoyaktuk sequence sediments is inferred. The informally named Tapkaurak and Oruktalik sands are potential reservoir units of the Breakup and middle Brookian sequences, respectively.

Organic geochemical data show that this sedimentary section is mostly lean with respect to organic carbon. Significantly higher TOC's occur at the base of the middle Brookian and within the Breakup sequences. Pyrolysis shows that most kerogens are Type III or Type IV. However, chromatograms and C15+ extractable hydrocarbons suggest the middle Brookian units have been invaded by migrating hydrocarbons. The catagenetic zone is best defined by %Ro and Gas Wetness. It extends from approximately 2,901 to 5,334 m. Burial history reconstructions show a complex history of uplift and erosion at this location.

INTRODUCTION

A consortium of oil companies, with Tenneco acting as operator, drilled the Aurora OCS Y-0943 well on a Federal lease immediately offshore of the Arctic National Wildlife Refuge 1002 area (Fig.1). This location is important because it provides information pertinent to the geology of northeast Alaska and sectors of both the U.S. and Canadian Beaufort Seas. The nearby Chevron KIC #1 well, drilled onshore on Native corporation mineral estate, remains proprietary. Aurora #1 well was drilled from a semi-submersible platform in 21 m of water. The logs and geochemical data were subsequently released to the public in September 1991. This is a synopsis of the major findings from the well logs, cuttings, and geochemical data.

Despite hole problems that necessitated sidetracking at 4,725 and 5,046 m, Aurora was completed to a depth of 5,585 m. Only two wells, located in the National Petroleum Reserve-Alaska, are deeper exploration tests on the North Slope. No drill-stem tests were conducted. However, the mudlog indicates several minor gas kicks; thin, oil-stained sandstones; and tar. The only core recovered thin-to-laminated siltstone, shale, and sandstone. The log interpretation and geochemical analyses show that there are significant differences between the stratigraphy identified in or around the ANWR 1002 area and Aurora (Banet, 1992 and 1993). The interpretation of this well was one of the driving forces for the 1991 reassessment of oil and gas resources in the ANWR 1002 area.

STRATIGRAPHY

Barrow Arch and Breakup Sequence

Aurora tested an entirely clastic section that is composed of the Breakup and Brookian depositional sequences (Fig.2). The Breakup sequence refers to clastic rocks of Jurassic through Lower Cretaceous age that occur predominantly in the subsurface. They represent sedimentation from a long, linear series of local uplifts collectively called the Barrow Arch (Fig.3).

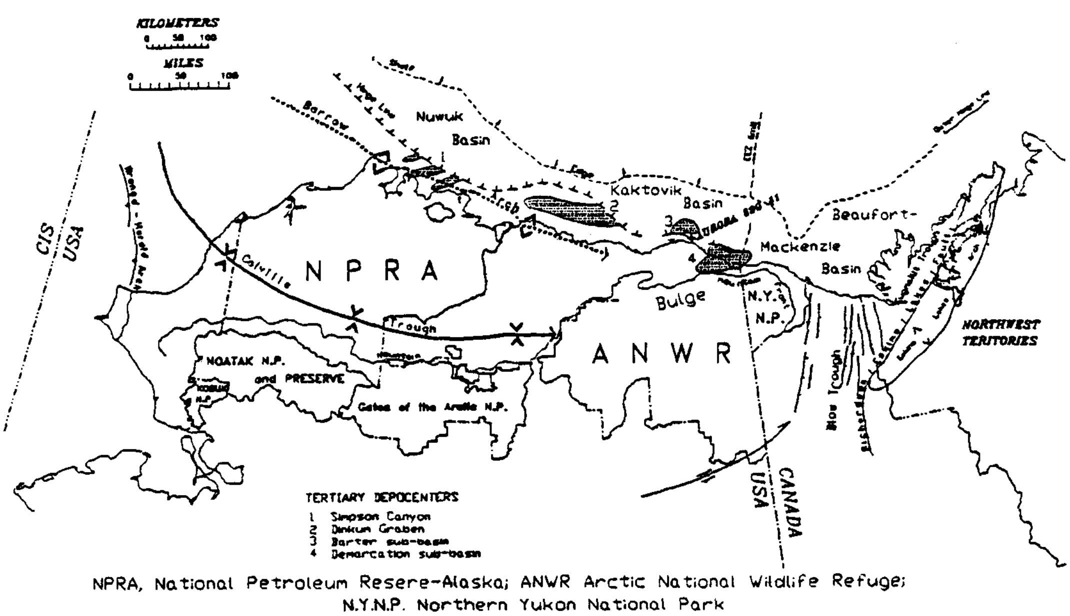

Fig.1. Location map and major tectonic features of the Arctic, emphasizing Barrow Arch, Colville Basin, major fault systems, and local depcenters.

The Barrow Arch uplift is the focus of tectonics germane to North Slope economic geology. Table 1 lists nomenclatures and characteristics that have evolved in describing this rift-related Breakup sequence.

The Barrow Arch uplifts are asymmetric and plunge southeastward. Along the south flank of the uplifts, Lower Cretaceous and older sediments dip into the Colville Basin (Fig.1). The north flank is a half graben,

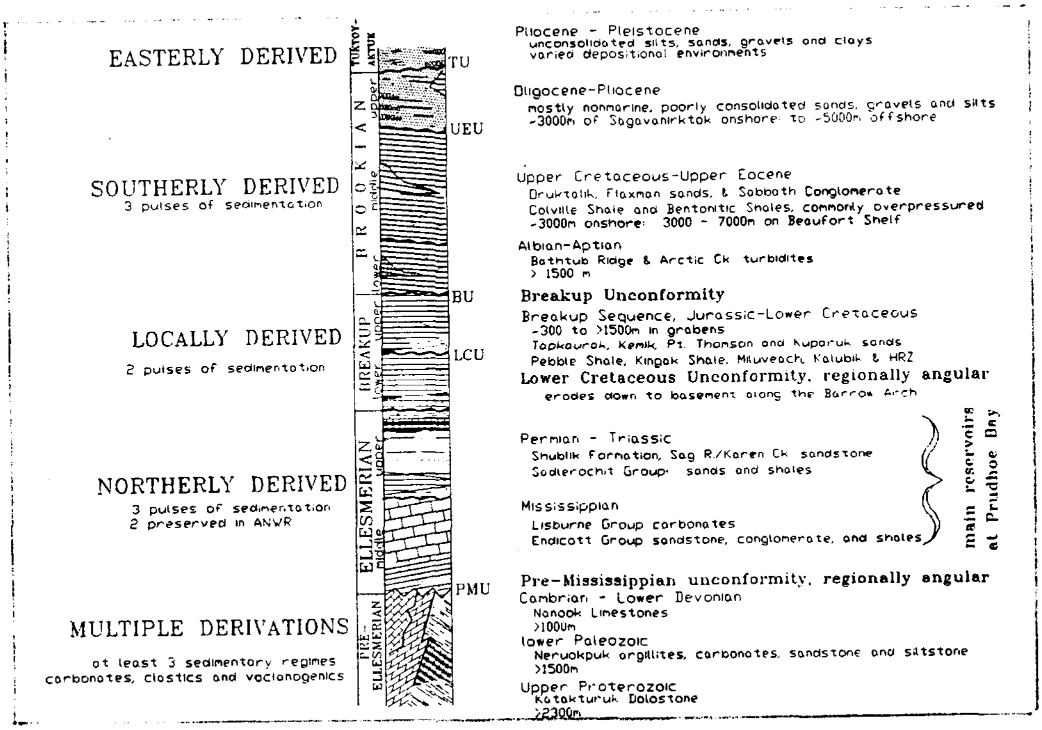

Fig.2. Generalized stratigraphic column for northeast Alaska.

Table 1. Comparison of Lower Cretaceous sands and shales from northeastern Alaska.

HRZ AT KUPARUK 4 - 9 %TOC shale w/ paper fissility ~60 m Albian - Aptian **KALUBIK FORMATION** below HRZ- 150 API internal, local HRZ overlies Kuparuk sands mudst & slst carbonaceous moderately fissile pyritic & sideritic 70 to 100 m marine deposition Barremian - Aptian BREAKUP SEQUENCE	**PEBBLE SHALE** GRZ LCU basal unconformity No. Slope regional silty shale black, fissile, pyritic minor bentonite 60 m to 70 m floating pebbles/grains rich source rock TOC to ~ 5% Haut. to Barr. BREAKUP SEQUENCE	**KONGAKUT FM.** sh, slst, minor ss 4 members deep-water turbidite ~600 m internal unconformities GRZ in Pebble Sh. black, manganiferous few fossils floating chert pebbles Kemik sand ~ 60 m quartz sand to feldspathic wacke very fine-grained basal contact conformable Berriasian - Barremian BROOKIAN	**ARCTIC CK.** ss & sh vf. to fine-grained quartzose 1.5 to 30 m beds ~ 80 m total sand thins eastward siliceous, hard 100% recrystallized deep marine & turbidites flutes, grooves & load casts blk. fissile shale minor bentonites Albian-Aptian BROOKIAN	**AURORA UNIT III** LTU at top sh, slst & carb sh gray to dk. gray very thin beds very silty cuttings ~ 150 m ~SE-NW transport lean source rock Lower-mid Cretaceous BREAKUP SEQUENCE
KUPARUK below GRZ multiple beds sand & shale shallow marine fine-grained, rounded glauconitic, sorted intraformational unconformities distinct contacts areally limited unit ~ 8 km X 10 km Haut. - Barr. oil & dissolved gas BREAKUP SEQUENCE		**KEMIK** below GRZ LCU basal unconformity sands to ~ 50 m sand & shale distinct to interbedded fine-grained, rounded well-sorted, marine No. Slope Regional ~ 10 km X 15 km northeast trend commonly imbricated mega-fossils Hauterivian gas BREAKUP SEQUENCE	**POINT THOMSON** below GRZ LCU basal unconformity thick single unit sand, conglomerate, breccia angular dolostone fragments sits on basement poorly to well-sorted nonmarine limited lateral extent ~ 2 km X 3 km east-southeast trend? distinct contacts barren of fauna oil & condensate BREAKUP SEQUENCE	**TAPKAURAK (Aurora Unit III)** no GRZ LCU at base distinct contacts interbedded ss & sh coarsens & thickens upwards ~ 53 m massive sand Tapkaurak sand fine to coarse-grained clear to white grains subrounded/subangular dolomitic cement unconsol. to med. hard BREAKUP SEQUENCE

Key:

GRZ gamma ray zone
HRZ highly radioactive zone
LCU lower Cretaceous unconformity
LTU lower tertiary unconformity

Stratigraphic position and geography emphasized. Some age relationships uncertain.

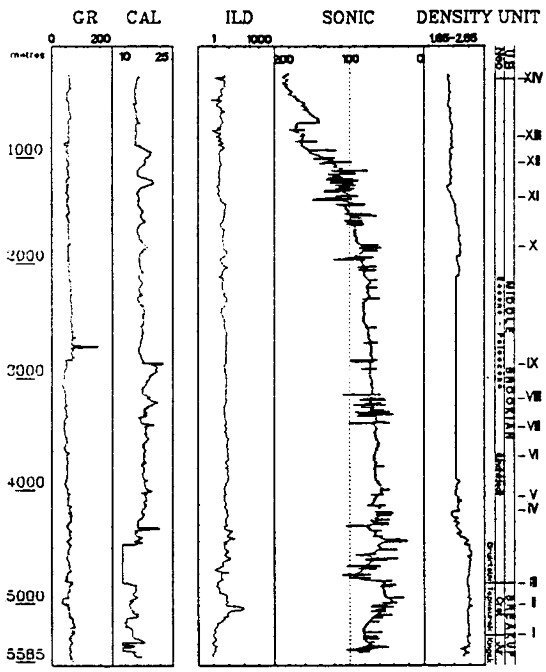

Fig.3. Aurora well geophysical logs.

a remnant from rifting that formed the Beaufort basin (Bird and Molenaar, 1992). Breakup sequence and older rocks are randomly preserved on some down-dropped fault blocks. Unconformities are common along the Arch because these uplifts are separated in both time and spatial extent (Banet, 1992).

The Lower Cretaceous unconformity (LCU) collectively identifies the major erosion at these uplifts. The LCU truncates varying thicknesses of the underlying sediments. Much of the northerly derived, quartzose and petrologically mature, Upper-Mississippian-to-Jurassic Ellesmerian sequence has been removed along the axis. These are the predominant economic reservoirs of the North Slope. The LCU also truncates sequences of older and tectonically disturbed shales, quartzites, phyllites, argillites, and carbonates.

Several fine- to coarse-grained marine and nonmarine sandstones comprise the coarse-grained facies of the Breakup sequence. These sandstones are peripheral to the uplifts and are thought also to be preserved north of the Arch on some down-dropped fault blocks. They cover rather limited areal extents and are not all the same age. The thickest sand bodies are found interbedded with the Upper Jurassic and Lower Cretaceous shales. Due to recent discoveries and from rethinking strategies, they are quickly becoming much sought-after exploration targets. The petrology of these local sandstones is usually quartzose, but the sands also reflect the unique bedrock lithologies from which they have been shed (Banet, 1992). In addition, there are hydrocarbon discoveries in the Breakup sequence sandstones from the Chukchi Sea to the Canning River (Banet, 1993).

Brookian Sequence

Hubbard et al. (1987) identify lower (Aptian to Albian), middle (Santonian to Eocene), and upper (upper Eocene to Pliocene) Brookian depositional sequences. These are southerly derived clastic sediments. They record the major pulses of tectonically induced sedimentation which began in the Aptian and proceeded sporadically through lower Pliocene (Banet, 1993). In both subsurface samples and outcrops, Brookian sediments are predominantly interbedded chert litharenites and shales.

Brookian input filled the Colville basin from the south and southwest, eventually overstepping the Barrow Arch and dumping onto the Beaufort Shelf. In northeast Alaska and northwest Canada, the Brookian deposition has been predominantly from the south. Maximum sediment thicknesses approach 10 km in the Colville basin and 13 km in the Beaufort basin (Bird and Molenaar, 1992; Dietrich and Lane, 1992).

Oil and gas have been found in all three Brookian sequences, in tectonic settings ranging from the foreland fold-and-thrust belt to the Beaufort margin. Also, there are recent and exciting discoveries in the upper Brookian sediments offshore. Volumetrically, oil in the middle Brookian may rival that of the Ellesmerian sequence at Prudhoe. However, reservoir temperatures are low, depths are shallow, and sediments typically are very friable. Consequently, appreciable recovery is beyond current technology.

Tuktoyaktuk Sequence

The Brookian sequences are unconformably overlain by the informally named Tuktoyaktuk sequence (Banet, 1992). These are unconsolidated sands, conglomerates, and silts deposited in a variety of marine and nonmarine periglacial environments. Unique rock-types found in the gravels suggest an eastern derivation for at least part of the Tuktoyaktuk sediments. Tuktoyaktuk sediment thicknesses vary from a thin veneer on the Arctic Coastal Plain to some 5,000 m in the Canadian Beaufort. Locally, the Tuktoyaktuk sediments overlie folded Brookian strata.

STRUCTURE AND TECTONICS

The Brooks Range and its foreland fold-and-thrust belt are the result of regional compressional tectonism that has deformed the southern portion of the North Slope. Deformational intensity decreases northward, leaving the Arctic Coastal Plain largely undisturbed. This regime changes to mostly extensional tectonism, beginning at about the present-day coastline and extending into the Beaufort Sea. However, in the area of the Bulge in northeast Alaska, compressional folding and faulting deforms both the Coastal Plain and the offshore. This affects the area where the Aurora well was drilled.

DESCRIPTION OF THE LOG UNITS

Breakup Sequence

Unit I

The deepest unit penetrated, 5,585 to 5,281 m, consists of light to dark-gray and dark grayish brown, splintery to fissile, hard shale. There are minor amounts of fine- to medium-grained, white to milky, mostly subrounded, quartzose sandstone. These lithologies are interbedded, with the log-discernible sandstones comprising less than 10 percent of the unit. The lithology, the sonic velocities, and the thickness indicate that Unit I is the Kingak Shale (Jurassic to Lower Cretaceous) of onshore nomenclature. By analogy to the Kuparuk River area (Carman and Hardwick, 1983), this unit is probably Upper Jurassic (Oxfordian). Consequently, the unconformity, suggested by the log interpretation at the top of this section, is the LCU. The presence of Kingak at this location suggests that the underlying Ellesmerian sequence may be present at this location and, perhaps, beneath the eastern part of the ANWR 1002 area.

Gamma-ray logs show that this unit has the highest readings, 75 to 105 API units. Resistivity curves show minimal separation. The decrease in the interval velocity on the sonic-log response indicates that there may be overpressure below about 5,471 m. Also, a minor gas show was reported.

Unit II

Unit II is informally named the Tapkaurak Unit (Banet, 1992). Distinct contacts show on all the logs where it unconformably overlies the Kingak at 5,281 to 5,013 m (Fig.4). The Tapkaurak is an overall coarsening-upwards sequence of interbedded sandstones and shales. These sandstones become thicker upsection, culminating in the informally named Tapkaurak sandstone unit, 5,066 to 5,013 m (Fig.4). The Tapkaurak is the major Breakup sequence sand in this area. It has some depositional and petrological characteristics similar to other Breakup sequence units in the region (Table 1).

Cuttings reveal the shales to be mostly dark gray to black, very silty, fissile to blocky, hard, pyritic, and micaceous. The Tapkaurak sands are fine- to coarse-grained and quartzose. They are thin bedded and widely spaced at the base, becoming very thick at the top. The Tapkaurak sandstone has minor amounts of tan, dolomitic cement. Quartz grains are fine to coarse in size, subangular to subrounded, and clear to milky or white. There are trace amounts of both igneous and volcanic rock fragments.

The gamma-ray and SP logs show that the Tapkaurak sand is relatively free of clay minerals. The ILD curves separate through the sand, suggesting some invasion of drilling fluids and permeability. Log calculations, though, show that sonic-derived porosities are less than 5 percent. Although fossils are not common, the Tapkaurak is determined to be Hauterivian-Barremian (Paul, pers. commun., 1992).

Unit III

Despite hole problems, the logs show Unit III quite distinctly with contacts at 5,013 and 4,858 m. Cuttings samples are almost entirely dark-brown to dark-gray shale with minor carbonaceous laminations and traces of siltstone. The siltstones are rare and thin.

Both log character and lithological changes at 4,858 m suggest an unconformity. This unconformity correlates to the lower Tertiary unconformity (LTU) of the Pt. Thomson area, approximately 150 km west (Craig et al., 1985; Banet, 1992). Thus, Unit III is pre-Turonian, probably Aptian to Albian.

Brookian Sequence

Middle and upper Brookian (Paleocene to Pliocene) sequence rocks comprise most of the remaining stratigraphy. The dipmeter log shows that these sediments have a marked and strong predominance for north-northwest

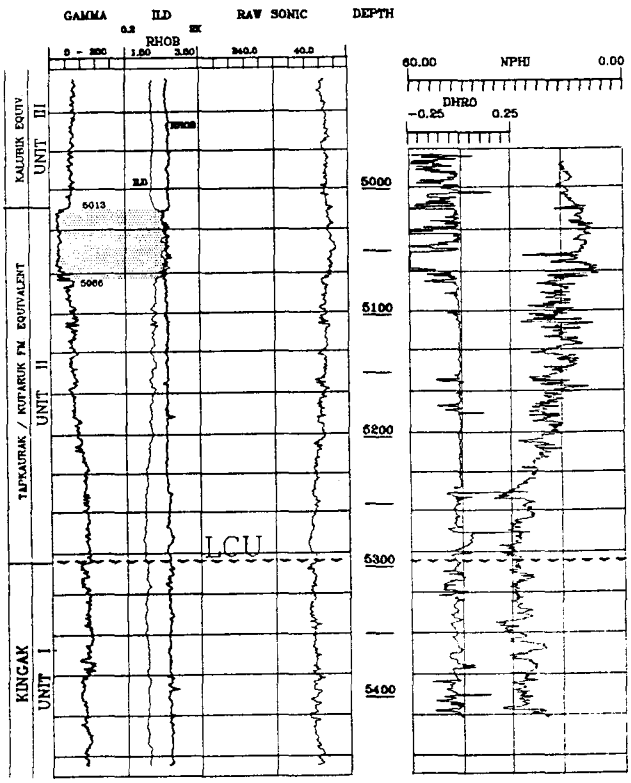

Fig.4. Geophysical logs through Tapkaurak Unit and U. Kingak.

transport. Rather subtle changes in gamma-ray, electric, and sonic-log character differentiate the Brookian units. Craig et al. (1985) estimate that there may be almost 5,500 m of middle Brookian, and in excess of 6,000 m of upper Brookian sediments in the eastern (U.S.) part of the Beaufort Sea. Dietrich et al. (1992) report similar or thicker estimates for the Brookian sediments in the Canadian portion of the Beaufort Sea.

Unit IV

The Oruktalik Unit, 4,856 to 4,183 m, is the fourth log unit identified in the Aurora well. It is Paleocene in age and lies at the base of the Brookian section. The Oruktalik Unit includes shale intervals, stacked sandstones, and interbedded sandstones and shales. The base of the unit is the LTU where blocky, gray to black, silty shales overlie the brown laminated and carbonaceous shales. Upsection, the shale is silty, splintery to fissile with traces of pyrite, and there are interbedded sands.

The Oruktalik sandstone unit from 4,520 to 4,476 m consists of about 20.5 m of distinct sands interbedded with shale (Fig.5). In cuttings samples, these sands are friable, mostly clear or white, fine- to coarse-grained with salt-and-pepper appearance from the black and white chert, and composed of subangular lithic fragments. The mudlog also describes a pebble conglomerate, consisting of larger black and white chert fragments. The Oruktalik sand had the most notable gas show encountered in the well.

Units V - XIII

The remaining middle Brookian sequence log units, from 4,183 to 727 m, consist of varying amounts of soft, gray, silty shale, gummy claystone and bentonite, or tuff. The coarser lithologies are thin, randomly wide-spaced, thin-bedded siltstones or sandstones. The logs do not usually record the individual sandstones or siltstones because they are generally too thin for accurate resolution. However, the logs do show thin stringers of relatively radioactive shales or bentonites (hot zones) at 2,758, 2,678, 2,633, and 2,627 m. There are no unconformities in this section (Fig.3).

Unit XIV

The log response and lithology change at a depth of 727 m suggest an unconformity. This is interpreted as the basal upper Brookian unconformity. The sonic log also shows overpressuring in the overlying section. In addition, there are several very high-resistivity zones in this section. Unit XIV consists of soft, silty, gummy claystone with minor amounts of unconsolidated sand and silt. There are also traces of wood fragments, peat, and chert pebbles.

Logging ceased at 283 m while still in the upper Brookian. However, at least a thin veneer of Tuktoyaktuk sequence rocks are inferred to be present at Aurora, based on regional mapping (Carter, 1987; Dinter, 1987).

ORGANIC GEOCHEMISTRY

Organic Richness (TOC, Kerogen, and Pyrolysis)

Tuktoyaktuk and Brookian Section

The Tuktoyaktuk and upper Brookian Unit XIV rocks have between 1- and 2-percent Total Organic Carbon (TOC). Amorphous kerogen is predominant with subordinate amounts of exinite, vitrinite, and inertinite macerals. However, pyrolytic analyses show some peculiarities to these kerogens.

Data from the upper Brookian show mostly low organic-richness values, genetic potentials, and production indexes. These kerogens are at low Tmax thermal maturities (Fig.6). The Hydrogen Index (HI) and Oxygen Index (OI) plots typically show thermally immature sediments, having potential for generating gas (Fig.7). These values suggest that the amorphous kerogens reported are not oil prone. Upper Brookian rocks in the region typically have higher potential to generate hydrocarbons and have some coaly material, wood or peat (Banet, 1990a, 1990b, 1991, and 1993).

Middle Brookian Section

Cuttings and sidewall core samples have an almost uniform 1-percent TOC through the entire Middle Brookian section. There are notable exceptions with TOC's up to 7.5 percent in both Unit V at 4,084 m and through the basal section of Unit IV, between 4,724 and 4,858 m.

Both sidewall cores and cuttings show higher TOC's through the basal portion of this section. Amorphous kerogen is as high as 60 to 80 percent with minor amounts of vitrinite and traces of exinite in most samples above 2,900 m (Fig.7). The deeper Brookian section has amorphous kerogen, vitrinite, and inertinite macerals.

Pyrolysis data show Genetic Potentials and Production Indexes mostly lower than through the upper Brookian section. Tmax, %Ro, and Gas Wetness put the onset of catagenesis at 2,901 m (Fig.6). (This is coincident with the log break between Units IX and X.) However, even with the onset of thermal maturity, organic richness remains very low. The only samples with moderate hydrocarbon-generating potential occur at 2,987, 3,352, 4,084, and 4,359 m. The Oruktalik sand (4,520 to 4,476 m) had a gas show, while the cuttings reported a minor show of oil. Regionally, the basal middle Brookian has high potential to generate hydrocarbons (Magoon et al., 1987; Snowdon, 1987; Banet, 1990a, 1990b, 1991, and 1993).

Pyrolysis also shows that the middle Brookian kerogens have mostly low potential to generate either oil or gas, regardless of thermal maturity or stratigraphic position (Fig.7). Evidently, the kerogens reported as amorphous are actually inertinite, or Type IV, and do not contribute to the hydrocarbon generating potential at this location.

Breakup Sequence

TOC's throughout the Breakup sequence vary between 0.5 and 3 percent, with most values falling between 1 and 2 percent. Through Unit III, cuttings samples are 2 percent or more, whereas sidewall core samples are 1 percent or less. This difference is likely due to sloughing and mixing of material from Unit IV associated with some drilling problems. About 90 percent of the kerogens are reported as amorphous. Like the Brookian rocks, this material is actually inertinite, having the least potential of any section in this well to generate hydrocarbons (Fig.6). Other Breakup sequence shales, however, typically have much higher potential for hydrocarbons (Banet, 1990a, 1990b, and 1992).

TOC's are between 1 and 2 percent in the Tapkaurak Unit. Unlike Brookian kerogens, the Tapkaurak Unit appears to be a mature source for gas (Fig.7). Unfortunately, there are no sidewall cores for comparison. Consequently, these relatively high potential values may be a relic of contamination by drilling circulation-control fluids. Oddities in the pyrolysis data support this tenet. However, these data are unlike typical lignite-based drilling additives and actually more like mature, gas-prone source rocks, which would be expected at this stratigraphic position.

Organic richness through the Kingak is practically identical to that of the Tapkaurak Unit (Fig.4). Magoon and Claypool (1984) describe Kingak facies that are prone to generate petroleum near Prudhoe Bay with trends suggesting that the Kingak becomes a gas source eastward.

Extractable Organic Matter

Bitumen extracts are available only for the Brookian section above 4,825 m. Soxhlet extraction with methylene chloride (CH_2Cl_2) solvent recovered 314 to 14,269 ppm in the C15+ hydrocarbon range. Nonhydrocarbon ashpaltenes and resins comprise a smaller portion of the extractables (Banet, 1993). Overall, the C15+ extracts do not increase with depth and thermal maturity. In fact, values are highest in the thermally immature section where extracts should be minimal. The presence of bitumen in thermally immature sediments and the amounts of bitumen present indicate the presence of migrated hydrocarbons.

Pristane-to-phytane ratios do not vary with depth. Their relatively high values indicate deposition under rather oxidizing conditions, but they are unresponsive to increased thermal maturity. Other thermal maturity indicators, CPI and pristane/nC-17, show no dramatic changes related to thermal maturity. Again, migrated hydrocarbons are suspect.

Chromatograms show that the most abundant hydrocarbons are severely biodegraded. Superficially, they resemble some chromatograms of extracts from the ANWR 1002 area, particularly from oil-stained sediments along the Jago River (Banet, 1990a, 1990b, and 1993). Chromatograms of extracts do not appear to be related to the maturity of the indigenous sediments. Migrated hydrocarbons are suspect. More complete comparisons are not possible because Aurora samples were not analyzed for biomarkers or isotopes. Also, an unidentified peak in some chromatograms suggests either a unique biomarker or possibly a drilling-fluid contaminant (Banet, 1993).

Thermal Maturity

Thermal maturity indicators, %Ro, Gas Wetness, Tmax, and TAI, show that the diagenetic zone extends to a depth of 2,901 m. By contrast, catagenesis begins at about 4,000 m at nearest wells (Magoon et al., 1987; Banet, 1990a). Maturity increases steadily through this section. Catagenesis begins with dramatic changes to %Ro and Gas Wetness at this depth, whereas Tmax and TAI increase steadily (Banet, 1993).

All indicators define catagenesis between 2,901 m and about 5,334 m. Through the catagenetic zone, %Ro show three distinct sections. These sections represent more severe burial/thermal conditions. Geothermal-gradient analysis confirms that the Aurora well has a more severe and complex burial history than other wells in this region (Banet, 1993). Figure 8 is a burial-history reconstruction showing modeled uplifts and erosional periods. It shows the onset of catagenesis in the Kingak at approximately 48 Ma, and in the basal Brookian, Oruktalik Unit at about 36 Ma. Banet (1993) explains the necessary assumptions and compares the fit of the data to this model versus several alternatives.

SUMMARY

Aurora is the deepest test well in the Beaufort and one of the deepest wells on the North Slope. It encountered 5,585 m of clastic section belonging to the Breakup, middle and upper Brookian, and Tuktoyaktuk depositional sequences. The middle Brookian Oruktalik sand had a notable gas show. The Tapkaurak sand demonstrates the presence of potential Breakup sequence reservoirs in this area. The presence of a thick section of Kingak Shale at this location suggests that the Ellesmerian section, which includes the main reservoirs at Prudhoe Bay, may be present. It also increases the probability that potential Ellesmerian sequence reservoirs may be present onshore, as well.

Organic geochemistry shows that most of the stratigraphy has poor petroleum-generating potential. TOC's are generally low and kerogens are mostly inertinite, Type IV. Type III kerogens are present in the thermally immature upper Brookian and mature Breakup sequence. However, extractable hydrocarbons have migrated into the Brookian section, suggesting that an undefined petroleum-generating system is active in this area.

Burial-history reconstructions indicate that Aurora has undergone several periods of deposition and erosion, particularly through the Brookian. Catagenesis began approximately 48 Ma in the Breakup sequence and as early as 36 Ma for the basal middle Brookian. Thermal maturity begins at 2,901 m in the middle Brookian.

Although the Aurora well was not a discovery, the data suggest that important Ellesmerian reservoirs may be present in the region. The presence of extractable hydrocarbons in a section that has poor petroleum-generating potential suggests that a petroleum-generating system, with as yet unknown potential, is active in this region.

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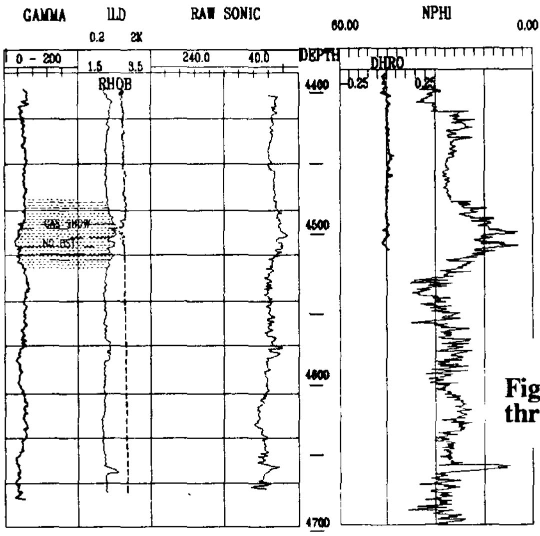

Fig.5. Geophysical logs through Oruktalik sand.

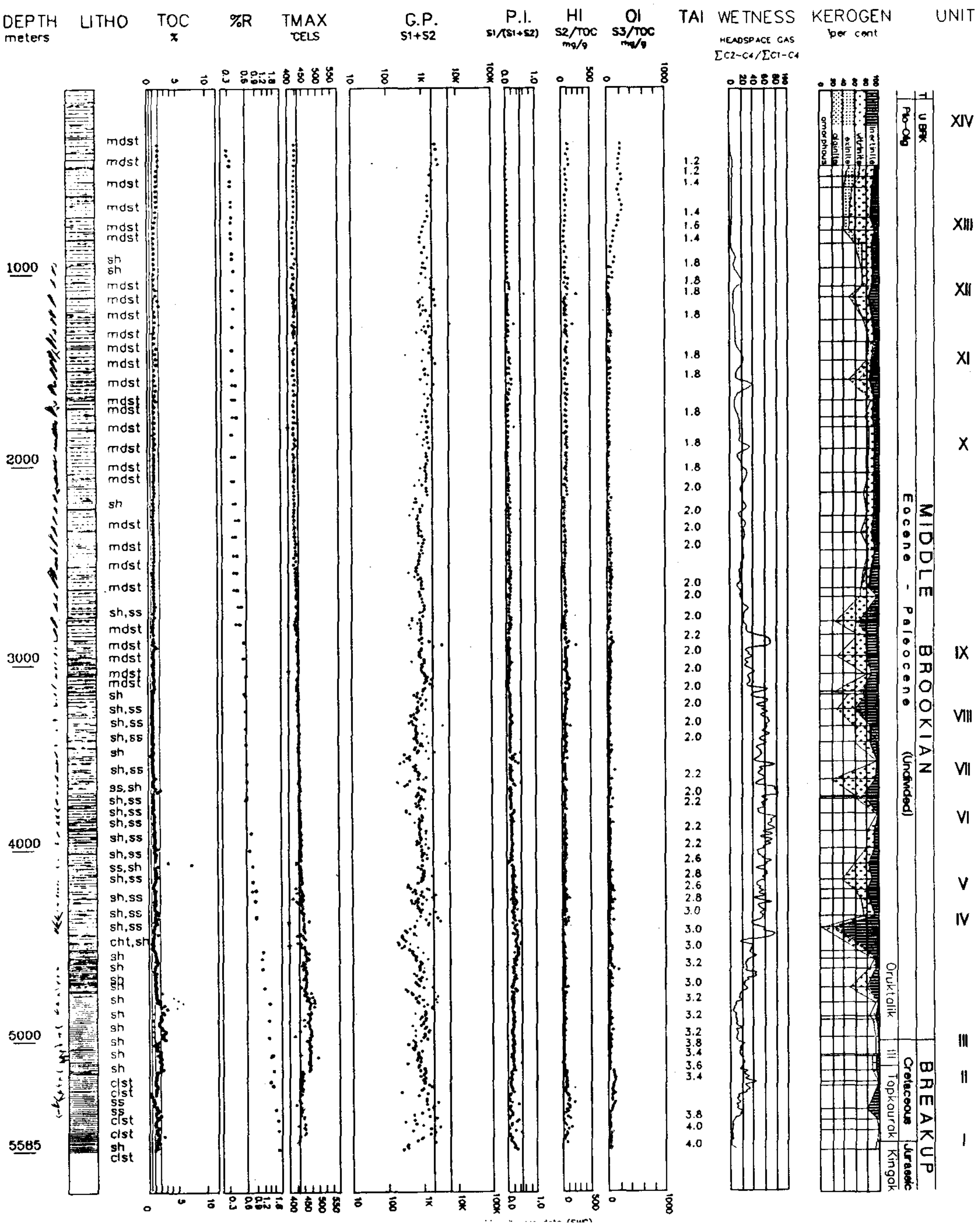

Fig.6. Geochemical profile for Aurora well

ss--sandstone
sh--shale
slst--siltstone
mdst--mudstone
cht--chert
clst--claystone

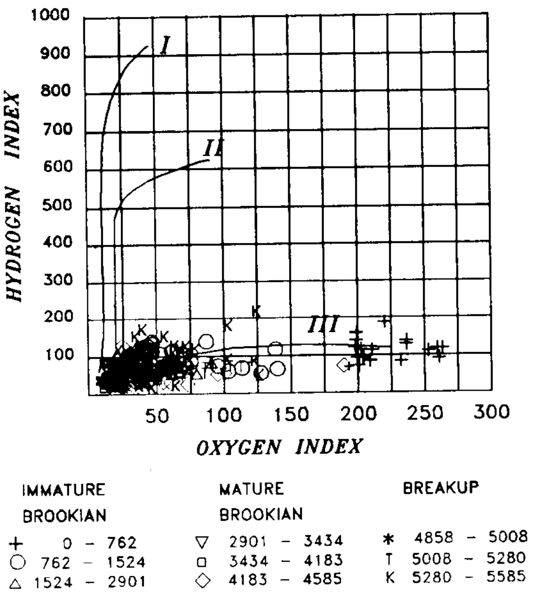

Fig.7. Modified van Krevelen diagrams for Aurora well kerogens.

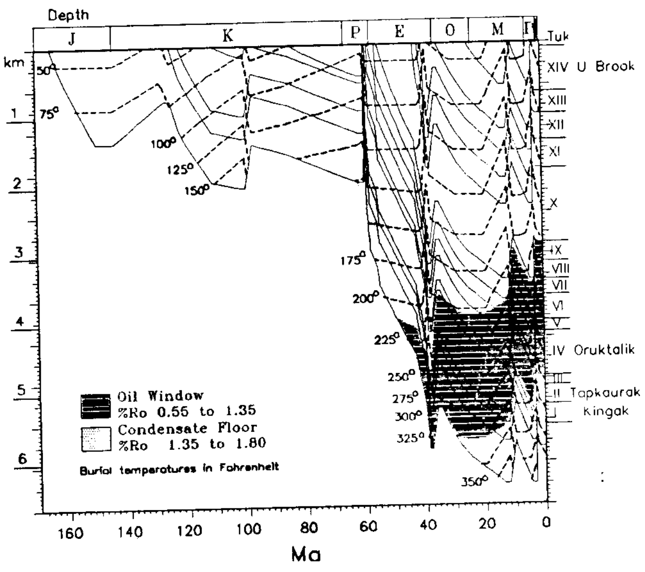

Fig.8. Burial history for Aurora well.