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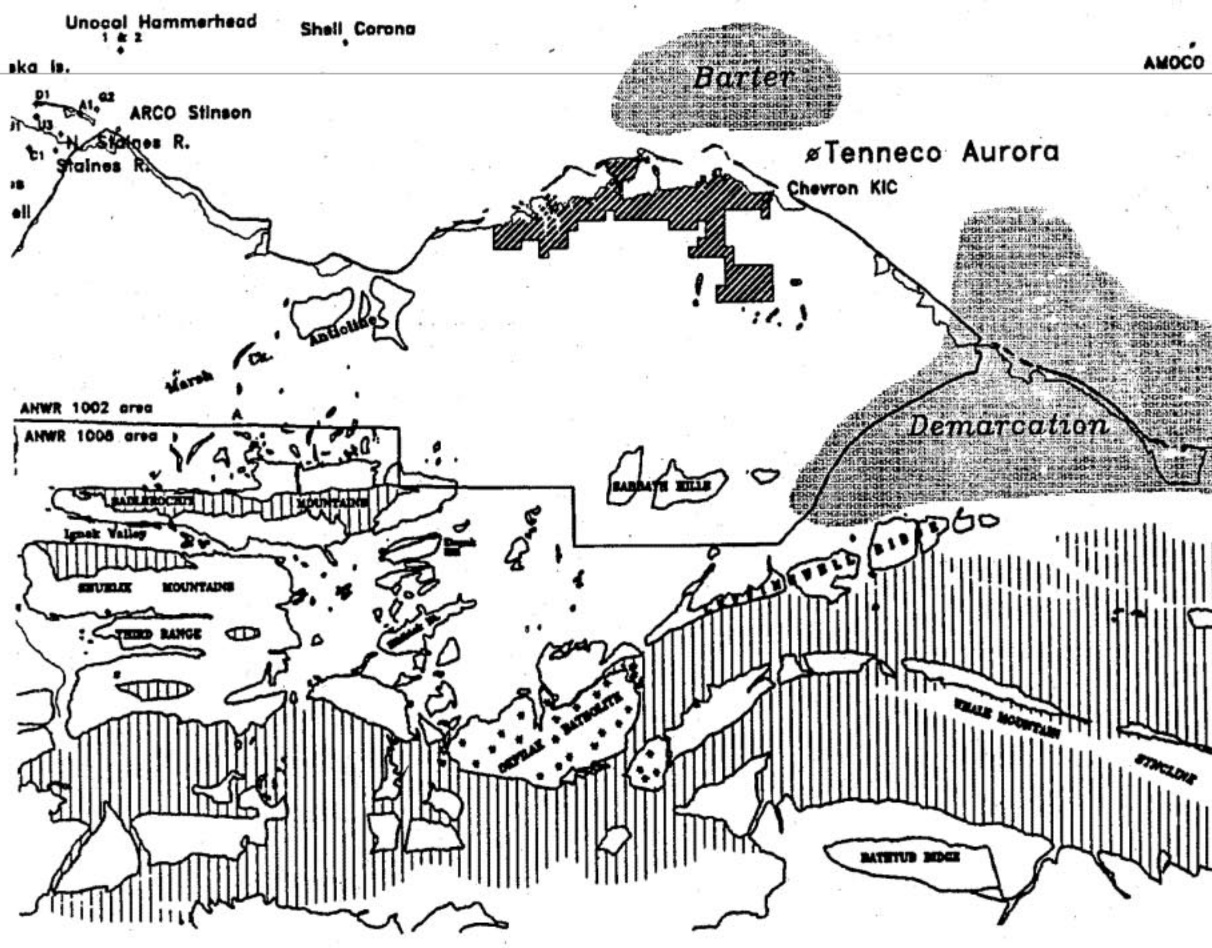
Aurora 089 No. 1 OCS-Y-0943 Well Offshore Northeast Alaska: Petrography-Petrology

Thomas C. Mowatt
Arthur C. Banet, Jr.
John W. Reeder
Joseph A. Dygas



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Authors

Thomas C. Mowatt is a geologist in the Branch of Lease Operations, and Arthur C. Banet, Jr. is a geologist in the Branch of Mineral Assessment—both within the Division of Mineral Resources, Alaska State Office, Bureau of Land Management, United States Department of the Interior, Anchorage, Alaska.

John W. Reeder is a geologist with the Division of Geological and Geophysical Surveys, State of Alaska, Eagle River, Alaska.

Joseph A. Dygas is a geologist, and the Chief, Branch of Lease Operations, Division of Mineral Resources, Alaska State Office, Bureau of Land Management, Anchorage, Alaska.

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Aurora 089 No. 1 OCS-Y-0943 Well, Offshore Northeast Alaska: Petrography-Petrology

Abstract

The Aurora well affords the most recently available geological information pertinent to the Arctic National Wildlife Refuge (ANWR) to the south. The well is located approximately four miles north of Griffin Point (T.8N., R.37E., sec. 9), and approximately five miles north, forty-five degrees east, of Tapkaurak Point (T.8N., R.36E., sec. 1), which is the site of the Chevron KIC No. 1 Jago well. This report presents summary discussions of regional geological relationships, and of the petrology and stratigraphy associated with the Aurora well.

Petrographic analyses were performed of twenty six thin-sections representing suites of well cuttings fragments from selected stratigraphic horizons over the depth interval I3,800-18,190 feet. Emphasized were two zones of well-developed sand/sandstone, the "Oruktalik Sand" (14,680-14,860 feet), of predominantly litharenite/cherty aspect, and the somewhat more quartzose "Tapkaurak Sand" (16,445-16,630 feet).

Results of this work provide information fundamental to increased understanding and further elucidation of geological, petrophysical, and geophysical characteristics of this key well, and implications regarding regional relationships and resource potentials.

1. Introduction

The Aurora 089 No. 1 OCS-Y-0943 well is located offshore from the Arctic National Wildlife Refuge 1002 area, approximately 20 miles east of Barter Island and 3.5 miles orth-northeast of griffin Point (figures 1 and 2). The Aurora drilled 18,325 feet of clastic section, making it one of the deepest wells on the North Slope (plates 1 and 2). It required almost a year onsite for drilling during 1987 and 1988 because of various unforseen hole problems (Banet, 1992a).

This report is based on previous scrutiny of the available well data including the suite of geophysical and mud logs, as well as megascopic/stereo microscopic examination of cuttings. Salient aspects of this work were discussed in Banet (1992a), portions of which have been refined further and incorporated in the present report. The present report supersedes an earlier one (Mowatt, Banet and Reeder, 1992) which was intended principally as a vehicle for timely release of our initial petrographic work on the Tapkaurak and Oruktalik zones.

The petrographic analyses reported here are of cutting samples representing 10-foot increments of selected depth intervals between 13,000 and 18,190 feet (below Kelly bushing). Emphasis is on two predominantly sandstone intervals: 14,680-14,860 feet, and 16,445-16,620 feet. These intervals include the informally-named "Oruktalik" sand (14,685-14,828 feet) and "Tapkaurak" sand (16,446-16,620 feet) of Banet (1992a). The thin-section descriptions are divided into generalized summaries of the predominant and subordinate cuttings fragment types. The Arctic National Wildlife Refuge, 1002 area is approximately 20 miles east of Barter Island and 3.5 miles north-northeast of Griffin Point (figures 1 and 2). The Aurora drilled 18,325 feet of clastic section, making it one of the deepest wells on the North Slope (plates 1 and 2). It required almost a year onsite for

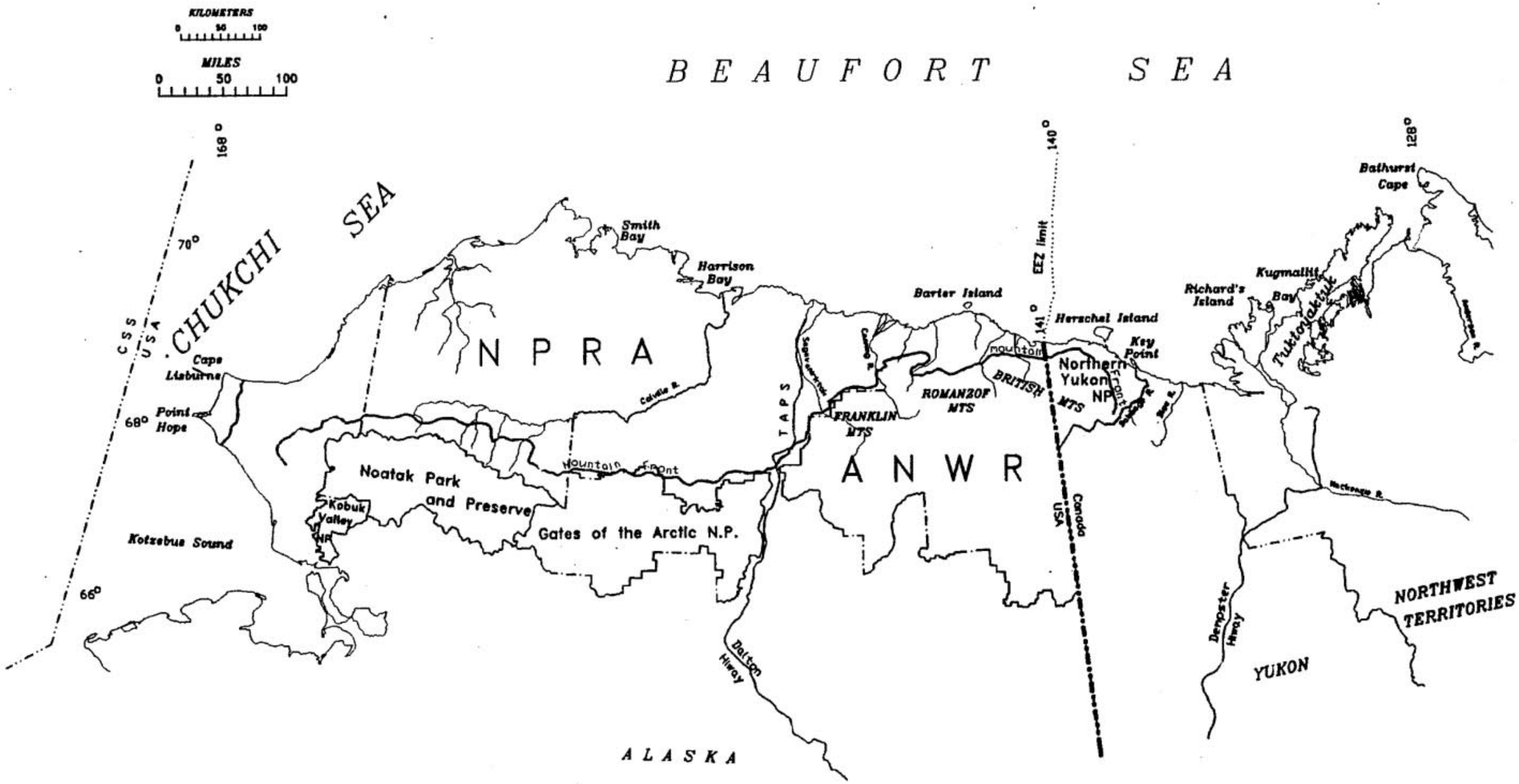

Figure 1

Index map of the Arctic showing major geographic features in Alaska, Yukon and Northwest Territories.

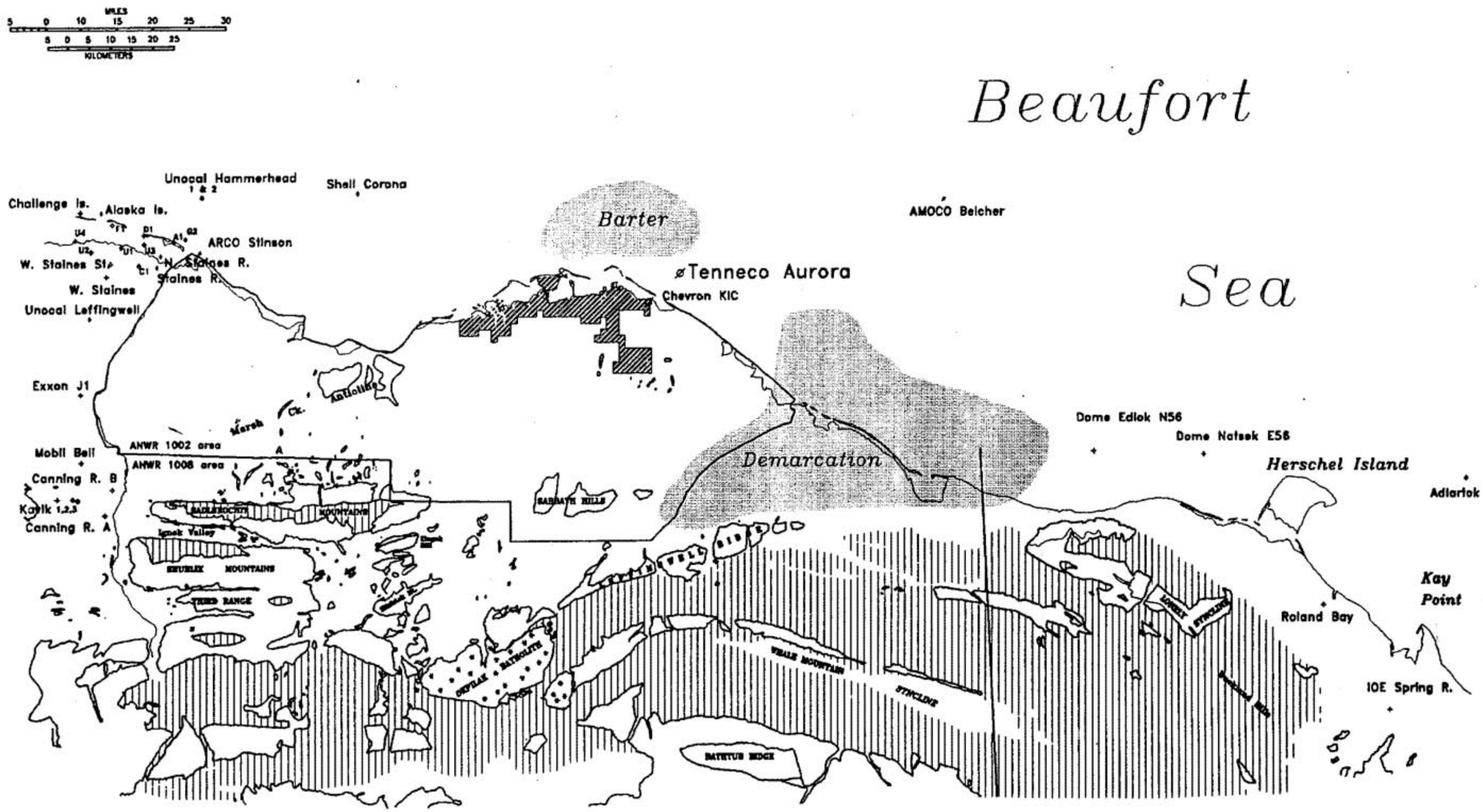

Figure 2

Aurora well location and major geographic features, including ANWR 1002 area, seismic grid and nearest exploration wells

(Barter and Demarcation sub-basins shaded, pre-Ellesmerian rocks hatched) drilling, during 1987 and 1988, because of various unforseen hole problems (Banet, 1992a).

The present report is based on previous scrutiny of the available well data; there are additional comments on important specific fragments, in terms of framework grain characteristics, amounts and types of cements, matrix constituents, visible porosity, degree of apparent compaction, and aspects of reservoir quality, present as well as potential. This information is complementary to Banet (1992a), which describes the megascopic aspect of washed cuttings of selected intervals, and discusses log analyses.

2. Summary Overview of Regional Geology

Data from this exploration well partially fills an extensive gap between exploration efforts in Alaska and in the Canadian Beaufort Sea and on the Mackenzie Delta where integrated geologic and seismic data are available. Figure 3 shows some of the major tectonic features of the North Slope. The Barrow Arch is the most important of these. Rather than being a single entity, it is a mostly linear series of temporally, and spatially, separated uplifts central to the regional tectonics. The Mountain Front is the surface expression of the structurally competent allocthons involved in this portion of the foreland fold and thrust belt in the northern part of the Rocky Mountain Cordillera. The Colville Trough and Beaufort Shelf are the depocenters of Brookian sedimentation.

The Aurora well location is to the north of—and external to—the northernmost Bulge of the Rocky Mountain Cordillera's leading edge at the Niguanak area (the surficial representation of the greatest distal extent of deformation into the foreland). The Bulge is a compressional uplift, in which stratigraphic units from all the major depositional megasequences in this region are exposed. Figure 4 presents a summary description and comparison of these major depositional megasequences in northeast Alaska. The common folds and faulting reveal that this area has an extensive history of multiphasic deformation. Also the severity of induration indicates that most of the sediments exposed along the mountain front have been deeply buried prior to uplift (Tailleur and Weimer, editors, 1987; Bird and Magoon, editors, 1987; Kelley and Detterman, 1989; Banet, 1990).

The Aurora well is also located along the trend of the Hinge Line (figures 2 and 3), which is an extensional tectonic feature affecting the subsurface geometry of the major depositional megasequences, offshore. Craig and others (1985) illustrate that pre-Ellesmerian basement rocks are down-dropped to the north along normal faults, typically forming grabens (figure 5). Along the Barrow Arch, mostly separate and discrete blocks of Ellesmerian and basement rocks were regionally uplifted and eroded at an angular lower Cretaceous unconformity (LCU). Locally, complete or partial Ellesmerian sections are preserved in some of these grabens.

During lower Cretaceous time, several pulses of locally deposited Breakup Sequence sands were shed from the Barrow Arch uplifts. The lithologies of these sands reflect their distinct, separate and unique provenances (table 1). Most of the sands are quartzose, with varying amounts of subordinate clasts, fragments, clays, and cements characteristic of their sources and environments of deposition. Craig and others (1985), and Hubbard and others (1987) posit that extraordinarily thick sections of these Breakup Sequence sands and finer-grained clastic sediments were shed northward into the grabens.

Regional subsidence, and the Brooks Range uplift, resulted in the deposition of thick, extensive progradations of petrologically immature sands and finer-grained clas-

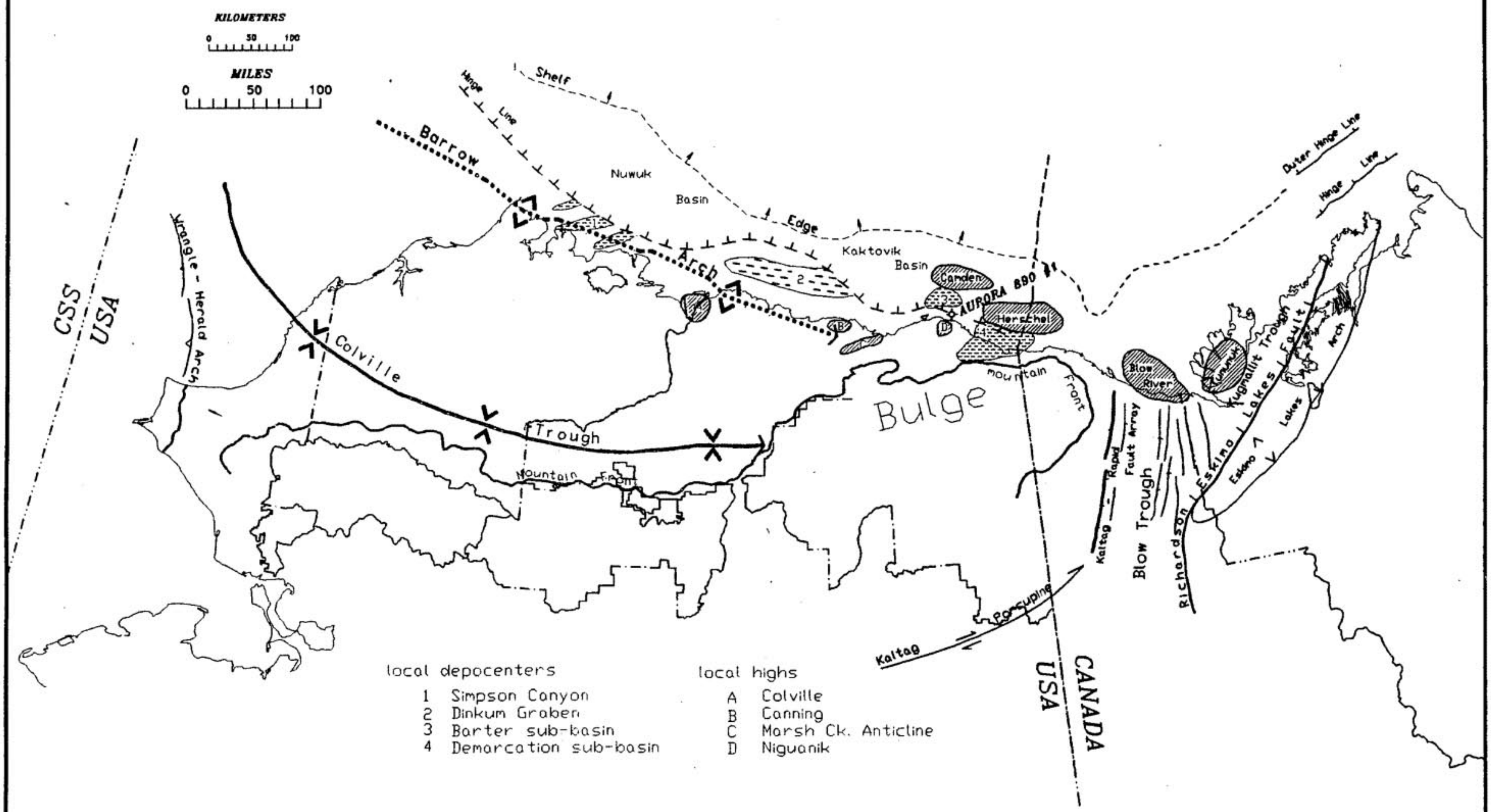

Figure 3.
Major tectonic features of Arctic Alaska and adjacent Canada.

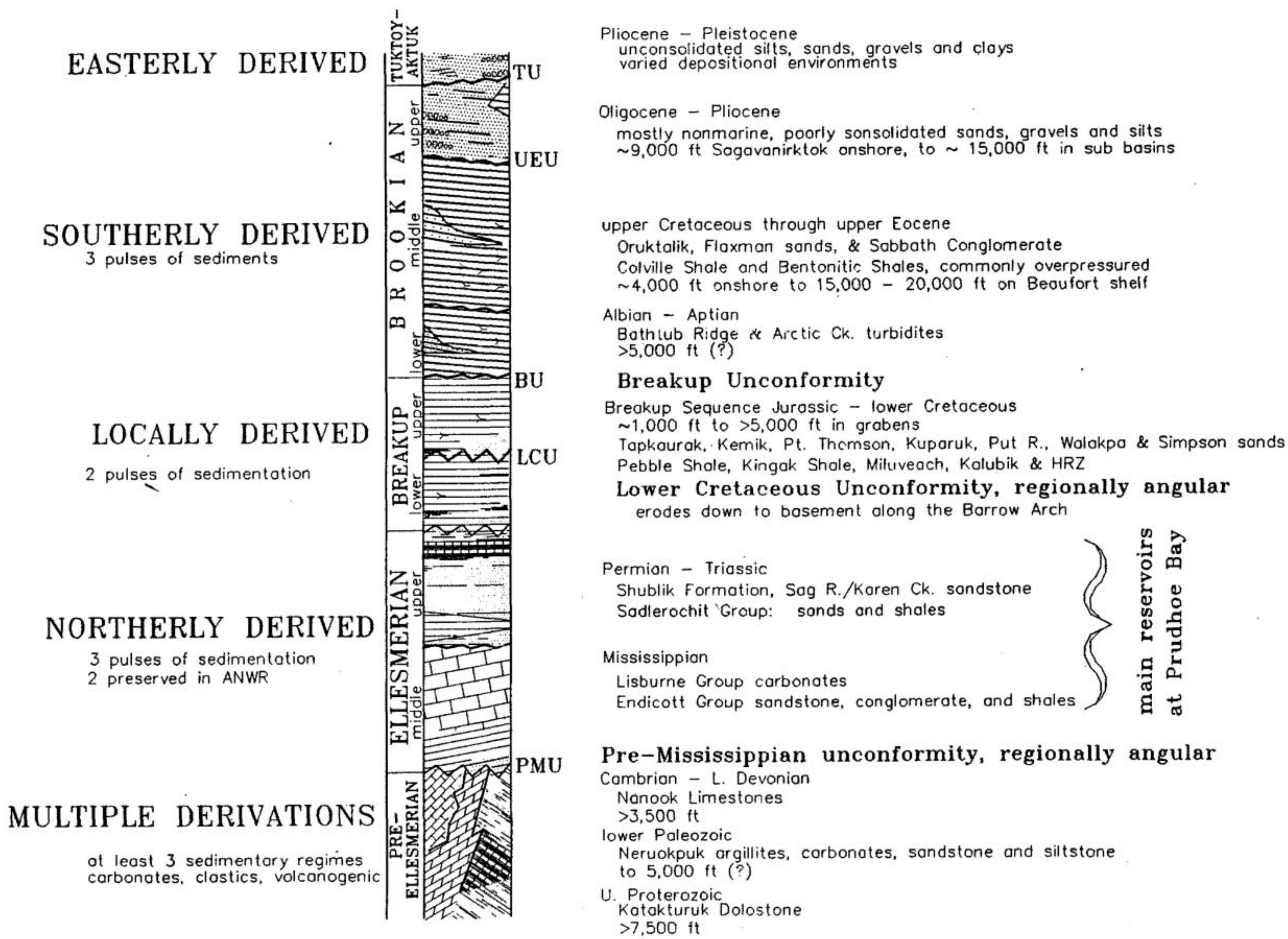

Figure 4
Generalized stratigraphy of northeast Alaska

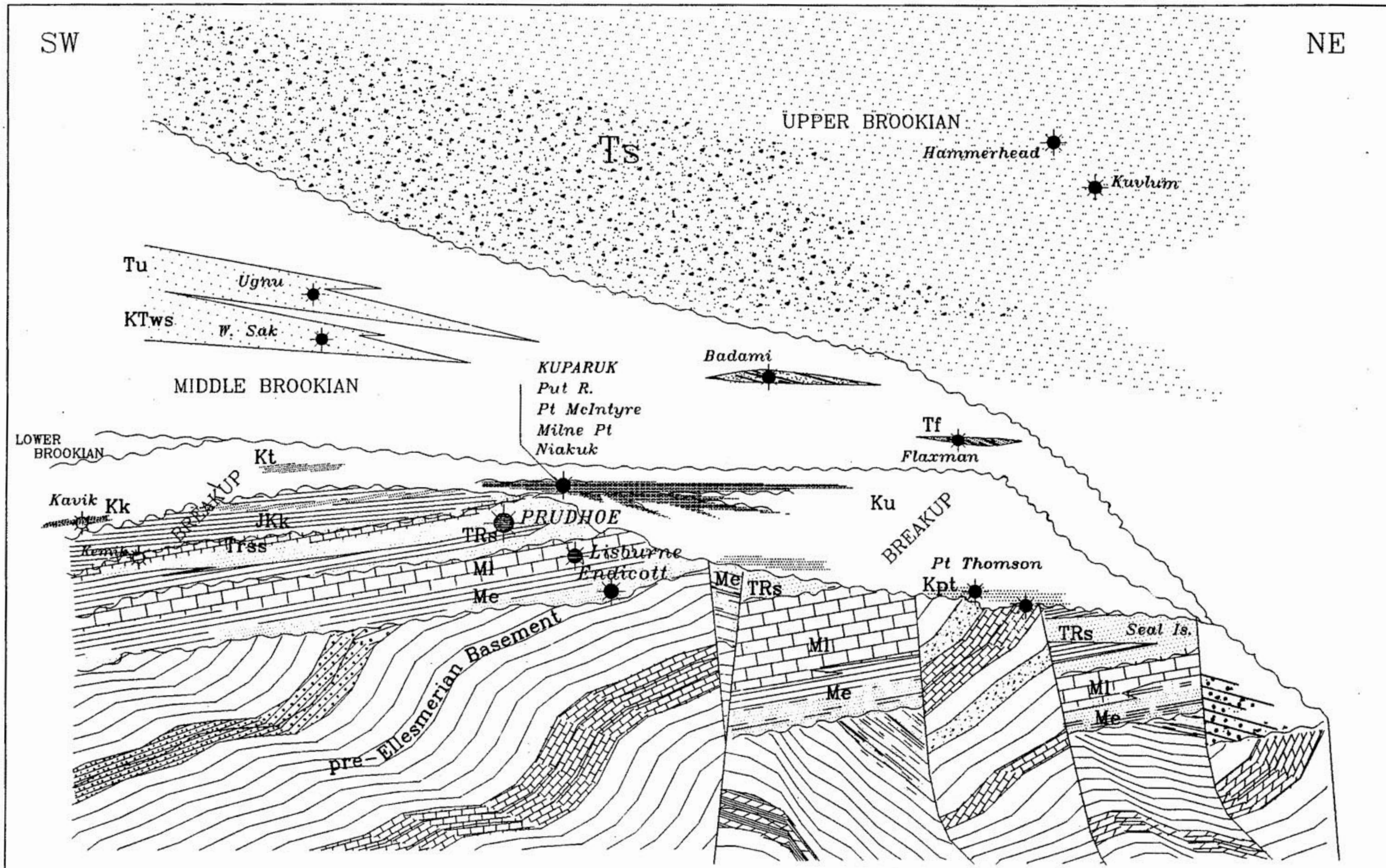

Figure 5

Generalized SW–NE cross section, superimposing major North Slope petroleum traps. Faults, unconformities, thicknesses and stratigraphic geometries highly stylized.

Gas and oil discoveries on coastal plain, highlighted.
Locally deposited Breakup Sequence sands:

Tapkaurak (Kt), Kuparuk R., Put R., Pt. Thomson (Kpt), Pt. Mc Intyre, Kemik (Kk), Simpson, Walakpa.

Table 1

A comparison of lower Cretaceous sands and shales from northeastern Alaska

HRZ AT KUPARUK

4 – 9 %TOC
shale w/ paper fissility
~200'
Albian – Aptian

KALUBIK FORMATION

below HRZ– 150 API
internal, local HRZ
overlies Kuparuk sands
mudst & slst
carbonaceous
moderately fissile
pyritic & sideritic
200 ft. to 300 ft.
marine deposition

Barremian – Aptian
BREAKUP SEQUENCE

PEBBLE SHALE

GRZ
LCU basal unconformity
No. Slope regional
silty shale
black, fissile, pyritic
minor bentonite
200 ft. to 300 ft.
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
~ 1900 ft. thick
internal unconformities
GRZ in Pebble Sh.
black, manganiferous
few fossils
floating chert pebbles
Kemik sand ~ 260 ft.
quartz arenite to–
feldspathic wacke
very fine–grained
basal contact conformable

Berriasian – Barremian
BROOKIAN

ARCTIC CK.

ss & sh
vf. to fine grained
quartzose
5 ft. to 90 ft. beds
~ 250 ft. 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
500 ft.
~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
~ 5 mi. X ~15 mi.
Haut. – Barr.

oil & dissolved gas
BREAKUP SEQUENCE

KEMIK

below GRZ
LCU basal unconformity
sands to ~ 150 ft.
sand & shale
distinct to interbedded
fine–grained, rounded
well sorted, marine
No. Slope Regional
~6mi.X 24mi. units
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
~ 3mi X 5mi
east–southeast trend?
distinct contacts
barren of fuana

oil & condensate
BREAKUP SEQUENCE

TAPKAURAK: AURORA UNIT II

no GRZ
LCU at base
distinct contacts
interbedded ss & sh
coarsens & thickens upwards
174 ft. massive sand at top
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
Stra[illegible] phi[illegible] sitic[illegible] nd [illegible] aph[illegible] nph[illegible] d. [illegible]e a[illegible] elat[illegible] hips [illegible]erta[illegible]

tic sediments. Three distinct pulses of Brookian sedimentation occurred from middle Cretaceous through Pliocene time. Subsequent deformation began in western Alaska and generally proceeded to the east-northeast (Molenaar, 1983; Craig and others, 1987).

However, in the northeast the Bulge-forming uplift shed north-northwest prograding middle and upper Brookian depositional sequences (upper Cretaceous-Pliocene) which overstepped the Barrow Arch and the Hinge Line. Seismic stratigraphic analyses suggest that the middle Brookian sediments may be on the order of 20,000 feet thick on the Beaufort shelf. The Aurora location is also juxtaposed to the Barter Island and Demarcation sub-basins (Grantz and Mays, 1983), which are believed to contain thick sections of upper Brookian sediments (Craig et al, 1985; Banet, 1990, 1992a, 1992b; Dietrich and Lane, 1992; Scherr, et al, 1991).

3. Stratigraphy

The Aurora well penetrated a sedimentary section composed of both Brookian and Breakup Sequence rocks (figure 4).

Breakup Sequence

The deepest section is termed Unit I. At the Aurora well, it is made up of at least 1,000 feet of interbedded shales and thin-bedded sandstones that correlate to the Kingak Formation (upper Jurassic/lower Cretaceous). A lower Cretaceous unconformity (LCU of onshore nomenclature) truncates the Kingak. The overlying Unit II is the Tapkaurak Unit (17,325-16,646 feet). This is a coarsening and thickening upward section of interbedded sandstones and shale, which culminates in the very thick-bedded Tapkaurak sand (16,646-16,620 feet)- cf. figure 6.

In cuttings, this sandstone is mostly quartzose, fine- to coarse-grained, with subangular to subrounded clasts. There are abundant, clear to milky quartz grains with minor amounts of chert, volcanic, and other igneous rock fragments; biotitic micas from drilling additives (?) are also present.

Unit III is mostly shale (16,446- 15,937 feet). The shale is mostly brown to dark-gray with some carbonaceous laminations. There are a few thin, light gray or brown siltstone stringers. Logs indicate that Unit III is truncated by an unconformity. This is the lower Tertiary unconformity (LTU), and it is analogous to the lower Tertiary unconformity at the Point Thomson area, where middle Brookian sediments overlie Breakup Sequence sediments and basement rocks.

Middle Brookian Sequence

Unit IV is the basal part of the middle Brookian sequence at Aurora. This is the Oruktalik Unit. By analogy to the Point Thomson area, it is considered to be Paleocene in age (Banet, 1992a). The Oruktalik consists of an overall coarsening-upwards sequence of interbedded shales and sandstones. The shales are mostly blocky, gray to black, and silty. The sandstones are widely spaced near the base of the section, becoming amalgated into a single predominantly (67% sand) sandstone unit between 14,828 and 14,685 feet (figure 7). The Oruktalik sand consists of thin to thick beds that are generally friable. The cuttings are comprised of fine to coarse-grained, predominantly black and white chert fragments. Upsection, larger-grained, subangular fragments become common, and the mudlog includes reported conglomerate. Minor lithologies include siltstone, white and clear quartz clasts, and some coal. This section recorded overpressure, a gas show , and some minor staining.

Soft, friable, and interbedded siltstones, gummy clays, and shales with minor amounts of thin-bedded and widely-spaced sandstones comprise the remainder of the

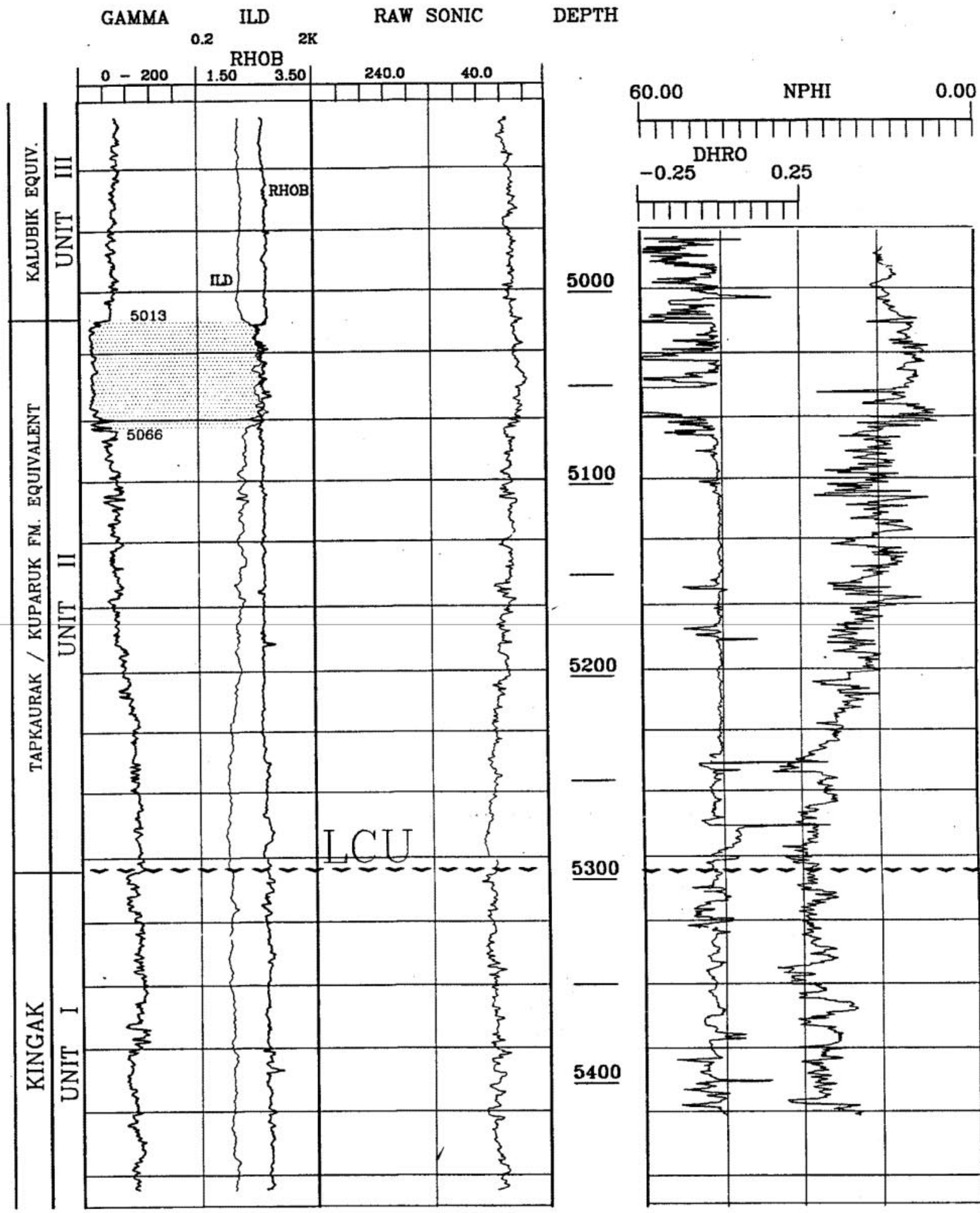

Figure 6

Geophysical logs through Tapkaurak Unit

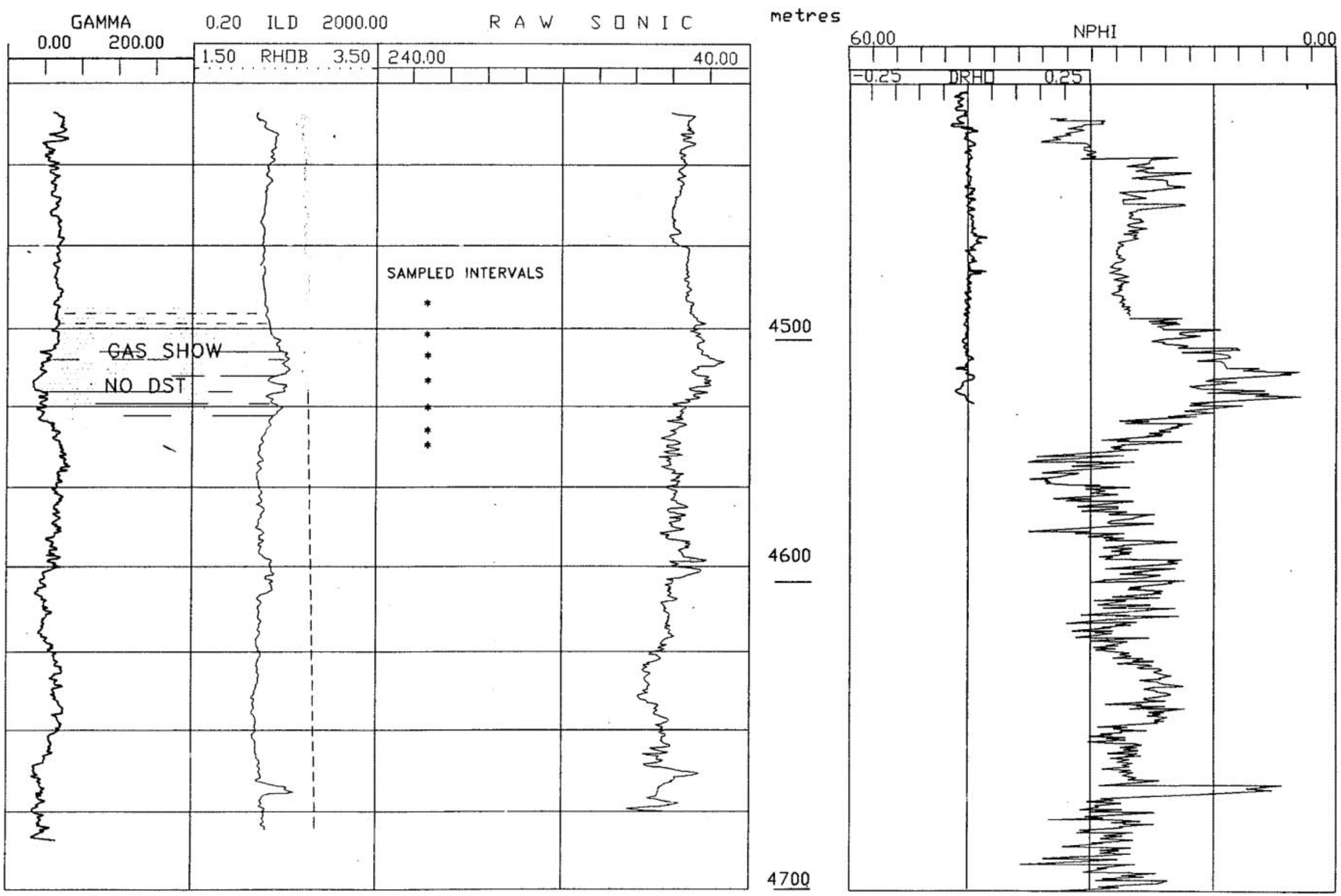

Figure 7

Geophysical logs through Öruktalik sand of Unit IV middle Brookian sequence sediments at Aurora. Units V through XIII (13,725-2,385 feet) are differentiated on their log characteristics and geochemistry (Banet, 1992a). These lithologies represent shelf environments of deposition. Regional interpretations indicate that this sequence is Paleocene to upper Eocene in age (Hubbard and others, 1987; Banet, 1992a, 1992b).

Upper Brookian Sequence

Log analysis suggests that an unconformity at 2,385 feet separates the middle from the upper Brookian sediments. This unconformity is of middle- to upper Miocene age (Hubbard and others, 1987). However, comparisons to the Canadian Beaufort suggest that multiple unconformities may also be present at this location (Dixon and others, 1985). Lithologically, Unit XIV is similar to the underlying middle Brookian sediments, but it also includes some conglomerate, peat, and partially coalified wood fragments. These constituents are commonly found in the mostly nonmarine Sagavanirktok Formation (Oligocene-Pliocene) of onshore nomenclature.

Tuktoyaktuk Sequence

Regional geology suggests that the upper Brookian section is overlain by some of the easterly-derived Tuktoyaktuk Sequence sediments (Banet, 1990). In northern Alaska, these are commonly referred to as the Gubik Formation. There is an angular unconformity between the upper Brookian Sagavanirktok and the Gubik at exposures in the ANWR area. Comparisons to the Tuktoyaktuk Sequence of the Canadian Beaufort suggest that this area may have also undergone several episodes of local uplift and erosion.

4. Petrographic Studies

This report presents the results of petrographic analyses of selected materials from the Aurora well. This well is of significant interest for a number of reasons, which, with further particulars of the well, are discussed elsewhere (Banet, 1992a, b, 1993a; Mowatt and Banet, 1993).

The studies described were somewhat limited, due to several factors. Information on the well was scheduled to be made public on August 26, 1991. On August 21, 1991, the Bureau of Land Management (BLM) made a formal request to the Geological Materials Center (GMC), State of Alaska, Eagle River, for access to, and sampling of materials of interest from this well, as soon as the materials had been transferred to the GMC repository and, thus, entered the public domain. This was the first request received by the GMC regarding the Aurora well materials. In the interim, however, prior to public release of these materials, representatives of a major petroleum company also expressed similar interests to the GMC. BLM agreed to defer to this organization, which promptly proceeded to examine, and sample, the drill cuttings and core materials upon their being made public.

Fourteen samples- all consisting of drill cuttings fragments- were selected by this company, from each of which a standard petrographic thin-section was prepared. After the company analyses had been carried out, these thin-sections were returned to the GMC, and made available to BLM for independent study. During the course of our analyses, yet another major petroleum company expressed strong interest, on two separate occasions, in also examining these thin-sections, and each time they were immediately made available to this organization. Additionally, an independent consulting geologist from outside Alaska subsequently made a special trip here to examine this suite. BLM also examined the entire collection of materials from the Aurora well presently on hand at the GMC, and selected an additional suite of twelve samples, which were analyzed petrographically as well.

The present report deals with our analysis of the entire suite of twenty six thin-sections.

5. General Analytical Considerations

Twenty-six standard petrographic thin-sections were examined, using a Nikon petrographic microscope in transmitted light, supplemented by inclined reflected light illumination. During preparation, one-half of each thin-section had been chemically treated with staining reagents to facilitate the identification of calcite, ferroan calcite, dolomite, and ferroan dolomite phases.

Each thin-section is comprised of a large number (many hundreds) of small (+/- 3.0 mm, and smaller) drill cuttings fragments. As is well-known, there are distinct disadvantages- and some advantages- to working with such samples.

Additional to materials representing stratigraphic horizons (rocks, ie.) penetrated by the drill, each sample contains significant- often predominant- proportions of apparent "contaminant" materials added during the the drilling operations. The more-readily recognized of these latter components included micas (apparently principally vermiculite/hydrobiotite/biotite; with lesser muscovite); woody (+/- bone?); and-possibly- other organic materials. There may be others as well. Perhaps (?) the "granitoid", as well as the perthitic fragments, similarly, represent introduced materials- possibly in this case associated with the micaceous materials. It should be noted that, though found as discrete cuttings fragments throughout the entire interval studied, neither "granitoid" nor perthitic grains have been recognized as constituents of sedimentary rock fragments in any of the thin-sections we have examined thus far from the Aurora well.

The "metamorphosed" sandstones-wackes, as a variation on this "anthropogenic materials" theme, may well not represent indigenous stratigraphic materials of this nature. "Artefacts" of the "metamorphic" effects of the drill bit on rock materials, though somewhat difficult to recognize as such in many instances, have been reported, and documented in the technical literature. The essentially ubiquitous presence of trace amounts of fragments with this type of texturally disrupted appearance in the thin-sections studied thus far in the Aurora well tends to suggest that they may well be representative of such "artefacts".

The descriptions which follow include generalized summary comments for each thin-section examined. Additionally, as appropriate, more detailed analyses of particular fragments are presented as well. Numerous photomicrographs were made during the course of the work, and are on file with the Branch of Lease Operations, Division of Mineral Resources, BLM, Alaska State Office, Anchorage.

Copies of portions of selected geophysical logs are included here as Figures 6 and 7, covering the depth intervals represented by these samples. Depths, in metres, are below the Kelly bushing, which was reported as 32 metres above the sea floor at the drill-site.

6. Sample Descriptions

Those cuttings fragments identified with a capital letter (i.e., "A") have been either subjected to detailed petrographic analysis, or described in summary fashion, and recorded as photomicrographs.

Terminology-classification follows Pettijohn, et al, 1987, in general fashion, as adapted from modified schemes used within the petroleum industry. Percentages represent visual estimates, using standard comparators.

Reference should be made to Plates 1 and 2 regarding stratigraphic and log information relative to these samples. Plates 3, 4 and 5 present selected representative photomicrographs; materials featured in these plates are highlighted in bold print within the text descriptions.

7. Reservoir Quality

We define "reservoir quality" for the purposes of the present report as: Those characteristics/properties of rocks/sediments which determine their capacity to contain, and to permit technologically feasible recovery of, petroleum (oil, gas, condensates). Principal petrophysical factors of significance in terms of petrographic analysis are porosity, permeability (i.e., effectiveness of porosity), mineralogy, and fabric; in essence, the pore-rock properties as determinable via the petrographic microscope.

Our comments as to "reservoir quality potential" with regard to a particular specimen/rock have reference principally to potential for development of appreciable secondary dissolution porosity (in the sense of Schmidt and McDonald, 1979a,b). This concept remains in an unresolved status of certitude/confusion at the present time. Summary points of view include Surdam, et al. (1984, 1989, among other papers) for a "pro", as contrasted with, for example, Giles and DeBoer (1990) as exemplifying a "con" position. Mowatt and Mowatt (1991) summarize aspects of this, principally in terms of earlier (through 1982) perspectives, in context of Brookian sedimentary rocks elsewhere in northern Alaska.

The not uncommon/essentially ubiquitous occurrence of secondary dissolution porosity has been reasonably well established as a geological reality. Initial optimism (early 1980s) regarding its potential for leading to development of "enhanced" overall porosity/reservoir quality in rocks has, however, been tempered somewhat by a seeming paucity of demonstrable examples of effects of this sort, other than in relatively localized situations. This latter state of appreciation has been supported by various lines of experimental work and theoretical reasoning as well, although this remains a topic of intense interest, research, and continuing discussion/debate. The technical literature in recent years is replete with examples keyed to this theme.

The present authors' approach remains somewhat "agnostic" to all of this. Certainly secondary dissolution porosity is a geological fact; part and parcel/an essential accompaniment of the modification of many/most sediments/sedimentary rocks, as they undergo "diagenesis" subsequent to deposition. We prefer to consider each situation on an individual basis regarding potential for development of significant porosity, in any particular combination of rock type-geologic setting. Hence our appraisal of "potential" herein is predicated solely on consideration of a given sediment/rock in terms of its present complement of those characteristics-mineralogy and fabric-which are judged most relevant to potential development of secondary dissolution porosity per se. Amount, extent, significance, degree of enhanced porosity likelihood are not, in our opinion, readily amenable to "prediction" in any rigorous sense, given limitations of present knowledge.

A recent paper by Bloch (1991) nicely illustrates the empirical approach currently utilized to attempt to predict reservoir quality (porosity and permeability, i.e.). As Bloch points out (p.1145):

> Current efforts to predict porosity and permeability in sandstones prior to drilling are focused on empirical and process-oriented models. Empirical predictions are based on the correlation between porosity and permeability and a limited number of parameters obtained

> from calibration data sets or estimated from appropriate geologic models...... Process-oriented approaches attempting to model the effect of diagenesis on reservoir quality are hampered by inadequate quantitative understanding of the processes responsible for preserving primary porosity and generating secondary porosity and permeability. Until adequate quantification of the sandstone diagenesis processes is achieved, empirical models have a distinct advantage over process-oriented models in providing reliable predictions of reservoir quality in many sandstone intervals.

He goes on to present a well-reasoned demonstration of this thesis in the remainder of his paper. Bloch also makes the following cogent observations:

> The focus of process-oriented techniques is on modeling diagenetic processes and their effects on the evolution of reservoir quality. Among those techniques, chemical and mathematical models are useful in simulating diagenetic sequences (Bruton, 1985; Meshri, 1989), but are not yet capable of quantifying changes in porosity and permeability (Surdam and Crossey, 1987; Schmoker and Gautier, 1988; Meshri, 1989). (p.1145)

> Despite its successes in many geological settings, the empirical approach is not the ultimate answer to porosity and permeability prediction. In some targets, important diagenetic processes may not be accounted for by parameters comprising a given calibration data set and result in quantitatively inaccurate predictions. However, despite its limitations, the empirical technique presently provides the only feasible approach to reservoir quality prediction. (p. 1158)

Lacking the requisite calibration data sets, etc., our approach to "reservoir quality- present/potential" needs remain rather simplistic, hence the approach adopted above. We are continuing our studies of diagenetic relationships in the Aurora well, with the view to obtaining a more comprehensive appreciation of controls on reservoir properties within this well, and regionally.

8. Thin-Section Analysis

13,800-13,810'

Principal fragment types

Predominant: 1. Cherts, of various types; some contain appreciable pyrite, or carbonate minerals (eg., photos "Y, G"). 2. Litharenites; feature cherts, lithic grains, plagioclase carbonate(s); constituent grains range from very-coarse (at least) sand, and finer. Photographs "A, B, C, R, S, U, V, W, Y, Z" show some examples. 3. Argillaceous rocks; siltstones-mudstones/shales, some are organic-rich. Photos "W, G" show examples.

Subordinate: 4. Discrete quartz; some exhibit quartz overgrowths. Photos "G, W" show examples. 5. Plagioclase; twinned, from litharenites (?). Photo "T" shows an example. 6. Carbonate minerals; calcite, dolomite. 7. Organic material(s); black, red. Some recognizable plant material. 8. Wood/bone(?); from drilling contamination (?). 9. Carbonate rocks; dolomite, some containing plagioclase grains, some containing appreciable pyrite. 10. "Metamorphosed" rocks; medium sand/silt-bearing xargillaceous rocks. Photo "X" shows an example.

13,800-13,810'

Fragment A:

Feldspathic litharenite. Fine-medium sand-sized; massive. Grains moderately sorted, angular-subrounded. Texturally, mineralogically, and diagenetically immature. Grains = 90%; matrix = 10%; cement nil; visual porosity nil. Grains consist of quartz (20%+/-), including monocrystalline and polycrystalline varieties, with straight and undulose extinction represented; feldspars (10%)- plagioclase, potassium (?) feldspar; lithic fragments (70%+/-)- cherts, argillaceous arenites/wackes, argillaceous rock fragments, calcite fragments, plagioclase, plagioclase with quartz (i.e., "granitoid" ?); trace amount of detrital opaque mineral(s)- white; also one chert grain which contains on the order of 50% pyrite; biotitic micas (<5%). Matrix of argillaceous materials. Grain contacts are irregular; there is a slight degree of deformation of the matrix. This rock has undergone moderate apparent compaction. This rock has nil reservoir quality as is. Poor-fair (?)potential for improvement diagenetically, via dissolutiion of labile grains (feldspars, cherts, carbonates, ie.).

13,800-13,810'

Fragment C:

Feldspathic litharenite. Fine sand-sized, massive. Grains moderately sorted, subangular-subrounded. Texturally, mineralogically, and diagenetically immature. Grains = 85%+; matrix = 10%; cement = +/-5%; visual porosity is nil. Grains consist of quartz (+/-40%)- mostly monocrystalline, some polycrystalline, with both straight and undulose extinction represented; feldspars (10%)- plagioclase, possibly some potassium feldspar; lithic fragments (+/- 50%)- cherts, argillaceous rock fragments; white-grey opaques (3%); micas and chlorite (5%).

Matrix of argillaceous materials; associated organic materials; also some pseudomatrix after argillaceous rock fragments. Cement consists of quartz. Grain contacts irregular; some deformation of argillaceous rock fragments and micas. This rock has undergone moderate apparent compaction. This rock has nil reservoir quality as is, and poor potential for improvement via diagenesis. /

14,440-14,450'

Predominant: 1. Feldspathic-arkosic litharenites/wackes; medium sand size and smaller; may contain appreciable plagioclase (oligoclase-andesine); some have dolomite +/- calcite lithic grains as well. Some are pyrite-rich. Photomicrographs "A, B" are representative; "C" show a unique fragment; "D, E, F, Z" also feature examples.

Subordinate: 2. Argillaceous rocks: siltstones-mudstones/shales; many are organic-rich (eg. photomicrographs "E"); some are pyrite-rich. 3. Organic matter; black. 4. Discrete quartz. 5. Cherts 6. "Metamorphosed" sandy/silty argillaceous rocks 7. Discrete pyrite Photomicrographs "D, E, F, Z" present general aspects of this thin-section.

14,440-14,450'

Fragment A:

Feldspathic litharenite. Very fine-fine sand-sized, massive, moderately/well-sorted, subangular/subrounded grains; texturally, mineralogically, diagenetically immature. Grains=90%+/-; matrix=10%+/-; cement=trace; visual porosity nil. Grains consist of quartz (30+%), monocrystalline principally, some polycrystalline, straight and undulose extinction represented; feldspars (30+%)- plagioclase, (?) potassium feldspar; lithic grains (30+%)- principally cherts, argillaceous rocks, (?) metamorphic rocks. Opaque materials (trace); white, black. Cement consists of traces of quartz. Grain contacts range through concavo-convex; the rock appears to have undergone a moderate degree of compaction. This specimen is not a reservoir rock as is, but it might offer fair potential for improvement elsewhere via secondary dissolution of labile constituents (plagioclase, cherts). The argillaceous matrix/pseudomatrix, as well the degree of compaction are negative factors in this regard. On balance, poor/fair (?) potential.

Fragment B:

Feldspathic litharenite. Very fine-fine sand-sized; massive. Grains moderately sorted, range angular-rounded. Texturally, mineralogically, diagenetically immature. Grains=85%+/-; matrix=10%+/-; cement=5%+/-; visual porosity nil. Grains consist of quartz (30%+/-), mostly monocrystalline, some polycrystalline, with straight as well as undulose extinction represented; feldspars (10%+/-)- plagioclase, (?) potassium feldspar; lithic fragments (60%+/-)- cherts, argillaceous rocks, trace of carbonate rock fragments (calcite), perhaps (?) trace amounts of metamorphic and/or igneous rock fragments. Opaque minerals (3-5%+/-), principally associated with argillaceous materials. Micas- biotitic (3%+/-). Matrix of argillaceous materials, with associated organic matter and pyrite. Some pseudomatrix developed from argillaceous lithic grains. Cement consists of pyrite, often in association with argillaceous materials, as well as trace amounts of quartz. Grain contacts range through concavo-convex; also some apparently intergrown grain boundaries as well. Some pseudomatrix developed. This rock has undergone a moderate (+) degree of apparent compaction. This rock is not a reservoir rock, as is. Fair potential for improvement elsewhere might be considered, via secondary dissolution of labile grains (feldspars, cherts). However, the argillaceous matrix and pseudomatrix, the degree of apparent compaction, and the mica grains are all negative factors in this regard. On balance, poor potential.

Fragment C:

Feldspathic sublitharenite. Very fine sand-sized; massive. Grains well/very well sorted, subangular- rounded. Grains= 80%+/-; matrix=3%; cement=15%+/-; visual porosity nil. Grains consist of quartz (70%), monocrystalline, lesser polycrystalline, both straight and undulose extinction represented; feldspars (10%)- plagioclase; lithic fragments (20%)- cherts, argillaceous rocks (?), perhaps also trace amounts of metamorphic and/or igneous rocks (?). Biotitic micas, chlorite (3%). Matrix of argillaceous materials. Cement consists of quartz, as well as subequal amounts of pyrite. Grain contacts range through concavo-convex, with indications of some intergrown grain boundaries as well. This rock has undergone a moderate (+) degree of apparent compaction. This rock has nil reservoir quality as is. Poor potential for improvement elsewhere, diagenetically, because of low labile minerals content, degree of cementation, degree of apparent compaction, argillaceous materials, and grain size. However, prior to the quartz cementation, this very fine/fine sand might have offered fair or better reservoir quality.

14,680-14,690'

Principal fragment types:

Predominant- 1. Fine-medium-grained litharenite. The dominant rock material in this thin-section. "A" and "B", described below, are representative. Some fragments are feldspar-bearing/feldspathic (plagioclase: oligoclase-andesine). "E" is an example. 2. Siltstone-mudstone/shale. A major constituent of the suite of cuttings fragments in this thin-section. Some are bimodal, with sand-sized grains (quartz, rock fragments, some plagioclase) "floating" in a silt-clay matrix.

Subordinate- 3. Discrete quartz. Trace. 4. Calcite/limestone. Trace. 5. Discrete plagioclase (oligoclase/andesine). Trace. 6. Discrete potassium feldspar; at least one perthitic fragment was noted. "C" is an example. Trace. 7. Pyrite-rich clastic sedimentary rocks- some may, rather, be volcanic rocks (?). Trace. 8. "Granitoid" rocks: plagioclase (twinned)-quartz-muscovite. "D" is an example. Trace. 9. "Metamorphosed" sandstone/micaceous sandstone; metamorphic rocks/fault-related/artefacts of drilling (?). "F" is an example. Trace. 10. Organic materials; many are black, a few are reddish.

A minor component.

Fragment A:

Litharenite. Fine sand-sized, massive fabric, moderately/well-sorted, sub-angular/subrounded grains, texturally submature, mineralogically and diagenetically immature. Grains = 80%+/-; matrix = nil; cement = 10%; visual porosity= 10%. Grains consist of quartz (30%), monocrystalline principally, some polycrystalline, most exhibit undulose extinction; feldspars (10%)-plagioclase, +/-?; lithic grains (+/- 60%)- principally sedimentary rocks, featuring argillaceous rocks and cherts, with trace amounts of carbonates (limestone, dolomite), and trace proportions of metamorphic (?-chloritic) and igneous (felsic volcanic?) rock fragments. Opaque materials (+/- 3%)- organic (also some hydrocarbon staining ?), and pyrite in detrital lithic grains. Cement principally carbonate (dolomite, most likely), with subordinate quartz. Suggestions of organic materials (hydrocarbons?) associated with inter- and intragranular porosity, and with fractures. Visual porosity principally secondary in character, featuring corroded grain edges and interiors, as well as cemensignificant microporosity as well. Some apparent fracture porosity may well, rather, represent artefacts of sampling/sample preparation. Effectiveness of total porosity fair-good(?). Grain contacts range through concavo-convex, perhaps greater; the rock appears to have undergone a moderate degree of compaction. This specimen represents fair reservoir quality as is, with potential for improvement elsewhere via further development of secondary dissolution porosity (carbonates, cherts, other lithic fragments, feldspars are possible candidates).

Plate 3-C depicts this fragment.

14,680-14,690'

Fragment B:

Litharenite. Very fine-fine sand sized. Massive fabric. Grains moderately-well sorted, subangular-subrounded. Texturally immature-submature. Mineralogically and diagenetically immature. Grains = 80%+/- ; matrix = 5% (also some pseudomatrix); cement = 5%; visual porosity = 3%+/-.

Grains consist of quartz (40%+/-); feldspars (10%+/-)- plagioclase, potassium feldspar (?); lithic fragments (50%)- featuring cherts, argillaceous rocks, carbonate fragments, metamorphic rocks (?), igneous rocks (??); opaques (5%+/-)-organic matter, traces of pyrite; trace amounts of glauconite (?), chlorite.

Matrix of argillaceous materials, with indications of associated organic materials (hydrocarbons ?).

Cement principally consists of carbonate mineral(s?), most likely dolomite; subordinate quartz cement. Visual porosity secondary in character, principally reflecting dissolution of detrital grain edges and interiors (lithic fragments, feldspars), as well as partial dissolution of cements (carbonates). Associated subordinate microporosity. Effectiveness of total porosity essentially nil. Grain contacts range through concavo-convex. The rock has undergone a moderate degree of apparent compaction. This rock possesses essentially nil reservoir quality as is. It has a fair degree of potential for improvement elsewhere, via secondary dissolution porosity development (carbonates, cherts, lithic fragments, feldspars are possible candidates). However, the grain size, degree of compaction, clay content, and quartz cementation are negative factors in the latter regard.

Plate 3-B depicts this fragment.

Fragment E:

Feldspathic litharenite. Fine sand-sized; vaguely layered. Grains moderately sorted, subangular-subrounded. Texturally, mineralogically, and diagenetically immature. Grains = 95%+; matrix = <5%; cement = trace; visual porosity is nil.

Grains consist of quartz (30%+/-), mostly monocrystalline, with straight as well as undulose extinction represented; feldspars (10%+)- plagioclase (An5 or 35), potassium feldspar (?); lithic fragments (50%+)- cherts, carbonate fragments, argillaceous rock fragments, metamorphic and/or igneous rock fragments (?); trace amount of possibly detrital opaques- most likely organic materials; trace amount of mica(s?) in particle sizes sufficiently large to warrant their being distinguished from being considered under the term "detrital matrix". Matrix of argillaceous materials; also lesser pseudomatrix. Cement consists of quartz; there may be small/trace amounts of clay minerals ocurring as cement as well; this is optically indeterminate here.

Visual porosity is nil. Grain contacts range through concavo-convex; some lithic fragments and micas have been deformed sufficiently to be termed pseudomatrix. This rock has undergone moderate apparent compaction. This rock has nil reservoir quality as is. Poor/fair(?) potential for improvement elsewhere, via development of secondary dissolution porosity (carbonates, cherts, feldspars are the most likely candidates). However, the grain size, degree of compaction, and the clays/micas matrix/pseudomatrix are negative factors in the latter regard.

14,710- 14,720'

Principal fragment types:

Predominant- 1. Cherts; a variety of types. Major component of these cuttings fragments. Some contain appreciable amounts of carbonate minerals. "C" is an example. 2. Litharenites. Various constituent grain sizes, conglomeratic to fine sand. A major component. Many are feldspar-bearing/feldspathic (plagioclase, +/- ?). Chert grains are important constituents as well. Appreciable amounts of carbonate minerals may be associated. "A" and "B" are examples. 3. Organic materials. An appreciable component. Mostly black, a few are reddish.

Subordinate- 4. Siltstones-mudstones/shales. Some are organic-rich. There are also quartz and carbonate-filled veins in some. A minor component of these cuttings fragments. 5. Discrete quartz. Some are well-rounded. A minor component 6. Discrete plagioclase. Trace. 7. Arenites with abundant pyrite, as rims on fragments, grains; within fragments. Trace. 8. Volcanic ("felsic") rocks. "D" is an example- featuring: euhedral plagioclase phenocrysts, twinned, albite/andesine composition, slightly zoned; in a very-fine grained groundmass of quartz, +/- (?) of "cherty" aspect. Trace component. 9. Medium (+?) grained litharenite, comprised of sedimentary rock fragments, and one igneous (basaltic) rock fragment. The latter features: sub-euhedral plagioclase phenocrysts, 0.1 mm (+) in size, of optically indeterminate composition; chlorite interstitial to the plagioclase. Moderate degree of alteration- of plagioclase to clinozoisite/and, possibly, also albitization (?), and chlorite (representative of original glassy to fine-grained matrix material) suggests metamorphism (low-grade) of this rock, prior to its' being incorporated into the litharenite. Only one fragment was recognized in this thin-section, "E". 10. Igneous (volcanic ?) rock fragment. Plagioclase; euhedral, twinned, fairly fresh, albite/andesine. It is problematic as to whether this cuttings fragment "F" represents one lithology- ie. a volcanic (?) rock, or, rather, the fragment is a sedimentary rock (litharenite), with grain(s?) of igneous rocks incorporated 11. "Metamorphosed" sandstones-wackes. Metamorphic rocks/fault-related/artefacts of drilling (?). Trace component. 12. Carbonate materials- calcite, dolomite. Trace.

Fragment A:

Conglomeratic litharenite/conglomerate. One constituent grain (partial) is of granule -or possibly larger- size; the other detrital grains comprising this specimen are in the fine-medium sand size range. Vague layering is manifest. The grains are poorly sorted, subangular-subrounded; the specimen is immature texturally, mineralogically, and diagenetically.

Grains = 80%+; matrix = <5%; cement = 8%+/-; visual porosity is nil. Grains consist of quartz (10%)- monocrystalline, polycrystalline, straight as well as undulose extinction;lithic fragments (90%+/-)- siltstones/very fine sandstones, cherts, argillaceous rock fragments; opaques (<3%)- pyrite, organic materials. Matrix of argillaceous materials. Some of the associated organic materials may represent hydrocarbons (?). Cements consist of carbonate minerals (70%—ferroan calcite, principally), as well as "opaline" (?) silica/zeolites(?)—on the order of 30% of the total cement— of a paragenesis subsequent to at least some of the carbonate cement. Visual porosity is nil. Grain contacts range through line to concavo-convex. This rock shows the effects of moderate apparent compaction. This rock has nil reservoir quality as is. Fair -or better- potential for improvement elsewhere, via development of secondary dissolution porosity (carbonates, cherts, "opaline silica"/zeolites(?) are principal candidates).

Fragment B:

Litharenite. Very fine- fine- medium sand size grains. Isotropic fabric. Grains poorly-moderately sorted; subangular-subrounded-rounded. Texturally, mineralogically, diagenetically immature. Grains =90%; matrix =<5%; cement =<5%; trace of visual porosity. Grains consist of quartz (40%)- monocrystalline, undulose extinction; feldspars (10%)- plagioclase; lithic fragments (50%+/-)- cherts, argillaceous siltstones, sandstones; opaques (<5%)- pyrite, organic materials. Matrix of argillaceous materials; associated organic materials may represent hydrocarbons (?) at least in part. Cement consists of quartz. Visual porosity trace (microporosity). Nil effectiveness.

Grain contacts range through concavo-convex. This specimen has undergone moderate apparent compaction. Nil reservoir quality as is. Poor-fair(?) potential for improvement elsewhere, via development of secondary dissolution porosity (feldspars, cherts the principal candidates). However, the degree of compaction, and matrix/pseudomatrix militate against this somewhat.

Fragment C:

Chert. Fragment includes one fine sand-size quartz grain, as well as numerous rhombs of carbonate (ferroan calcite), in a crystalline silica matrix.

Visual porosity nil.

Nil reservoir quality as is. Cherts, particularly those containing appreciable carbonate mineral components, are candidates for secondary dissolution porosity development under appropriate conditions.

14,740-14,750'

Principal fragment types:

Predominant- 1. Wood/bone (?) material; contaminant from drilling operations. The predominant component of the cuttings fragments in this thin-section. "B" is an example. 2. Cherts, of various aspect; there is a plethora of types in this thin-section. A major component of the cuttings fragments from this interval. Some are pyritic, or carbonate-bearing. 3. Argillaceous rocks: mudstones/shales-siltstones. Include organic-rich, quartz-veined, siliceous (some spiculitic ?) varieties. A major component of the cuttings fragments in this thin-section.

Subordinate- 4. Litharenites: conglomeratic and finer-grained. Feature quartz, cherts, lesser argillaceous rock fragments. "A" is an example. Some ("G", eg.) are feldspar-bearing (plagioclase). A minor component of this thin-section. 5. Organic materials. Black, some reddish. Minor component. 6. Volcanic rock fragments. "C" is an example. Trace component. 7. Calcite/limestone. Trace component. 8. "Metamorphosed" litharenites-siltstones. Metamorphic rocks/fault-related/artefacts of drilling?

Trace component. 9. Photomicrographs "X" feature a fragment comprised of a chert (?)/volcanic rock (?) grain, with carbonate (some is ferroan calcite); grains of argillaceous rocks; a grain of volcanic/igneous rock, with highly altered plagioclase, associated with carbonate +/- other phases. This fragment is a silica-cemented ("cherty") litharenite; or, rather, a felsic tuff/breccia (?). 10. Photomicrographs "W, Y" are overviews of this thin-section. "W" include parts/all of fragments "A, X". "Y" feature a fragment of silty mudstone adjacent to fine sand-size wacke, as well as other fragments.

Fragment A:

Conglomeratic litharenite. Fine-medium sand size grains, with one pebble of chert. Poorly sorted; sand size grains are angular-subrounded, pebble is rounded/well-rounded. Texturally submature; mineralogically and diagenetically immature. Grains = 90%; matrix = trace/nil (although the sand size grains may be considered as "matrix" to the pebble); cement = 10%; visual porosity = trace/nil. Grains consist of quartz (20%+)- mono- and polycrystalline, with straight as well as undulose extinction represented; lithic fragments (70%+)- cherts (some with pyrite), argillaceous rocks; others (5%+)- chlorite, micas, glauconite (?). Matrix of argillaceous materials, as well as some pseudomatrix after lithic fragments. Cement consists of carbonate minerals- dolomite, with zones of ferroan dolomite at the margins; also discrete ferroan calcite. Visual porosity nil. Grain contacts range through concavo-convex; also feature pseudomatrix developed from deformation of lithic fragments. This specimen has undergone moderate apparent compaction. Nil reservoir quality as is. Moderate potential for improvement elsewhere, via development of secondary dissolution porosity (carbonates, cherts are principal candidates). If hydrocarbons were to enter a rock such this as prior to carbonate cementation, the rock would have good reservoir characteristics.

Plate 3-D depicts this fragment.

Fragment C:

Felsic volcanic rock. Probably a constituent of a coarser-grained sedimentary rock type (conglomerate/breccia). Features phenocrysts of quartz, plagioclase (oligoclase-twinned, zoned, deformed, occurring as glomeroporphyritic aggregates).

Groundmass of siliceous, +/- other optically obscure materials- including some plagioclase laths, opaques (pyrite, +/-?). A relatively unaltered rock.

14,770-14,780'

Principal fragment types:

(this suite is very similar to that from the overlying interval, 14,740-14750').

Predominant- 1. Wood/bone (?) material, contaminant from drilling operations. The predominant component of this thin-section. 2. Cherts, of various aspect. Includes pyritic, organic-rich, carbonate mineral(s)-associated (some rhombic ferroan calcite) types. A major component of this thin-section. 3. Argillaceous rocks: mudstones/shales. May be organic-rich, veined with quartz (eg. "B"), spiculitic? (and/or radiolarian?).

Subordinate: 4. Litharenites: conglomeratic to fine sand-sized constituent grains. "A" is a feldspar-bearing (plagioclase; oligoclase-andesine) example. A minor component of this thin-section. 5. Organic materials. Black, some reddish. Minor component. 6. Volcanic ("felsic") rocks. Trace component. 7. Photomicrographs "W" show an overview of this thin-section, including fragment "A".

Fragment A:

Litharenite. Vague layering. Fine sand size grains; well sorted; subangular-subrounded. Texturally, mineralogically, diagenetically immature. Grains = 90%; matrix = 10%; cements nil; visual porosity = trace. Grains consist of quartz (50%+/-)- mono-and polycrystalline, with straight and undulose extinction represented; feldspars (10%)- plagioclase, potassium feldspars (?); lithic fragments (40%)- cherts, argillaceous rocks; chlorite (3%+/-); trace pyrite. Matrix of argillaceous materials; also some argillaceous lithic fragments have been deformed into pseudomatrix. Visual porosity consists of traces of microporosity and —possibly— fracture porosity. Pore linings of clay materials—apparently principally detrital. Porosity effectiveness is nil. Grain contacts range through concavo-convex, with some deformation resulting in formation of pseudomatrix. This rock has undergone moderate apparent compaction. Nil reservoir quality as is. Clays, grain size, degree of compaction militate against further improvement. However, development of secondary dissolution porosity (from cherts, feldspars, +/-?) could be construed as reasonably feasible. Perhaps, on balance, there is likely poor-fair potential for significant improvement.

14,800-14,810'

Principal fragment types:

Predominant- 1. Wood/bone (?) material. Contaminant from drilling operations. A major component of this thin-section. 2. Cherts, of various aspect. Some spherule (radiolarian ?)-bearing. A major component. 3. Argillaceous rocks: siltstones-mudstones/shales. Some are organic-rich, veined. A major component. 4. Litharenites: conglomeratic and finer-grained. "A" is an example. A major component. 5. Organic matter; most is black, some reddish. A minor component of this thin-section. 6. Volcanic rocks. "B" is an example; "C" may be, also. Trace component. 7. Discrete plagioclase (albite-andesine). Trace component. 8. Calcite/limestone. Trace component. 9. Ferroan calcite. Trace component. 10. Discrete quartz. Trace component. 11. "Problematic" fragment ("W"). Comprised of grain showing micrographic/micro-pegmatitic texture (?)- quartz, in a "host" of orthoclase (?) microperthite (?), with an attached rhomb of ferroan calcite. 12. "Metamorphosed" litharenites-siltstones. Metamorphic/fault-related/artefacts of drilling? Trace component. 13. Photomicrographs "D" show general overviews of this suite.

Fragment A:

Litharenite. Massive fabric. Grains are principally coarse-medium sand size; poorly-moderately sorted, subangular-subrounded. Texturally submature; mineralogically, diagenetically immature. Grains = 90%; matrix trace; cement = 10%; visual porosity trace (artefact?). Grains consist of quartz (30%)- mono- and polycrystalline, straight and undulose extinction represented; feldspars (10%)- plagioclase, potassium feldspars (?); lithic fragments (50%+/-)- cherts, argillaceous rocks, sandstones/siltstones; opaques (5%)- organic matter, lesser pyrite. Matrix of argillaceous materials. Cement consists of dolomite; indications of associated organic materials (including hydrocarbons?). Traces of visual porosity, as microporosity; also fracture porosity (artefact?). Effectiveness nil. Grain contacts range through concavo-convex; some argillaceous lithic fragments have been deformed to pseudomatrix. This rock has undergone a moderate degree of apparent compaction. Nil reservoir quality as is. Fair potential for improvement, via development of secondary dissolution porosity (carbonates, cherts, feldspars, are principal candidates).

Fragment B:

Mafic/intermediate (?) volcanic rock. This fragment is 0.9mm in its' longest dimension in thin-section. It consists of scattered microphenocrysts of plagioclase (oligoclase)- moderately deformed, twinned; finer grained matrix of plagioclase crystals of similar character, with associated interstitial chlorite (after original pyroxene/ glass?, presumably). Cf. comments above regarding fragment "C", 14,740-14,750'.

14,800-14,810'

Fragment C:

Comprised of two grains, each on the order of 0.3+mm. One, perhaps, represents an altered olivine (?)- as evidenced by olivine-like partings, black opaque phases associated, and reddish iddingsite-like material along the partings. Or, rather, an unusual "chert"(?). The other grain has the general aspect of a very fine-grained volcanic rock (?), or representative of "chilled marginal zone/matrix" (?). There are plagioclase laths, barely discernible, in a quartz— +/-(?) groundmass. In any event, a curiosity here, as a lithic fragment.

14,830-14,840'

Principal fragment types: *(cf. Plate 3-A)*

Predominant- 1. Discrete quartz. Fragments are mostly angular-subangular; range from 0.8 mm and smaller in size, as cuttings fragments. A major component of this thin-section. 2. Cherts, of various aspect. Some are carbonate-bearing (including ferroan calcite). A major component. 3. Argillaceous rocks: siltstones-mudstones/shales. May be organic-rich, pyritic. A major component. 4. Litharenites: conglomeratic and finer-grained. "B" and "C" are examples. Some are pyritic (one is >50% pyrite); one feldspar-bearing (plagioclase) example ("Y") was noted. A major component of this thin-section. Subordinate- 5. Carbonate rocks. "A" is an example. A minor component. 6. Organic material; mostly black. Minor component. 7. Wood/bone (?) material; contaminant from drilling operations. Minor component. 8. Volcanic rocks. "E" is an example. Predominantly plagioclase, twinned, albite-andesine; minor quartz, opaque minerals. Trace component. 9. Discrete plagioclase (+/-potassium feldspars?). Twinned, albite-andesine; some strongly zoned. Trace component. 10. Ferroan calcite. Trace component. 11. Calcite/limestone. Trace component. 12. "Granitoid" rock (?). "X" - quartz, plagioclase (albite-andesine). 13. Photomicrographs "Z" show overviews of this thin-section, including a chert-bearing conglomeratic litharenite. Also other quartz, carbonate-bearing (ferroan calcite), argillaceous rocks (pyrite-rich) fragments.

Fragment A:

Arenaceous (very fine-fine sand size quartz grains) dolomite. Visual porosity trace amount (artefact?)- fracture; effectiveness nil.

Fragment B:

Litharenite. Vague layering. Framework grains range from medium sand (trace)- fine (principally)- very fine sand size, with finer materials as well; poorly-moderately sorted; angular-subangular-subrounded. Texturally, mineralogically, diagenetically immature. Grains = 90%+; matrix = 5%+; cement is nil; visual porosity = traces (artefacts?). Grains consist of quartz (50%+/-)- mono- and polycrystalline, straight and undulose extinction represented; feldspars (5%+/-)- plagioclase, potassium feldspars (?); lithic fragments (40%+/-)- cherts, argillaceous rocks; opaques (5%+/-)- pyrite, also dark organic materials; trace amounts of chlorite. Matrix of argillaceous materials. Cement nil (pyrite may, actually, be authigenic/diagenetic, here). Visual porosity (fracture; artefacts?) in trace amounts. Effectiveness nil. Grain contacts range through intergrown/interlocompaction, and the clay/matrix are all negative factors in this regard. On balance, probably poor potential for improvement of reservoir quality.

Fragment C:

Litharenite. Massive fabric. Detrital grains range from medium sand (trace)- fine sand size, with lesser amounts of very fine sand, silt sizes. Sorting moderate-good. Grains are subangular-subrounded. Texturally submature; mineralogically, diagenetically immature. Grains = 95%+; matrix = trace; cements = 5%+/-; visual porosity = trace (artefacts?). Grains consist of quartz (40%)- mono- and polycrystalline, straight and undulose extinction represented; feldspars (5%)-plagioclase, potassium feldspars (?); lithic fragments (50%+)- cherts, argillaceous rocks, subordinate carbonate fragments (ferroan calcite, ferroan dolomite); traces of glauconite (?), chlorite (?). Matrix of argillaceous materials. Cements consist principally of carbonate minerals— ferroan calcite, ferroan dolomite (?); subordinate amount of pyrite; questionable traces of quartz- perhaps relict on detrital grains. Visual porosity consists of fractures, which may in fact be artefacts of sampling/sample preparation. Effectiveness is nil. Grain contacts range through intergrown/interlocking; some lithic fragments have been deformed to pseudomatrix. The rock has undergone a moderate (+) degree of apparent compaction. Nil reservoir quality as is. Fair potential for improvement elsewhere, via development of secondary dissolution porosity (cherts, feldspars, carbonate minerals are principal candidates). However, the degree of compaction, and the matrix/pseudomatrix are negative factors in this regard. On balance, a poor-fair potential for improvement.

14,850-14,860'

Principal fragment types:

The cuttings in this thin-section are rather similar in types, and relative abundances, to those in the overlying interval (14,830-14,840'). The thin-section here is, again, dominated by discrete quartz fragments- generally angular to subangular. There are lesser amounts of cherts, and argillaceous rocks- siltstones/mudstones/shales. Also present, in subordinate amounts, are organic materials (mostly black), occasional discrete plagioclase, and carbonates (calcite/limestone, dolomite). A minor proportion of this cuttings suite consists of litharenites; conglomeratic and finer-grained.

Photomicrographs "A-D, X" depict general characteristics of this thin-section.

15,000-15,010'

Principal fragment types:

Predominant: 1. Discrete quartz. Mostly on the order of 0.6mm and smaller, as cuttings fragments. Angular; undulose as well as straight extinction represented; monocrystalline, some polycrystalline. Some carry vestiges of quartz cement/overgrowths; others (few) have vestigial rims/patches of argillaceous materials. Photomicrographs "T, W" provide examples. 2. Argillaceous rocks: siltstones-mudstones/shales (some contain sand-size grains). Shown in photomicrographs "T, W". Subordinate 3. Cherts. 4. Plagioclase (cf. photomicrographs "T, TT". 5. Argillaceous sandstones; some contain plagioclase, and or carbonate materials (cf. photomicrographs "T, W"). 6. Pyrite-rich rock fragments; with chert, carbonate, +/- plagioclase (cf. photomicrographs "V, W"). 7. A few fragments of igneous (?- volcanic) rock, consisting principally of plagioclase (cf. photomicrographs "T, U"). 8. Organic matter; black (cf. photomicrographs "W"). 9. Potassium feldspar (?); trace amount.

16,410-16,420'

Principal fragment types:

Predominant 1. Argillaceous rocks: siltstones (some contain sand size grains)-mudstones/shales. Some are organic-rich/ pyrite-rich; some contain carbonate clasts; some feature rounded "floating" sand grains. Photomicrographs "A" are representative. Subordinate 2. Discrete plagioclase (contaminant ?). 3. "Granitoid" rocks; plagioclase+/-quartz+/-muscovite+/- potassium feldspar (orthoclase). Contaminant ? 4. Organic materials; black. 5. Sandstones/ wackes (fine sand size and smaller). Some contain carbonate clasts and/or plagioclase. Photomicrographs "A, B" feature examples. 6. Discrete quartz. Much is polycrystalline. Perhaps a contaminant, along with the "granitoid" rocks (?). 7. Micas; muscovite, +/-"hydrobiotite". Contaminant? 8. Wood/ bone material (contimnant). 9. Cherts; some are pyrite-rich. Photomicrographs "A" show examples of the more abundant of these fragment types.

Fragment B:

Litharenite. Very fine sand-sized grains. Massive fabric. Grains moderately sorted; subangular-subrounded. Texturally, mineralogically, diagenetically immature. Grains=90%; matrix=5%+/-; cement=5%+/-; visual porosity nil. Grains consist of quartz (70%)- most are monocrystalline, some are polycrystalline, both straight as well as undulose extinction are represented; feldspars (5%)- plagioclase, potassium feldspar (??); lithic grains (25%)- cherts, argillaceous rocks, carbonate grains. Trace amount of black opaques. Matrix of argillaceous material; also some pseudomatrix/micas. Cement consists of quartz; trace of clays (?). Grain contacts range through concavo-convex. This specimen has undergone a moderate degree of apparent compaction.

Nil reservoir quality as is. Poor potential for improvement elsewhere, due to grain size, argillaceous materials/micas, quartz cementation, relative paucity of potentially labile minerals, degree of compaction.

16,445-16,450'

Principal fragment types:

Predominant- 1. Discrete quartz. Angular-subangular, to well-rounded, range 0.9 mm and smaller in size, as cuttings fragments. Some show quartz cement/ overgrowths. Photomicrographs "C-G" illustrate these features. A major component of this thin-section. 2. Argillaceous rocks: siltstones-mudstones/shales. May be organic-rich. Shown in photomicrographs "C, D, G". A major component. 3. Litharenites-quartz arenites. Fragments "A" and "B" are representative. Photomicrographs "C, E, F" also show these. A major component of this thin-section. Subordinate- 4. Discrete feldspars. Plagioclase- twinned, oligoclase-andesine. Microcline microperthite. Orthoclase (?). Orthoclase (?) microperthite. Collectively, represent a minor component of this thin-section. 5. Cherts. May be pyritic- one fragment consists of >50% pyrite "framboids". A trace component. 6. Carbonate materials: dolomite rhombs; calcite/ limestone; ferroan calcite. Trace components. 7. Wood/bone (?) material. Contaminant from drilling operations. Trace component. 8. Mica (s?): of "bleached" aspect- perhaps vermiculitic; some muscovite. Indigenous to the strata, or, rather, contaminants from drilling operations? Trace components. 9. Organic materials; black. Trace component. 10. "Metamorphosed" wackes-siltstones. Metamorphic/fault-related/artefacts of drilling? Trace component.

Fragment A:

Quartzarenite. Massive fabric. Medium sand size grains, well-very well sorted, subrounded-rounded-well rounded(?). Texturally mature-supermature (?). Mineralogically, diagenetically immature/ submature. Grains = 90%; matrix nil; cement = 10%; visual porosity nil. Grains consist of quartz (100%+/-)- most are monocrystalline, with straight extinction; some are polycrystalline, with undulose as well as straight extinction represented. Cement consists of carbonate mineral(s)- dolomite, some siderite, most likely- (90%), and quartz (10%). The carbonate cement occurs in the unstained portion of the thin-section, unfortunately. Some of this material shows discernible zoning, from darker central portions of patches of intergranular cements to lighter toned margins- ie. perhaps from less to more ferroan, paragenetically, with deposition from pore margins inward. Remnant visual porosity is nil. Grain contacts range through intergrown/interlocking. The rock has undergone a moderate (+) degree of apparent compaction. Nil reservoir quality as is. Fair potential for improvement elsewhere, via dissolution of carbonate minerals. Quartz cementation, degree of apparent compaction, patchy distribution of carbonate cement are negative factors in this regard. On balance, poor/fair (?) potential for improvement. Pre-cementation, of good reservoir quality.

Fragment B:

Litharenite/sublitharenite. Vague layering. Detrital grains range from trace amounts of very coarse (?) sand to predominant proportions of fine-very fine sand size materials. Sorting is poor-moderate, the grains are angular-subangular-subrounded-rounded. Texturally, mineralogically, diagenetically immature. Grains = 90%; matrix = 8%+/-; cement = trace; visual porosity is nil. Grains consist of quartz (70%)- mono- and polycrystalline, straight and undulose extinction are represented; lithic fragments (30%)- chert, siliceous arenite, perhaps (?) trace amounts of volcanic rocks; trace of glauconite. Matrix of argillaceous materials; indications of organic materials associated (hydrocarbons?). Cement consists of traces of quartz. Visual porosity nil (some fractures, which likely are artefacts). Grain contacts range through concavo-convex/ intergrown. This rock has undergone a moderate (+) degree of apparent compaction. Nil reservoir quality as is. Poor-fair potential for improvement elsewhere, via development of secondary dissolution porosity (cherts, glauconite are principal candidates). Clays, grain size, degree of compaction, quartz cementation are negative factors in this regard. On balance, poor potential for improvement.

16,470-16,480'

Principal fragment types: *(cf. Plate 4-A)*

Predominant- 1. Discrete quartz. Angular to well-rounded, 1.0 mm and smaller in size, as cuttings fragments. Some show quartz cement/overgrowths. Photomicrographs "E, G, H, L" illustrate these. A major component of this thin-section. 2. Argillaceous rocks: siltstones-mudstones/shales.. A variety of types; some organic-rich. Photomicrographs "E, F, H, L" show examples. A major component. 3. Arenites-wackes. Several varieties. Very coarse sand sized, and finer. Some contain glauconite. "A-D, G, I" are examples of these lithologies. Photomicrographs "F, J, K, Q" also show others. A major component. 4. Discrete plagioclase; twinned. Trace component. 5. Cherts. Some are pyritic. Trace component. 6. "Metamorphosed" arenite-wacke. Metamorphic/ fault-related/artefacts of drilling? Trace component.

Fragment A:

Sublitharenite. Massive fabric. Detrital grains include trace amount of coarse sand, and predominant proportions of medium sand size materials. Moderately-well sorted, the grains are subrounded-rounded. Texturally mature, mineralogically and diagenetically immature. Grains = 85%; matrix nil; cement = 10%; visual porosity = 5% (much/all actually artefact?). Grains consist of quartz (80%)- mono- and polycrystalline, most exhibit undulose extinction; feldspars (trace)- plagioclase (and/or as cement ??); lithic fragments (20%)- argillaceous rocks, cherts, possibly some glauconite(?), perhaps trace amounts of volcanic rocks (?). Cements consist of quartz (75%), dolomite (25%), trace of plagioclase (??). Visual porosity ambiguous as to "artefact/non-artefact" character. Consists of apparent (?) secondary dissolution- edges and internal portions- of lithic fragments, and also of fractures. If (??) non-artefact, the resultant porosity could be fairly effective. Grain contacts range through concavo-convex/intergrown. The rock has undergone a moderate (+) degree of apparent compaction. Poor reservoir quality as is. Poor potential for improvement elsewhere, via dissolution of dolomite, and/or lithic fragments. Quartz cementation, degree of apparent compaction, and paucity of potentially labile grains are all negative factors. Prior to deep burial-compaction-quartz cementation, however, this rock likely had fair- or better- reservoir quality.

Fragment B:

Quartzarenite. Massive fabric. Medium sand (trace) and fine sand size grains, very well sorted, subangular-subrounded. Texturally submature/mature, mineralogically and diagenetically immature. Grains = 85%; matrix nil; cement = 15%; visual porosity = trace (artefact?).

Grains consist of quartz (98%+/-)- most are monocrystalline, some are polycrystalline, undulose extinction is ubiquitous; lithic fragments (trace)- argillaceous rocks; traces of black organic matter. Cements consist of quartz (30%), and carbonates (70%)- dolomite, and siderite. The latter occurs as a "beadwork" along detrital grain margins, in places, and shows no evidence of reaction to the staining reagents applied. Visual porosity consists of fractures, likely artefact in character (?). Effectiveness nil. Grain contacts range through intergrown. The rock has undergone a moderate (+) degree of apparent compaction. Nil reservoir quality as is. Fair potential for improvement elsewhere, via development of secondary dissolution porosity. In particular, the carbonate cements- especially the "beadwork"- represent prime candidates for this. Negative factors include the quartz cementation and the degree of apparent compaction.

Fragment C:

Litharenite. Vague layering. Detrital framework grains principally of fine sand size, moderately sorted, angular-subangular-subrounded. Texturally, mineralogically, diagenetically immature. Grains = 90%; matrix = 10%; cement = trace; visual porosity = trace (artefact?). Grains consist of quartz (50%)- most are monocrystalline, some are polycrystalline, with straight as well as undulose extinction represented; feldspars (trace)- plagioclase, potassium feldspars (?); lithic fragments (45%)- cherts, argillaceous rocks, subordinate volcanic rocks; traces of organic materials; micas/chlorite (5%). Matrix of argillaceous materials, with indications of associated organic materials (including hydrocarbons?). Cements consist of quartz and carbonates (dolomite?). Visual porosity consists of apparent secondary dissolution at certain grain edges, as well as of fractures; both may well represent artefacts of sampling/sample preparation (?). Grain contacts range through concavo-convex, with slightly deformed layer silicate minerals (micas/chlorites, ie.). The rock has undergone moderate apparent compaction. Nil reservoir quality as is. Fair potential for improvement elsewhere, via development of secondary dissolution porosity (cherts, lithic fragments, feldspars, are candidates). Negative factors include clays/micas/chlorites, and the degree of apparent compaction.

Fragment D:

Sublithic wacke/arenite. Massive fabric. Framework grains very fine sand size, principally, with appreciable proportions of finer grained materials as well. Poorly-very poorly sorted, ranging from very angular through subangular. Texturally, mineralogically, diagenetically immature. Grains = 85%; matrix = 15%; cement nil; visual porosity nil. Grains consist of quartz (80%+/-)- most are monocrystalline, some are polycrystalline, straight as well as undulose extinction are represented; feldspars (5%)- plagioclase, potassium feldspars (?); lithic fragments (15%)- cherts, argillaceous rocks, trace of carbonate fragments; black organic matter (3%); glauconite (trace). Matrix of argillaceous materials; associated organic materials. Grain contacts range through concavo-convex; somewhat "cushioned" by the matrix. The rock has undergone a moderate degree of apparent compaction. Nil reservoir quality as is. Poor potential for improvement- relative paucity of dissolution candidate materials, grain size, argillaceous matrix are all negative factors.

Fragment G:

Quartzarenite. Massive fabric. Framework grains consist of predominant medium sand and subordinate coarse sand size materials, moderately-well sorted, subangular-subrounded. Texturally mature, mineralogically and diagenetically immature. Grains = 85%; matrix nil; cement = 15%; visual porosity = 5% (at least part of which may well be artefact). Grains consist of quartz (90%)- mono- and polycrystalline, most exhibit undulose extinction; lithic fragments (10%)- one grain, now partially leached, of argillaceous(?)/volcanic(?) character. Cements consist of quartz (10%), and carbonate (90%). The latter, unfortunately, do not occur in the stained portion of the thin-section, hence their mineralogic composition is ambiguous-likely calcite, possibly dolomite, some siderite. Visual porosity consists of partial secondary dissolution (of an argillaceous?/volcanic? lithic fragment), as well as fractures (which may well represent artefacts of sampling/sample preparation). Grain contacts range through intergrown/sutured. This rock has undergone moderate (++) apparent compaction. Nil reservoir quality as is. Fair potential for improvement elsewhere, via development of secondary dissolution porosity (carbonates, lithic fragments are candidates). Degree of apparent compaction, quartz cementation are negative factors in this regard. On balance, poor-fair potential for improvement.

Plates 4-A, B depict this fragment.

Fragment I:

Litharenite. Massive fabric. Framework grains principally medium sand size, moderately-well sorted, subangular-subrounded. Texturally submature, mineralogically and diagenetically immature. Grains = 90%+; matrix = trace; cement = 5%+; visual porosity nil. Grains consist of quartz (50%)- mono- and polycrystalline, most exhibit undulose extinction; feldspars (5%)- plagioclase, potassium feldspar (?); lithic fragments (45%)- cherts, argillaceous rocks. Matrix of argillaceous materials; associated black organic materials (somewhat granular in aspect, = dead oil?). Cement consists of quartz. Grain contacts range through intergrown, with some lithic fragments deformed to pseudomatrix. This rock has undergone a moderate (++) degree of apparent compaction. Nil reservoir quality as is. Poor-fair potential for improvement elsewhere, via development of secondary dissolution porosity (cherts, lithic fragments are candidates). The degree of apparent compaction, pressure solution/intergrowths/quartz cementation, and pseudomatrix development are negative factors. On balance, poor potential for improvement.

16,500-16,510'

Principal fragment types: The principal

differences between the cuttings fragments suite from this interval and that from the overlying interval (16,470-16,480') are a relative decrease in the proportion of discrete quartz fragments, and a relative increase in arenite fragments (made up principally of quartz grains) in the 16,500-16,510' materials. These two fragment types are each major components of this suite. There is also somewhat more discrete micaceous material in this thin-section (contaminants from drilling?). Otherwise, the constituent fragments in the two suites are not dissimilar. "A" is representative of the quartz arenite-sublitharenite fragments noted. Photomicrographs "B-I, Q" show other examples/ varieties- some containing glauconite grains. Photomicrographs "J, K" show general aspects of the suite- quartz, arenites, argillaceous rocks, cherts, plagioclase, orthoclase microperthite, pyrite-bearing fragments, wood, micas. Photomicrographs "E" show an arenite featuring carbonate and quartz cements, as well as glauconite (?). "C" features glauconite grains- a not uncommon constituent in other fragments in this thin-section. This lithology is a major component of the cuttings fragments in this thin-section. *Plate 5-A depicts this fragment..* "D" is another example, showing a somewhat deformed ("squashed") glauconite grain, with associated (micro) porosity. Photomicrographs "H" show an arenite-wacke, with some 30% pyrite "cement". Photomicrographs "F" show a siltstone with coarser grains, including glauconite. Photomicrographs "G" include views of discrete plagioclase, and discrete orthoclase microperthite with enclosed twinned plagioclase "guests".

Fragment A:

Quartzarenite/sublitharenite. Massive fabric. Framework grains are principally coarse-very coarse sand size, well sorted, and rounded-well rounded. Texturally mature, mineralogically and diagenetically submature-immature.

Grains = 85%; matrix nil; cement = 10%; visual porosity = 5%. Grains consist of quartz (90%)- principally monocrystalline, some are polycrystalline, most exhibit undulose extinction; lithic fragments (10%)- one rounded grain, a very fine sandstone/ wacke; one grain/flake of chlorite(?). Cements consist of quartz (90%), and carbonate(s). The latter do not occur in the stained portion of the thin-section, hence their mineralogy is somewhat ambiguous- most likely dolomite, and siderite. Visual porosity is secondary in character, representing partial internal dissolution of a lithic frgament. Effectiveness is nil. Grain contacts range through intergrown. This rock has undergone moderate (+) apparent compaction. Nil reservoir quality as is. Poor potential for improvement, due to degree of apparent compaction, quartz cementation, and paucity of potentially reactive dissolution candidate materials. Prior to compaction/cementation, the well rounded, coarse-very coarse sand size grains would have afforded excellent reservoir quality.

16,530-16,540'

Principal fragment types: (this suite is quite similar to that from the overlying interval, 16,500-16,510').

Predominant: 1. Arenites-litharenites. "A-C, M" are examples. Photomicrographs "L, Q-S" include others. Glauconite often present. A major component of this thin-section. 2. Argillaceous rocks: siltstones-mudstones/shales. Some are organic-rich. Photomicrographs "F, L, Q-S" include examples. A major component. 3. Discrete quartz. Mostly angular-subangular as cuttings fragments, similar in general aspect to the quartz grains comprising the arenites in this suite. Photomicrographs "F, L, Q-S" include examples. A major component.

Subordinate: 4. Discrete feldspar. Plagioclase, twinned, oligoclase-andesine; also (?) potassium feldspars. Minor component of this thin-section. 5. "Granitoid" rocks.

Associations of quartz-feldspars (plagioclase, orthoclase, +/- microperthites)-mica (muscovite). Photomicrographs "E, G, H" are examples; "L" show another. Minor component. 6. "Metamorphosed" arenites-wackes. Metamorphic/fault-related/ artefacts of drilling? Photomicrographs "D, I, J, K" are examples; "L" include others. Trace component. 7. Wood/bone(?) material. Contaminant from drilling operations. Trace component. 8. Organic materials. Black. Trace component. 9. Metamorphic rock. Consists of a grain of plagioclase (cordierite ?), and a grain(s?) of a pale yellowish mineral (an amphibole ? —on basis of apparent birefringence and cleavage). One fragment noted, shown in photomicrographs "Q". Indigenous (?), or a "contaminant" associated with micaceous and/or "granitoid" materials?

Fragment A:

Sublitharenite. Massive fabric. Framework grains principally of medium sand size, with subordinate coarse sand size materials. Well sorted, subrounded-rounded. Texturally mature/supermature, mineralogically and diagenetically immature/ submature. Grains = 80%; matrix nil; cement = 20%; visual porosity = trace. Grains consist of quartz (80%+/-)- mono- and polycrystalline, most exhibit undulose extinction; feldspar (5%)- one plagioclase grain; lithic fragments (10%)- cherts (?)/volcanic rocks (??). Cements consist of quartz (50%), and carbonate(s)- likely dolomite, possibly siderite. Some of the latter occurs as "beadwork" among framework grains. Visual porosity principally secondary in character, representing partial dissolution of cherts and other lithic fragments. Fractures are also present, most likely artefacts of sampling/sample preparation. Effectiveness of visual porosity nil. Grain contacts range through intergrown/sutured. This rock has undergone a moderate (++) degree of apparent compaction. Nil reservoir quality as is. Poor-fair potential for improvement elsewhere, via dissolution of carbonates and/or cherts/lithic fragments. Degree of apparent compaction, grain intergrowth/quartz cementation are negative factors. The spatial arrangement of the carbonate cements- as intergranular "beadwork"—is, however, a positive factor. On balance, a poor-fair potential for improvement.

Plates 5-B, C depict this fragment.

Fragment B:

Quartzarenite. Massive fabric. Framework grains principally medium sand size, well sorted, subangular-subrounded-rounded (?). Texturally submature/mature (?), mineralogically and diagenetically immature. Grains = 80%; matrix nil; cement = 20%; visual porosity = trace. Grains consist of quartz (90%)- mono- as well as polycrystalline, most exhibit undulose extinction; feldspars (5%)- one grain of plagioclase; lithic frgaments (5%)- one chert grain. Cements consist of quartz (10%), and carbonate(s)- probably dolomite, perhaps some siderite. Visual porosity secondary in character, representing partial dissolution of chert. Effectiveness nil. Grain contacts range through intergrown. This rock has undergone a moderate (++) degree of apparent compaction. The carbonate cementation preceded some of this compaction, shielding some of the quartz grains from pressure solutioning/attendant quartz cementation. Nil reservoir quality as is. Fair-good potential for improvement elsewhere, via development of secondary dissolution porosity (carbonates, cherts are candidates).

16,550-16,560'

Principal fragment types (this thin-section suite is very similar to that from 16,530-16,540')

Predominant: 1. Arenites. Grains principally quartz- medium sand size and finer; minor glauconite, plagioclase, cherts; trace tourmalines. Cements are quartz, carbonates (siderite, dolomite). Some fragments border on being very fine sandy wackes/ argillaceous arenites. *Photomicrographs "A, R, S, T, X" show examples.* 2. Argillaceous rocks; siltstones-mudstones/shales. Some are organic and/or pyrite-rich; some contain appreciable carbonate (fine). Some fragments contain appreciable amounts of very fine-fine sand size quartz and other detrital grains. *Photomicrographs "R, S, T, X" show examples.* 3. Discrete quartz. On the order of 1.0mm and smaller, as cuttings fragments. Some are rounded/well-rounded, with occasional vestiges of quartz cement/ overgrowths. These quartz fragments are similar in general aspect ot the constituent grains of the arenite fragments also found in this thin-section (cf. above). *Photomicrographs "A, S, T, X, Z" show representative examples.* Subordinate 4. Wood/bone (contaminant). 5. Plagioclase. Contaminant and/or from the plagioclase arenites found in this thin-section (?); cf. photomicrographs "A". 6. "Granitoid" rocks. Plagioclase-micas; plagioclase-quartz; quartz-plagioclase-potassium feldspar (cf. photomicrographs "Z"). Drilling contaminants (?); no grains with these mineral assemblages were observed in the arenite fragments in this thin-section. 7. Micas: muscovite/"hydrobiotites" (?)/ vermiculites (?). Contaminants (?); cf. photomicrographs "Z". 8. Plagioclase-amphibole, amphibole. Contaminants (?). 9. Cherts. 10. Organic materials; black, ill-defined. 11. "Metamorphosed" (bit/sample preparation ?) fragments of argillaceous/wacke aspect.

Fragment A:

Quartzarenite. Fine-medium sand size grains. Massive fabric. Grains well sorted; subrounded-rounded. Texturally mature; mineralogically, diagenetically submature. Grains=85%; matrix nil; cement=10%+/-; visual porosity=5%+/-(most/all artefact?). Grains consist of quartz (90+%)- most is monocrystalline, some is polycrystalline, with principally undulose extinction represented, and subordinate straight extinction; feldspars (<5%)- plagioclase, oligoclase-andesine; lithic grains (5%)- cherts, glauconite. Matrix nil. Cements consist of quartz (predominant), and a weakly- developed "beadwork" of siderite in much lesser relative amount. Visual porosity of various apparent character (ie. fracture, secondary dissolution, microporosity). The apparent fracture porosity is predominant, but, likely represents artefacts of sample preparation. The other types of apparent porosity observed may represent actual geologic porosity, but are collectively ineffective in this specimen. Grain contacts range through concavo-convex, with indications of some intergrown grain boundaries as well. This specimen has undergone a moderate (+) degree of apparent compaction. Nil reservoir quality as is. Poor-fair (?) potential for improvement elsewhere, via secondary dissolution of labile grains (viz. siderite- particularly given the beadwork character of its' occurrence, plagioclase, cherts, glauconite). Quartz cementation, degree of apparent compaction, sparseness of labiles are negative factors in this regard. With more extensive "early" carbonate cementation, and/or "early" migration of hydrocarbons into this material (pre-quartz cementation and compaction, ie.), this rock would have had much better prospects as regards reservoir quality.

16,560-16,570'

Principal fragment types:

This suite resembles that from the overlying interval, except that there is a somewhat greater proportion of argillaceous rock (siltstones-mudstones/shales) fragments in this thin- section. Predominant- 1. Argillaceous rocks: siltstone-mudstone/shale. May be organic-rich, and/or carbonate-rich. "A" is an example. Photomicrographs "B, E, F" show others. A major component of this thin-section. 2. Arenites-wackes. "C" is a fossilferous fine sand-sized example, with appreciable argillaceous matrix. *Photomicrographs "B, D, E, F" show other types.* "G" is a typical arenite. Photomicrographs "B and D" show several variants of this general type as well. "I" is a similar arenite, with glauconite grains. Arenite grain sizes include very coarse sand, and smaller. A major component of this thin-section. Subordinate- 3. Discrete quartz. Angular to well-rounded, as cuttings fragments. Some exhibit quartz overgrowths. Minor component of this thin-section. 4. Wood / bone (?) material. Contaminant from drilling operations. Minor component. 5. Discrete feldspar. Plagioclase, twinned, oligoclase-andesine; +/-potasssium feldspars (?). Trace component. 6. "Granitoid" rocks. Consist of intergrown feldspars-plagioclase, and orthoclase microperthites with twinned plagioclase- and quartz (some as rounded "blebs"). Photomicrographs "E, F, and H" show examples. Trace component. 7. Organic materials. Mostly black. Trace component. 8. Photomicrographs "Q" show a fragment featuring medium-fine sand-sized grains (quartz, mostly), "floating" (?) in a "matrix" (?)- now recrystallized (?)/surrounded by a "cement" (?) of carbonate. A grain of glauconite is also in evidence. 9. Photomicrographs "R" depict a fragment comprised of coarse, and smaller, sand-sized grains (quartz, cherts, feldspars, glauconite) in an optically indeterminate "matrix" (?)/"cement" (?) of argillaceous and/or carbonate material.

Fragment A:

Sandy-silty calcareous mudstone. Sand-silt size detrital grains "floating" in a matrix of argillaceous and carbonate materials. Poorly sorted, these grains range from angular subangular-subrounded. Texturally, mineralogically, and diagenetically immature. Grains = 20%; matrix = 50%+; cement = 30%+/-; visual porosity = trace (artefacts?). Grains consist of quartz (100%+/-)- mono- as well as polycrystalline, with both straight and undulose extinction represented. Matrix of argillaceous materials, with associated organic materials (including hydrocarbons?). Cement somewhat ill-defined as such; calcite. Visual porosity secondary in character (?), including microporosity. May well be artefact. Effectiveness nil. This rock has undergone a moderate degree of apparent compaction. Nil reservoir quality as is. Poor potential for improvement.

Fragment G:

Quartzarenite. Massive fabric. Framework grains principally medium-coarse sand size, well-very well sorted, rounded-well rounded. Texturally mature/supermature, mineralogically and diagenetically immature. Grains consist of quartz (100%+/-)- mono- as well as polycrystalline, most exhibit undulose extinction. Cements consist of quartz (60%), and carbonate(s). The latter, unfortunately, do not occur in the stained portion of the thin-section, hence some ambiguity as to their mineralogy- llikely dolomite, possibly siderite. Grain contacts range through intergrown. This rock has undergone moderate (+) apparent compaction. Nil reservoir quality as is. Poor-fair (?) potential for improvement elsewhere, via development of secondary dissolution porosity (carbonates). The degree of apparent compaction and the quartz cementation are negative factors. However, prior to this compaction/cementation, this clean medium-coarse sand/sandstone would have possessed excellentreservoir properties.

Plates 4-C, D depict this fragment.

16,600-16,610'

Principal fragment types (this suite is quite similar to that observed in the thin-section representing the depth interval 16,620-16,630', below).

Predominant 1. Argillaceous rocks; siltstones-mudstones/shales. Some are organic and/or pyrite-rich. Some contain scattered grains (quartz, for the most part) as large as medium sand size. Some contain appreciable carbonate material. Photomicrographs "X, Y" are representative. 2. Arenites. Coarse sand (at least) size and finer grains; principally quartz, with some glauconite, plagioclase as well (especially in the finer-grained specimens). Quartz is the principal cement, with subordinate carbonates (dolomite, siderite) and pyrite. Photomicrographs "A, X" contain examples. 3. Discrete quartz. Likely from attrition of arenites (cf. above). Some are very well rounded; vestiges of quartz cement/overgrowths are not uncommon. Photomicrographs "X, Y" provide examples. Subordinate 4. Micas/ "hydromicas". Contaminants (?). 5. Wood/ bone. Contaminants (cf. photomicrographs "X"). 6. Organic materials; black (cf. photomicrographs "X"). 7. Cherts. 8. Feldspars: both potassium feldspar (some of which is microperthitic), and (separate) plagioclase; some contain quartz blebs. Contaminants (?). 9. "Metamorphosed" arenite/wacke fragments. Artefacts of drilling/sample preparation (?); cf. photomicrographs "X". Photomicrographs "Z" also provide examples of the principal types of fragments observed in this thin-section.

Fragment A:

Quartzarenite. Medium-coarse sand size grains. Massive fabric. Grains moderately-well sorted; subrounded-rounded-well (?) rounded. Texturally, mineralogically, diagenetically mature. Grains= 85%+/-; matrix nil; cement=15%+/-; trace of visual porosity (artefact ?). Grains consist of quartz (95+%)- almost exclusively monocrystalline, trace amount of plycrystalline grains, essentially all grains exhibit undulose extinction; lithic grains (<<5%)- cherts, argillaceous rocks. Matrix nil/trace (argillaceous material). Cement essentially all quartz, with very minor pyrite as well. Visual porosity trace/ nil (artefact ?). Grain contacts range through intergrown (although the extensive/pervasive degree of quartz cementation makes grain boundaries somewhat indistinct, hence ambiguous as to character). This specimen has undergone a moderate (+) degree of apparent compaction. Nil reservoir quality as is. Poor potential for improvement elsewhere, due to thoroughness of quartz cementation, and paucity of labile grains. Prior to quartz cementation, however, this material would have had good-very good reservoir quality.

16,620-16,630'-

(Thin-section # 1) Principal fragment types: Predominant- 1. Argillaceous rocks: siltstone-mudstone/shale. May be organic, and/or pyrite-rich. Photomicrographs "G-I" include examples. A major component of this thin-section. 2. Arenites. A few contain very coarse-coarse-medium sand-sized grains; most are finer-grained. "A, B" are examples. Photomicrographs "C, F (which includes one plagioclase grain), G-I" include other examples. Glauconite was not noted. A few fragments show extremely "tight" quartz cementation developed (cf. photomicrographs "G"). Arenite fragments comprise a major component of this thin-section. 3. Discrete quartz. Angular to well-rounded. Photomicrographs "G, H" include examples. A major/minor component of this thin-section. Subordinate- 4. Organic materials. Black. Minor component. 5. Cherts. Some are pyritic. Trace component. 6. Discrete feldspars. Plagioclase, twinned, oligoclase-andesine. One grain of microperthitic/micropegmatitic (?) material. Trace component. 7. Carbonates: dolomite, ferroan calcite. Trace component. 8. Wood/ bone (?) material. Contaminant from drilling operations. Minor component. 9. Micaceous quartzite. Photomicrographs "D" show this. Trace component.

Fragment A:

Quartzarenite and quartz wacke; two lithologies represented in this cuttings fragment. Each will be discussed independently, below: Quartzarenite. Massive fabric. Principally medium sand size grains, well-very well sorted, subrounded-rounded. Texturally, mineralogically, and diagenetically mature. Grains = 90%; matrix nil; cement = 10%; visual porosity =trace (artefact?). Grains consist of quartz (90%)- mono- as well as polycrystalline, most exhibit undulose extinction; lithic fragments (10%)- one rounded grain of very fine sandstone/ siltstone aspect. Cement comprised of quartz. Grain contacts range through intergrown/sutured. This rock has undergone moderate (+) apparent compaction. Nil reservoir quality as is. Nil potential for improvement, diagenetically. Quartz wacke. Medium(?)-fine sand size detrital grains, in a matrix of argillaceous materials. Poorly sorted, the sand size grains range from subangular-subrounded-rounded. Texturally immature, mineralogically and diagenetically submature. Grains = 55%; matrix=45%; cement nil; visual porosity nil. Grains consist of quartz (100%+/-)- mono- as well as polycrystalline, most exhibit undulose extinction.

Matrix of argillaceous materials, with appreciable associated black organic materials (including hydrocarbons?). This rock has undergone a moderate degree of apparent compaction. Nil reservoir quality as is. Nil potential for improvement, diagenetically. This portion of this cutting fragment shows the pre-quartz cement aspect of the original sand-size grains. The original grains were approximately the same size, shape and composition in both the quartzarenite and the quartz wacke here.

Fragment B:

Quartzarenite/sublitharenite. Massive fabric. Principally medium sand size framework grains, well sorted, subrounded-rounded. Texturally mature, mineralogically and diagenetically immature. Grains = 85%: matrix nil; cement = 15%; visual porosity = trace (artefact?). Grains consist of quartz (90%)- mono- as well as polycrystalline, most exhibit undulose extinction; lithic fragments (10%)- cherts, argillaceous rocks. Cements consist of quartz (90%), and ferroan calcite (10%). Some of the latter may represent replacement (of feldspar/lithic fragment/?). Some crystals which may be dolomite are also associated. Visual porosity principally secondary in character, with associated microporosity, representing partial dissolution of lithic fragments (or, rather, artefact of sampling/sample moderate degree of apparent compaction. Nil reservoir quality as is. Nil potential for improvement, diagenetically. This portion of this cuttings fragment shows the pre-quartz cement aspect of the original sand size grains. The original grains were approximately the same size, shape, and composition in both the quartzarenite and the quartz wacke, here.preparation?). Grain contacts range through intergrown/sutured (quartz), with some lithic fragments deformed to pseudomatrix. This rock has undergone a moderate (++) degree of apparent compaction. Nil reservoir quality as is. Poor-fair (?) potential for improvement elsewhere, via development of secondary dissolution porosity (carbonates, cherts, other lithic fragments are candidates). The degree of apparent compaction, and quartz cementation are negative factors.

(Thin-section # 2):

Principal fragment types: virtually identical to the suite in thin-section # 1 from this same interval. Photomicrographs "V" feature an "overview" typical of this suite: discrete quartz, as well as fragments of arenites featuring quartz cement over rounded detrital grains; also organic materials, argillaceous rocks (siltstone- mudstone/shale), some of which are organic-rich. Photomicrographs "W" show similar materials, and also feature an organic-rich siltstone with a very-coarse sand-size, angular "floating" quartz grain. Photomicrographs "X" show another overview of this suite: medium sand, and very-fine sand-sized arenites, some with carbonate (dolomite ?) cements; discrete quartz; siltstones; organic materials. Photomicrographs "Y and Z" feature higher magnification views of the medium sand-sized arenite fragment shown in photomicrographs "X", illustrating the apparent bimodal texture, and the dolomite (?) cement. Similarities are readily apparent between this fragment and other typical arenites in both thin-sections from this interval. Photomicrographs "T" include an arenite fragment (possibly from an "up-hole" source ?), with two grains of glauconite (rare-unique in the thin-sections from this interval). These photomicrographs also show fragments of argillaceous rocks, quartz, other arenites.

16,710-16,720'

Principal fragment types:

Predominant 1. Cherts. Various types, some rich in pyrite. It seems worthy of note here that notable amounts of chert grains are not observed as constituents of the other lithologies seen in this thin-section. Photomicrographs "X, Y" provide examples. 2. Discrete quartz; range through well-rounded; some with vestigial quartz cement/overgrowths. Most exhibit undulose, some straight extinction. Photomicrographs "X, Y" include examples. 3. Argillaceous rocks; siltstones-mudstones/shales. Some include scattered grains (quartz, principally) of medium sand size and smaller; some are organic- and/or pyrite- rich. Photomicrographs "X, Y" include examples.

Subordinate 4. Arenites; coarse sand size and smaller grains; principally quartz; range through well rounded. Quartz, trace carbonate (dolomite, siderite) and pyrite cements (cf. photomicrographs "Y"). 5. Pyrite; some associated with traces of "host rocks"- ie., chert, argillaceous rocks, arenites (cf. photomicrographs "X, Y"). 6. Organic materials; most are black, some are red. 7. Dolostone. 8. "Metamorphosed" wackes (artefacts ?). 9. Plagioclase; oligoclase-andesine. Some contain rounded quartz blebs. Contaminants ?

17,020-17,030'

Principal fragment types:

Predominant: 1. Argillaceous rocks: siltstones/mudstones-shales. With patches/lenses/pebbles(?) of fine sand size wacke/arenite (cf. "A"); also with scattered medium sand and finer grains of quartz, potassium feldspar (trace), +/- (?). Some fragments are organic and/or pyrite-rich. The predominant fragment type in this thin-section. Many seem to contain very fine calcite (??) associated — the rocks take up a pervasive pink stain, as is also the case with some other argillaceous rocks at other stratigraphic horizons in this well. Rather than reflecting the presence of stained calcite, perhaps this pink "wash" effect in fact is related to interaction between the dye reagents applied to the thin-sections and either clays and/or organic materials (?)—cf. 17,540-17-550' thin-section, for example. Photomicrographs "X, A" present examples of these fragments.

2. Discrete sandstones. "A", as discussed above in association with its' "host" argillaceous rock, is a litharenite/sublitharenite?/wacke??, of the same general lithologic aspect as these fragments. Photomicrographs "X, Y" show examples. Subordinate 3. Organic materials; most are black, some are red. 4. Discrete quartz (from uphole ?). 5. Cherts; some with pyrite.

Fragment A:

Litharenite/lithic wacke (?). Is a sandstone patch/lens in an argillaceous rock fragment (cf. photomicrograph "X"). Very fine-fine sand size grains. Weakly layered fabric. Grains poorly-moderately sorted; angular-subrounded. Texturally, mineralogically, diagenetically immature. Grains= 85+%; matrix= 10%; cement= nil; visual porosity<3% (in part, at least, artefact?). Grains consist of quartz (85%)- monocrystalline, undulose as well as straight extinction are represented; feldspars (trace)-plagioclase;

lithic grains (15%)- carbonate rocks (dolomite,calcite), +/-argillaceous rocks; opaques (3%)- black; other grains (5%) include glauconite grains, and large mica (muscovite, +/-? flakes. Matrix of argillaceous (incl. micas) materials. Visual porosity secondary, via apparent dissolution of glauconite (artefact ?), and of microporosity. Effectiveness is nil. Grain contacts range through concavo-convex; "cushioned" somewhat by matrix, which is moderately "squashed". This rock has undergone a moderate degree of apparent compaction. Nil reservoir quality as is. Poor potential for improvement elsewhere, via secondary dissolution of labiles, due to grain size, matrix, degree of compaction, and relative paucity of labiles.

17,350-17,360'

Principal fragment types:

Predominant: 1. Cherts; various types. Some are pyrite-rich. Photograph "Z" shows examples. 2. Quartz; discrete grains, well-rounded to subangular, as cuttings fragments. Exhibit undulose-straight extinction. Photo "Z" shows examples. Subordinate 3. Argillaceous rocks; siltstones-shales/mudstones. May be organic- or pyrite-rich. Examples can be seen in photograph "Z". 4. Dolomite; as fragments/rhombs. 5. Organic material(s); most are black. 6. Potassium feldspar and quartz (as "blebs"); contaminant (?). 7. "Micro"-nodules/oolites (?); possibly phosphatic (?); similar in general appearance to those found commonly in Kemik horizons elsewhere in northern Alaska. Examples appear in photomicrographs "G, H, I, X".

17,540-17,550'

Principal fragment types:

Predominant: 1. Cherts, various types; 1.3mm and smaller, as cuttings fragments. Photomicrographs "A, B" show examples. 2. Organic matter- most are black, some red; some nicely cellular plant material. Indigenous to horizon, or contaminant (?). Examples are shown in photomicrographs "A, B". 3. Argillaceous rocks: siltstones, mudstones/shales. Some are organic-rich; some contain "floating" grains of quartz (fine sand-size and smaller). Photomicrographs "A" contain examples. Subordinate 4. Discrete quartz (cf. photomicrographs "A"). 5. Plagioclase (contaminant ?). 6. Dolomite rhombs/fragments. 7. Limestone/calcite. 8. Quartz arenite (from uphole ?). Cf. photomicrographs "B".

17,920-17,930'

Principal fragment types:

Predominant: 1. Argillaceous rocks; siltstones-shales/mudstones. Some with "floating" grains (quartz, mainly) of fine sand-size and smaller. Examples appear in photographs "A, B". 2. Quartz; discrete grains. Photographs "A, B" feature examples. 3. Cherts; various types, some rich in pyrite. Photographs "A, B" include examples.

Subordinate: 4. Organic material(s); most are black, some show cellular structure. 5. Plagioclase; with/without quartz. Contaminant (?). 6. Dolomite; fragments, rhombs. 7. "Metamorphosed" argillaceous rocks; artefacts (?) from drilling/sample preparation. 8. Wood/bone (?); contaminant.

18,180-18,190'

Principal fragment types *(cf. Plate 5-D)*:

Predominant: 1. Argillaceous rocks; siltstones-shales/mudstones. May be organic- and/or pyrite-rich. Some feature scattered "floating" grains (quartz, mainly) of medium sand size and smaller. Some grade to "wackes". Photographs "A, B" contain examples. 2. Quartz; discrete grains. Most are subangular-subrounded as cuttings fragments, one is well-rounded (from uphole ?).

Both straight and undulose extinction may be observed. Photographs "A, B" contain examples. 3. Cherts; various types. May be pyrite-rich. Photographs "A, B" contain examples. Subordinate 4. Organic material(s); mainly black. 5. Sandstones; wackes/litharenites. 6. Plagioclase (contaminant ?). 7. Micas/"hydromicas" (contaminants ?). 8. Glauconite; one discrete fragment.

Fragment "X"

Lithic wacke. Features very fine-fine sand-sized grains; weakly layered. Grains poorly sorted, subangular-subrounded. Texturally, mineralogically, and diagenetically immature.

Grains = 80%+/-; matrix = 15-20%; cement nil; visualporosity nil.

Grains consist of quartz (50%+/-)- mostly monocrystalline, some polycrystalline, with straight as well as undulose extinction represented; lithic fragments (50%+/-)- principally carbonate (dolomite, +/-) material, and argillaceous rock fragments; trace amount of black opaque/organic material(s) and micas.

Matrix of argillaceous materials; some pseudomatrix as well.

Grain contacts range through concavo-convex; "cushioned" somewhat by moderately "squashed" matrix/micas. This rock has undergone moderate apparent compaction. This rock has nil reservoir quality as is, and poor potential for improvement via diagenesis.

9. Summary

Data from the Aurora well represents a significant contribution to the publicly available stratigraphy and regional geology of the Arctic National Wildlife Refuge (ANWR) 1002 area, and the U. S./Canadian Beaufort Sea. This exploration endeavor drilled and logged almost 18,325 feet (KB was reported as 106 feet above the sea floor) of clastic section, making it one of the deepest North Slope wells. With depth, the drilling encountered the unconsolidated, easterly-derived Tuktoyaktuk depositional sequence sediments, the southerly-derived upper and middle Brookian sequence sediments, and the locally-derived Breakup sequence sands and shales.

The informally named Oruktalik sand is the major sand of the middle Brookian sequence. In both cuttings and thin-section descriptions it is predominantly a chert litharenite, resembling many other Brookian sands in the region. Traces of glauconite were observed. Stratigraphically and petrographically it is somewhat similar to the Flaxman sands, found to the west of the 1002 area. The Oruktalik interval indicates a gas anomaly on the borehole logs (cf. the neutron/NPHI log), and a gas kick was also noted during the drilling through this interval. The inter/intra-granular porosity observed in the cuttings fragments studied was not notably great, with the exception of some material from the upper portion of the interval, but additional porosity might well exist on a larger scale in the rocks in situ, as fractures.

The Tapkaurak sand is the principal sand of the Breakup sequence in this well. It shares similarities to both the Kuparuk River sands and the Kemik sands, found to the west, and southwest, respectively. Petrographically, the Tapkaurak sand is a mature, quartzose sandstone, like the Kemik and Kuparuk River sands. It is in part glauconite-bearing. It also contains some clasts perhaps associated with derivation from local basement uplifts- in this respect being somewhat akin to the Point Thomson sand in terms of manifesting features due to unique and local provenance.

These two zones of well-developed sand/sandstone have been discussed in general fashion, and informally named, elsewhere (Banet, 1992a, b). Observations regarding these zones, in terms of the present petrographic studies, are summarized below.

"ORUKTALIK SAND"

The uppermost of these two zones. It is encompassed by the cuttings samples representing the depth intervals between 14,680 and 14,860 feet (below the kelly bushing). It may be observed on our figure 7, as well. This zone has been informally designated the "Oruktalik sand" (Banet, 1992). Based on the observed nature of the cuttings fragments, some summary comments may be offered:

14,680-14,690'

Major: fine-medium sand-sized litharenites argillaceous rocks; siltstone-mudstone/shale

Minor: organic materials (?)

Trace: discrete quartz plagioclase potassium feldspars (including perthite) granitoid rocks limestone

14,710-14,720'

Major: cherts conglomeratic-fine sand-sized litharenites Minor: argillaceous rocks; siltstone-mudstone/shale discrete quartz organic materials (?)

Trace: plagioclase volcanic rocks ("felsic")

14,740-14,750'

Major: cherts argillaceous rocks; siltstone-mudstone/shale Minor: conglomeratic, and finer-grained, litharenites organic materials (?) Trace: volcanic rocks limestone

14,770-14,780'

Major: cherts argillaceous rocks; siltstone-mudstone/shale Minor: conglomeratic, and finer-grained, litharenites Trace: organic materials (?) volcanic rocks

14,800-14,810'

Major: cherts argillaceous rocks; siltstone-mudstone/shale conglomeratic, and finer-grained, litharenites Trace: organic materials (?) volcanic rocks discrete quartz plagioclase ferroan calcite calcite/limestone

14,830-14,840'

Major: discrete quartz cherts argillaceous rocks; siltstone-mudstone/shale conglomeratic, and finer-grained, litharenites Minor: organic materials (?) Trace: volcanic rocks plagioclase ferroan calcite calcite/limestone granitoid rocks

14,850-14,860'

Major: discrete quartz cherts argillaceous rocks; siltstone-mudstone/shale. Minor: conglomeratic, and finer-grained, litharenites organic materials (?) Trace: plagioclase volcanic rocks calcite/limestone

"TAPKAURAK SAND"

This is the lower of these two sandy zones, encompassed by the cuttings samples representing the depth interval between 16,445 and 16,630 feet. It may be observed on our figure 6, as well. This zone has been informally termed the "Tapkaurak sand" (Banet, 1992). Based on the observed nature of the cuttings fragments, the following summary comments are offered:

16,445-16,450'

Major: discrete quartz argillaceous rocks; siltstone-mudstone/shale litharenites-quartz arenites (coarse sand- sized and finer) Minor: feldspars; plagioclase, perthite Trace: cherts carbonate minerals organic materials (?)

16,470-16,480'

Major: discrete quartz argillaceous rocks; siltstone-mudstone/shale arenites-wackes (very-coarse sand-sized, and finer) Trace: plagioclase cherts

16,500-16,510'

Major: arenites-sublitharenites (very coarse sand-sized and finer) discrete quartz argillaceous rocks; siltstone-mudstone/ shale Trace: plagioclase cherts

16,530-16,540'

Major: arenites-litharenites (coarse sand-sized, and finer) argillaceous rocks; siltstone-mudstone/shale discrete quartz Trace: feldspars; plagioclase, +/-? granitoid rocks organic materials (?)

16,560-16,570'

Major: argillaceous rocks; siltstone-mudstone/shale arenites-wackes (very-coarse sand-sized, and finer) Minor: discrete quartz Trace: feldspars; plagioclase, +/-? granitoid rocks organic materials (?)

16,620-16,630'

Major: argillaceous rocks; siltstone-mudstone/shale arenites (very-coarse sand-sized, and-mostly- finer) discrete quartz

Minor: organic materials (?) Trace: cherts feldspars; plagioclase, perthite carbonates; dolomite, ferroan calcite

10. Conclusions

The foregoing descriptions of cuttings samples illustrate, and afford insights as to the petrologic/petrophysical characteristics of the stratigraphic horizons representing the two most well-developed deep zones of sand/sandstone occurrences recognized from wireline log responses in the Aurora well, and of adjacent strata below and above these zones. Relationships among mineralogies, lithologies, diagenesis, petrophysical and log characteristics remain to be elucidated, and geological implications- in particular as regards sedimentology, stratigraphy, and regional relationships- await further clarification as well. It is anticipated that such study of the Aurora well, in the context of the petrologic characteristics presented here, will provide information useful in furthering knowledge relevant to mineral resources- in particular, of course, petroleum- in the northern Alaska region, onshore as well as offshore.

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PLATE 3.

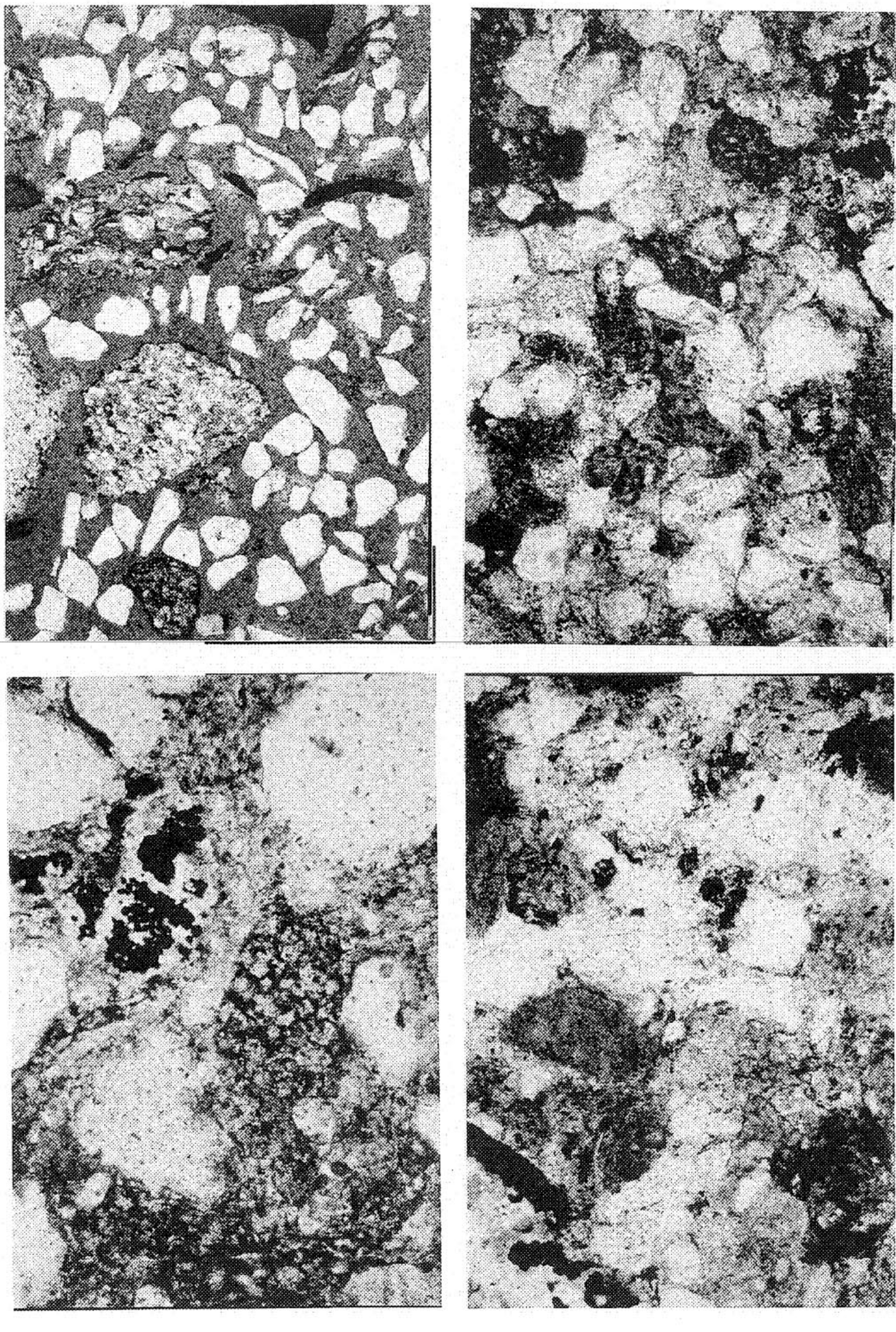
Transmitted light photomicrographs of representative materials from the Oruktalik interval. The greater width of each photograph is indicated in parentheses at the end of each summary description. Refer to text for more complete descriptions.

A. 14,830-14,840 feet. Overview of typical suite of cuttings fragments, featuring discrete quartz, and argillaceous litharenites. Plane polarized light. (2.9mm)

B. 14,680-14,690 feet. Cuttings fragment "B". Very fine-fine sand size litharenite. Note visual porosity in blue. Plane polarized light. (0.7mm)

C. 14,680-14,690 feet. Cuttings fragment "A". Fine sand size litharenite. Note visual porosity in blue. Plane polarized light. (0.35mm)

D. 14,740-14,750 feet. Cuttings fragment "A". Fine-medium sand size matrix of a conglomeratic litharenite. Note traces of visual porosity in blue. Plane polarized light. (0.35mm)



A.

C.

PLATE 4.

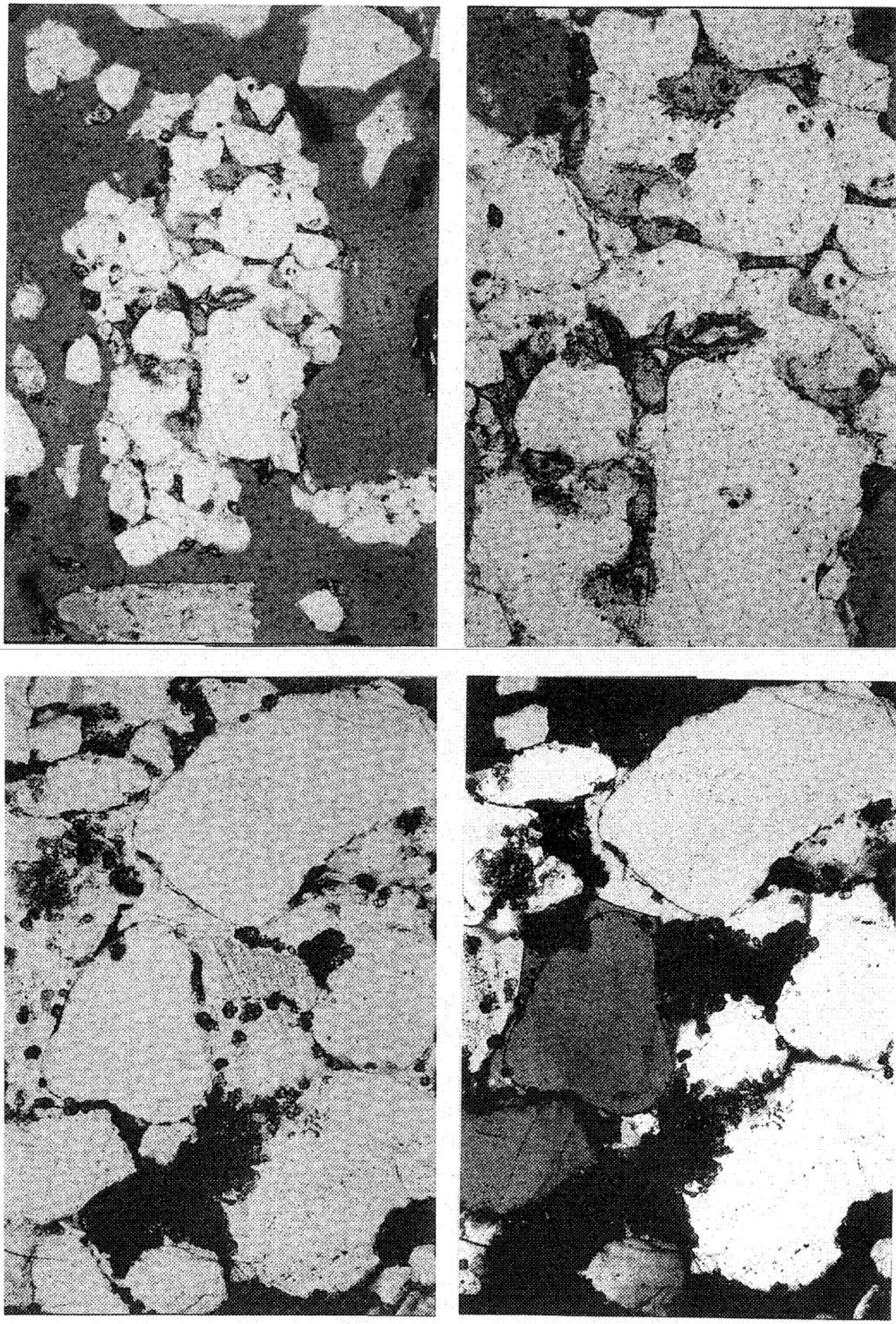
Transmitted light photomicrographs of representative materials from the Tapkaurak interval. The greater width of each photograph is indicated in parentheses at the end of each summary description. Refer to text for more complete descriptions.

A. 16,470-16,480 feet. Overview of typical suite of cuttings fragments, featuring quartzarenite fragment "G", as well as discrete quartz. Plane polarized light. (2.9mm)

B. 16,470-16,480 feet. Cuttings fragment "G". Coarse-medium sand size quartz-arenite. Note silica and carbonate (brownish) cements. Plane polarized light. (1.4mm)

C. 16,560-16,570 feet. Cuttings fragment "G". Coarse-medium sand size quartzarenite. Note silica and carbonate (brownish) cements, and their apparent spatial relationships. Plane polarized light. (1.4mm)

D. 16,560-16,570 feet. Same view as above, cuttings fragment "G". Crossed polarizing filters. (1.4mm)



A.

C.

PLATE 5.

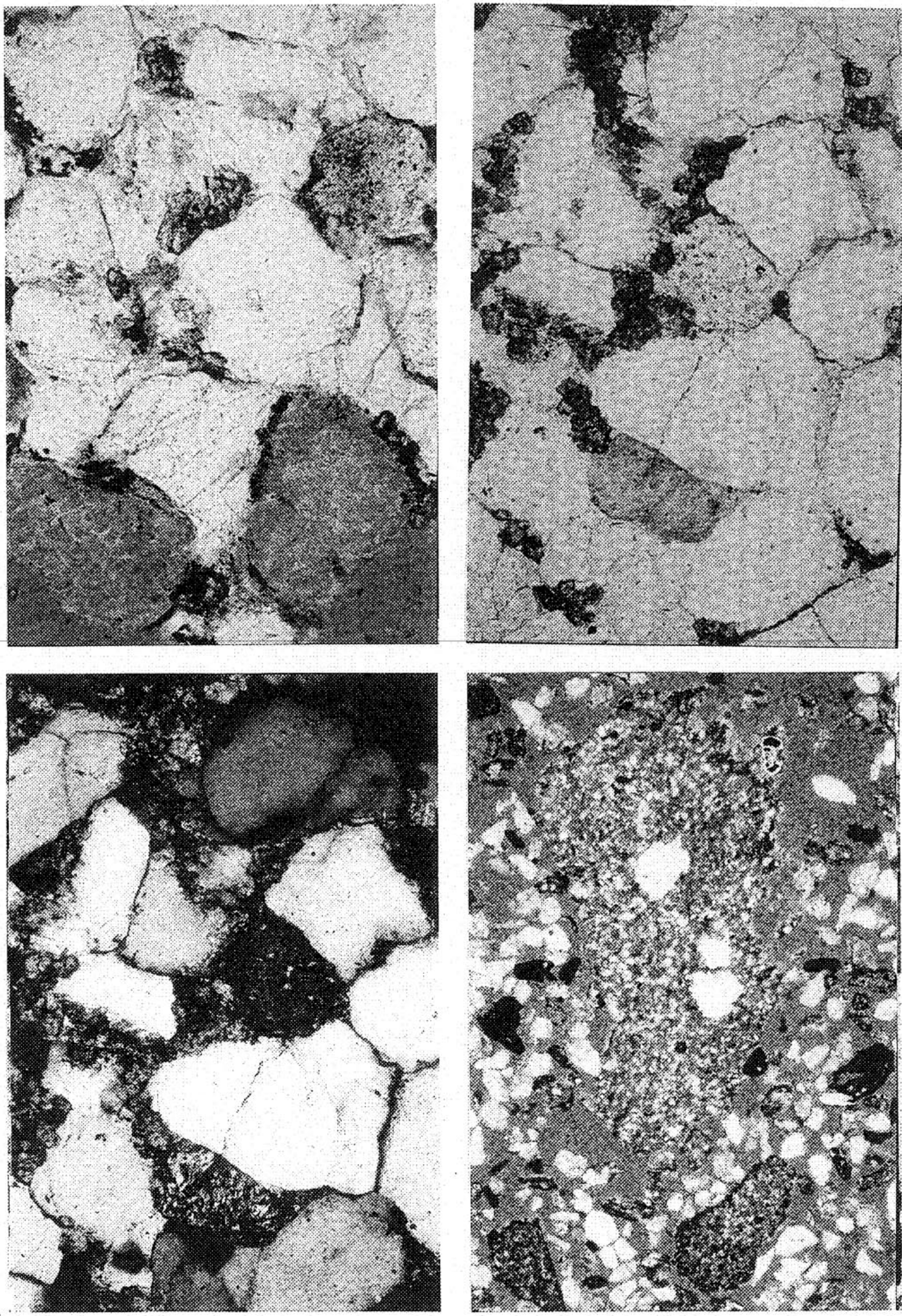
Transmitted light photomicrographs of representative materials from the Tapkaurak (A, B, C) and underlying (D) intervals. The greater width of each photograph is indicated in parentheses at the end of each summary description. Refer to text for more complete descriptions.

A. 16,500-16,510 feet. Cuttings fragment "C", featuring two glauconite grains (green) in a quartzarenite. Note also silica and carbonate (brownish) cements. Plane polarized light. (0.7mm)

B. 16,530-16,540 feet. Cuttings fragment "A". Medium sand size sublitharenite. Note silica and carbonate (brownish) cements, and their spatial relationships. Greenish-brown grain is glauconite. Plane polarized light. (0.7mm)

C. 16,530-16,540 feet. Cuttings fragment "A". Same view as above, with crossed polarizing filters. (0.7mm)

D. 18,180-18,190 feet. Overview of typical suite of cuttings fragments, featuring fragment "X" - a lithic wacke, as well as other argillaceous rock and discrete quartz fragments. Plane polarized light. (2.9mm)



A.

C.