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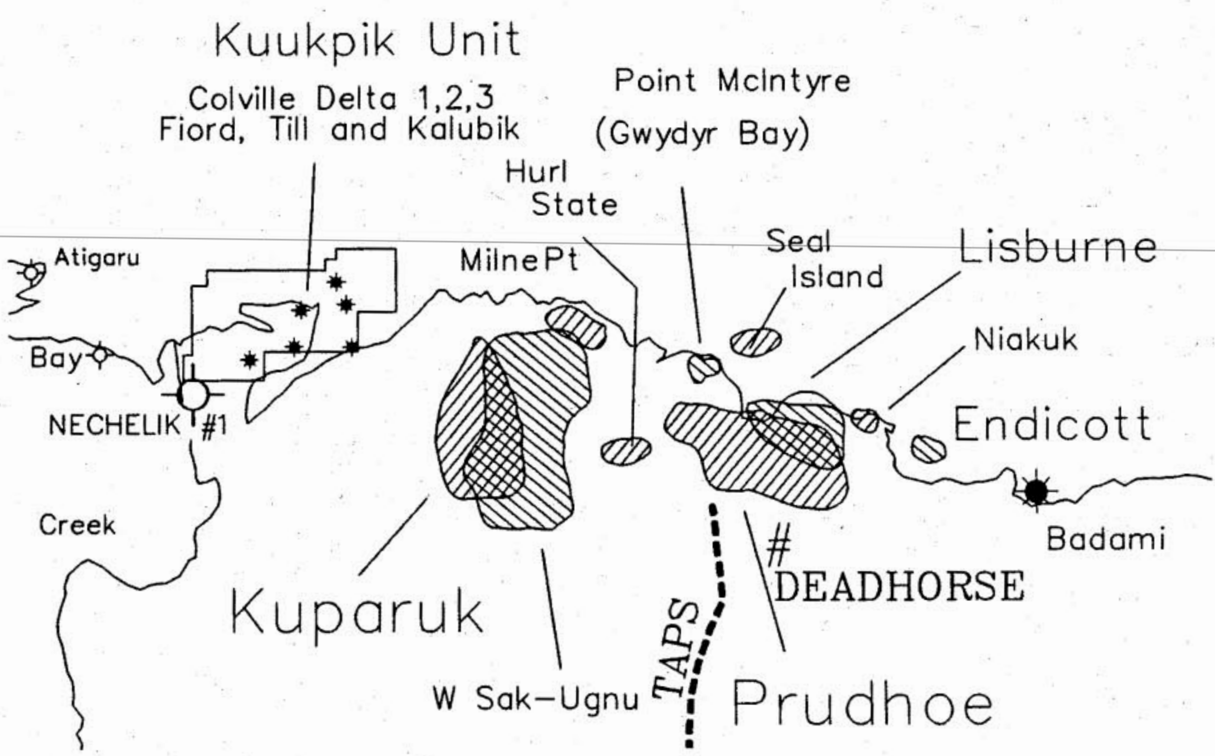
Anchorage, Alaska 99513

# The SOHIO Nechelik No. 1 Well, Colville River Delta Area, Alaska:

## Petrology, Diagenesis, Reservoir Quality in Selected Horizons in the Nuiqsut Unit and the Torok Formation

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# The SOHIO Nechelik No. 1 Well, Colville Delta Area, Northern Alaska:

## Petrology, Diagenesis, Reservoir Quality in Selected Horizons in the Nuiqsut Unit and the Torok Formation


**Abstract**

The SOHIO Nechelik No. 1 well is located in Sec. 18, T.12N., R.5E., Colville River delta area, northern Alaska, west of the Kuparuk and Prudhoe Bay fields, and just east of the National Petroleum Reserve in Alaska (NPRA). It was drilled in 1982, reaching a total depth of 10,018 feet.

Samples of core chips from eighteen horizons over the depth interval 7113-7216 feet were examined megascopically and microscopically. These horizons have been interpreted as being stratigraphic equivalents of the Kuparuk River Formation. They have informally been termed the "Nuiqsut Sands" by other investigators. Of principal interest were structural and textural characteristics, the nature and relative abundances of principal rock fabric elements-framework grains, matrix, cements, porosity, as well as proportions of constituent framework grain types. Reservoir quality attributes, diagenetic relationships, and sedimentologic information were of particular concern.

The samples analyzed are fine- to very fine-grained sandstones: principally sublithic arenites/wackes; one is a quartz arenite/wacke, another two are sublithic arenites. All contain appreciable proportions of pervasive and/or laminated clay-size materials, in part at least apparently involved in bioturbation. Grains of glauconite are commonly present, in trace amounts. With one exception, these rocks are all quite low in visual porosity, and presently exhibit poor apparent fluid storage or transmissive qualities. However, oil-staining/hydrocarbon shows have been recognized throughout this interval.

Additionally, two thin-sections representing depth intervals of 6382 and 6387 feet, within the lower portion of the Torok Formation (Brookian), were similarly studied petrographically.

The latter samples are very fine-fine grained sandstones: litharenites, with a preponderance of the constituent lithic grains comprised of sedimentary rocks: argillaceous, cherts, carbonate materials. These rocks are also slightly feldspathic, containing both plagioclase and potassium feldspars. Each of the two sandstones exhibits a moderate amount of visible porosity (12%), principally secondary in character, but there is appreciable microporosity associated as well.


## 1. Introduction

The SOHIO Nechelik No. 1 well is located in Sec. 18, T.12N., R.5E., Colville River delta area, northern Alaska, west of the Kuparuk and Prudhoe Bay fields, and just east of the National Petroleum Reserve in Alaska (NPRA; figure 1). The well was spudded January 17, 1982, only a few months after sufficient delineation drilling had been done to indicate that the nearby Kuparuk oil field was economically viable (late 1981). Nechelik No. 1 was drilled to a total depth of 10,018 feet. Several stratigraphic intervals showed oil staining, and twenty-one cores were cut, but no drill stem tests were run. The well was plugged and abandoned March 17, 1982.

Samples of core chips from horizons over the depth interval 7113-7216 feet (cores #2 and #3) were examined megascopically, under a stereomicroscope, and nineteen corresponding representative thin-sections were analyzed petrographically. These horizons have been interpreted as being stratigraphically correlatable to horizons within the Kuparuk River Formation, and been informally termed the "Nuiqsut Sands," by some operators. The core chip samples were rather limited in size- the largest being approximately two inches in maximum dimension, while most were of much smaller size, on the order of one-half inch in maximum dimension. As such, these samples were of some limited use to show the presence and distribution of laminations, organic material, and pyrite.

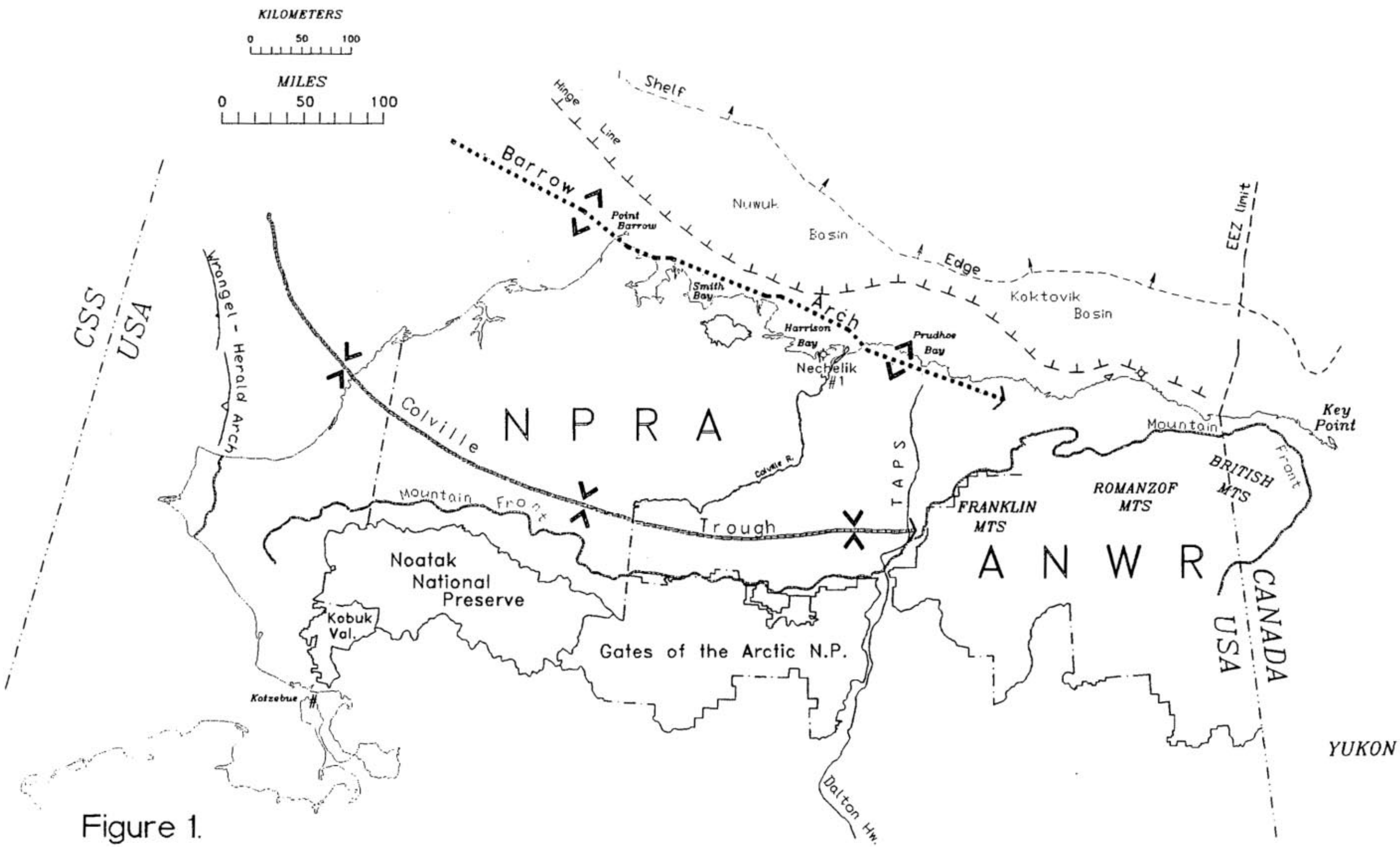



Figure 1.

Index map showing major geographic and tectonic features of the Alaska North Slope Nechelik #1 location indicated.

Two thin-sections were also available representing samples from the depth intervals 6382 and 6387 feet, within the lower portion of the Torok Formation (Brookian), and were also analyzed petrographically. These horizons are some two hundred feet below a relatively well-developed section of apparent sandstones within the Torok noted on the wireline logs from this well; unfortunately, no representative thin-sections from these higher, thicker sands were available to us.

These samples are from well materials archived at the Geological Materials Center (GMC), State of Alaska, Eagle River, Alaska. The samples studied here are only those for which thin-sections were available at the GMC. These petrographic thin-sections had been prepared previously by other investigators, from the same core chip materials, and each contained a relatively small amount of sectioned rock. These sections were examined with a Nikon Labophot-POL petrographic microscope, and photomicrographs were taken illustrative of representative portions of each sample. Point count modal analyses were performed in order to determine the relative abundances (volume percentages) of the principal rock fabric elements- framework grains, matrix, cements, porosity, as well as proportions of constituent framework grain types. Reservoir quality attributes, diagenetic relationships, and sedimentologic information were of particular interest.

## 2. Geology

The SOHIO Nechelik #1 well is one of the closest industry-drilled exploration wells to the NPRA (figure 1). It is also immediately outside the recently formed Kuupkik Development Unit, where a series of oil and gas discoveries have been announced recently (table 1).

Figure 1 shows the major features of North Slope geology. The Colville Basin and Alaska Arctic continental margin are depocenters separated by the east-southeast trending Barrow Arch. Basement rock consists of several distinct sequences of sedimentary rocks which have been locally metamorphosed to varying degrees (Banet, 1990; Moore and others 1992).

Lerand (1973) defined the overlying Ellesemerian sedimentary sequence as the northerly derived, upper Mississippian through lower Cretaceous age, trailing margin edge clastics and carbonates found across most of the North Slope. He also indicated that the Ellesmerian section is unconformably overlain by middle Cretaceous through upper Tertiary, overall east-northeasterly prograding clastic rocks shed from the Brookian orogenic uplifts of the region.

Refinements to these generalizations include the recognition of the sequence of lower Cretaceous age, locally deposited, clastic sediments along the Barrow Arch. Carman and Hardwick (1983) call these the Barrovian sequence. Craig and others (1985) refer to a Rift sequence, but prefer to restrict the sediments to those found only in grabens north of Barrow Arch. Hubbard and others (1987) include the Jurassic sediments in their Barrow Arch-derived Beaufortian depositional megasequence. Banet (1990 and 1992) and Mowatt, Banet and Reeder (1992) emphasize that multiple, temporally and spatially separated uplifts comprise the Barrow Arch. Thus, their Breakup sequence includes all the Jurassic through lower Cretaceous sediments and the various sandstones (including, but not restricted to the Barrow, Walakpa, Kuparuk, Put River, Nuiqsut, Simpson, Kemik, Pt. Thomson and Tapkaurak) which appear most likely to reflect the individually unique provenances resulting from the relatively small/areally restricted local uplifts.

The Nechelik well drilling encountered a stratigraphic section similar to that found at the Prudhoe Bay field (figure 2). At Nechelik #1, the deepest Ellesmerian con-

**TABLE 1.**
Drilling results from Colville Delta wells.

| OPERATOR | WELL | Tp., | R., | sec. | BOPD | API | GOR | PSI |
|---|---|---|---|---|---|---|---|---|
| SOHIO | NECHELIK | 12 | 5 | 18 | numerous oil shows | | | |
| TEXACO | COLVILLE DELTA #1 | 13 | 7 | 17 | oil stained sands | | | |
| TEXACO | COLVILLE DELTA #2 | 13 | 7 | 23 | 409 | 24-40 | 200-500 | |
| TEXACO | COLVILLE DELTA #3 | 13 | 6 | 25 | | | | |
| ARCO | FIORD #1 | 12 | 5 | 2 | 1065<br>180 | 32<br>26 | 500<br>--- | 600<br>--- |
| ARCO | KALUBIK #1 | 13 | 7 | 25 | 1200<br>410 | 26 | 450<br>250 | 380<br>315 |
| AMERADA HESS | COLVILLE DELTA #1 | 13 | 7 | 23 | 159 | 25 | 200-835 | |

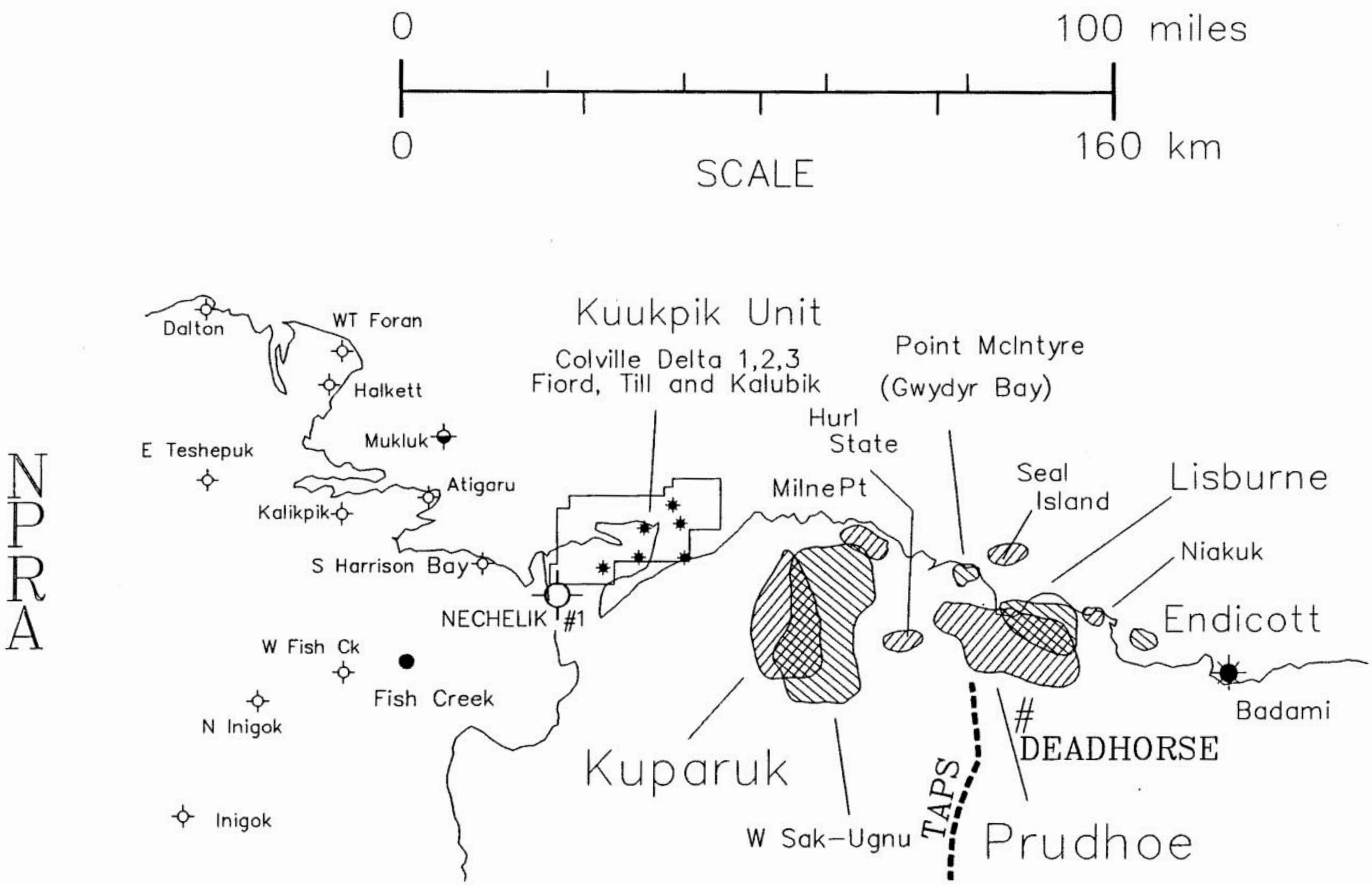



**Figure 2.**
Nechelik #1 well in relation to North Slope Oil and Gas development.
(NPRA– National Petroleum Reserve–Alaska, TAPS– Trans Alaska Pipeline System)

sists of white to light gray, hard, and fossiliferous (with sponge spicules and shell fragments) Lisburne Group limestone, 10,018 (TD)-9,908 feet.

The Lisburne is unconformably overlain by the Sadlerochit Group. The basal portion of the Sadlerochit is composed of interbedded sandstones and shales of the Echooka Formation (Permian). The sandstones (9,908-9,762 ft.) are gray, mostly silty to very-fine grained and fine-grained, with minor medium to coarse-grained zones. Glauconite is common through most of the Echooka, and there is local porosity. Shales and siltsones are dark gray, micaceous, and glauconitic, with some plant material on bedding planes. Geophysical logs show that the sand units are from to 2 to 30 feet thick, and are stacked into larger units. Total sandstone thickness is approximately 136 feet.

The Triassic age, gray to brown, hard and mostly fissile Kavik Shale (9,762-9,610 ft.) overlies the Echooka. Core descriptions feature interbedded and laminated siltstone. The logs show that the Kavik is overlain by predominantly blocky-shaped sandstone units and interbedded shale. These are the Prudhoe (formerly called the Ivishak) sands (9,610-8,750 ft.). Sandstone units are as thick as 30 feet, but most sands are between 5 and 10 feet thick. Contacts are sharp. Total sandstone thickness is approximately 441 feet. Core descriptions indicate that most of the sands are massive, with some crossbedded units noted upsection. The cuttings and core descriptions show the sands to be quartzose, mostly gray, brown or green, hard, silica-cemented, and fine-through coarse grained, with some chert-cobble conglomerates. Visible porosity varies between poor and moderate. Oil staining occurs in the upper portion of the section. Interbedded shales and mudstones are mostly gray with minor red or brown units, hard and silty.

The Shublik Formation (Triassic) overlies the Sadlerochit Group. As on typical logs, the Shublik has a distinctive, highly radioactive zone (8,750-8,586 ft.). The lithology consists of interbedded, hard, crystalline, white to dark-gray limestone and black, carbonaceous, hard brittle to fissile shale. Regionally, the Shublik is considered as an important source rock for much of the North Slope oil.

The Shublik is overlain by the Sag River sandstone (Triassic). This unit is mostly very fine- to fine grained quartzose sandstone. Glauconite is common. This unit was also slightly stained with oil.

At the Nechelik #1 well, the Breakup sequence consists of the Kingak Shale (Jurassic), a lower Cretaceous (?) Nuiqsut unit (of informal, local usage) and a Pebble Shale unit (figure 4). The Kingak Shale (8,436-7,632 ft.) is a mostly uniform section of light to dark-gray silty shale and brown siltstone. A dramatic offset of sonic velocities suggests an unconformity at 7,632 feet. Regional correlations indicate this to be the lower Cretaceous Unconformity (LCU). Well-defined on wireline logs from the Nechelik #1 well, the overlying Nuiqsut Unit is an interbedded, complexly coarsening and thickening upwards sequence of sands, silts and shales. It culminates in the hard, very fine-to fine-grained, oil-stained Nuiqsut Sand (7,150-7,087 ft.).

Cores #2 and #3 show that the Nuiqsut sand is quartzose, well sorted, and mostly subangular to subrounded. Small siderite nodules are common, dolomitic cement is patchy, and there is some pyrite. Lenticular and wavy bedding are common and are disrupted by burrows suggesting that there is considerable bioturbation. Glauconite is present, in trace amounts, in the Nuiqsut sands. The logs suggest that the Nuiqsut Unit correlates, or nearly correlates to Carman and Hardwick's (1983) nearby Kuparuk Formation (Hauterivian-Barremian) with its fine-to coarse grained and pervasively glauconitic, shallow marine, Kuparuk River sands (figures 4 and 5). Other considerations of this Kuparuk interval include contributions by Paris (1981), Eggert (1987), Masterson and Paris (1987),

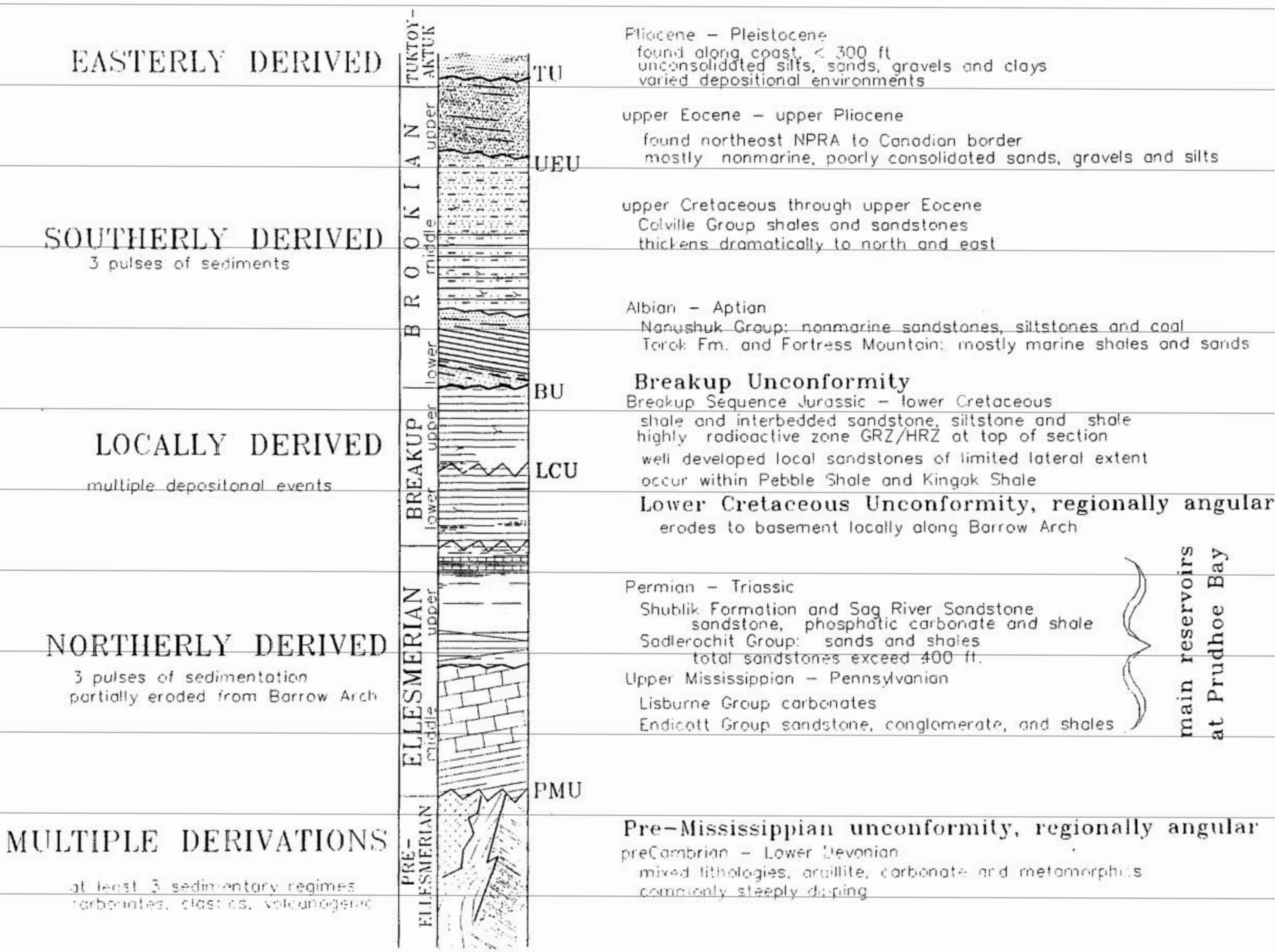



Figure 3.
Generalized stratigraphic relationships.

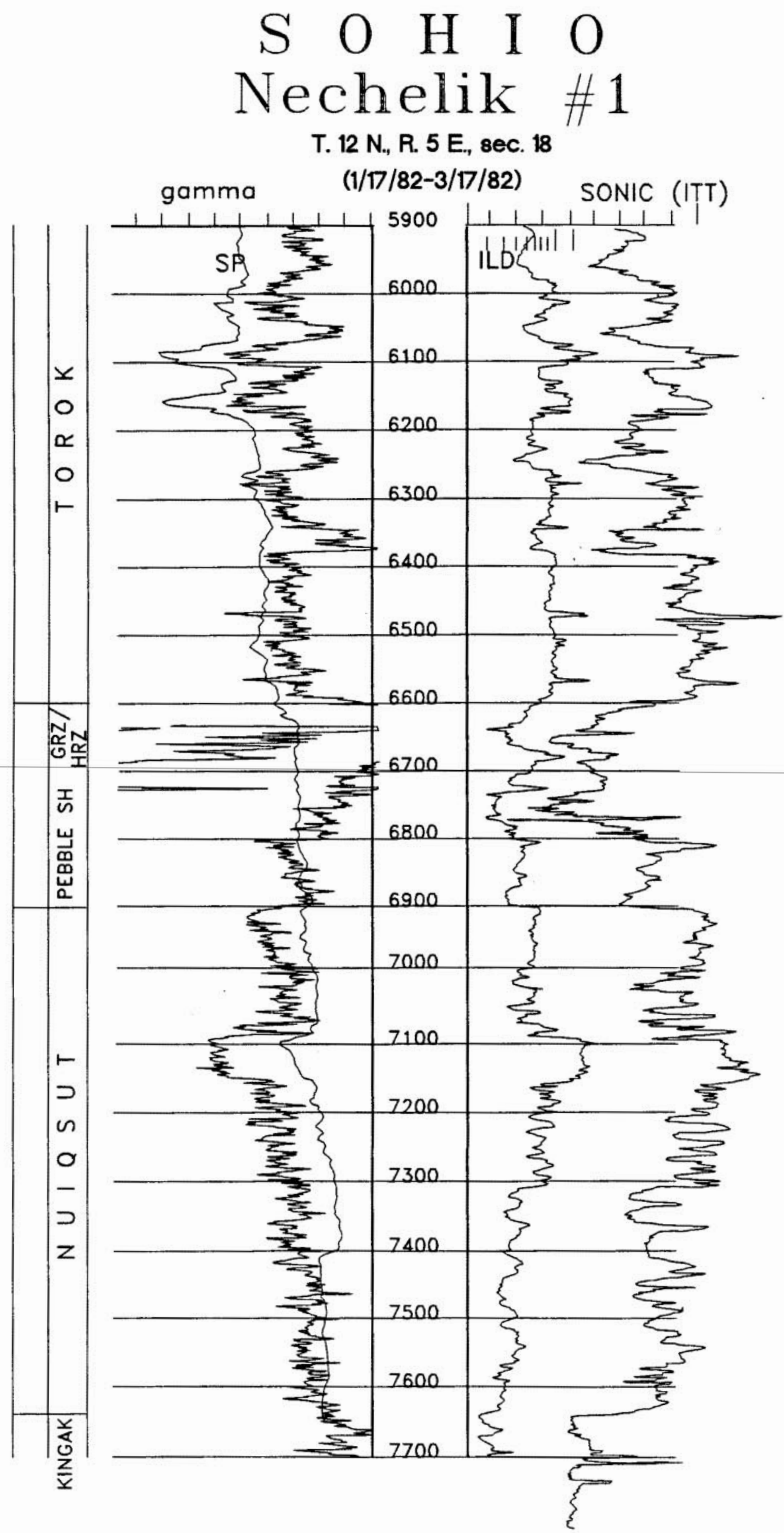



**Figure 4.**
Logs through Kingak Sh., Nuiqsut Unit, Pebble Sh., and lower Torok Fm.

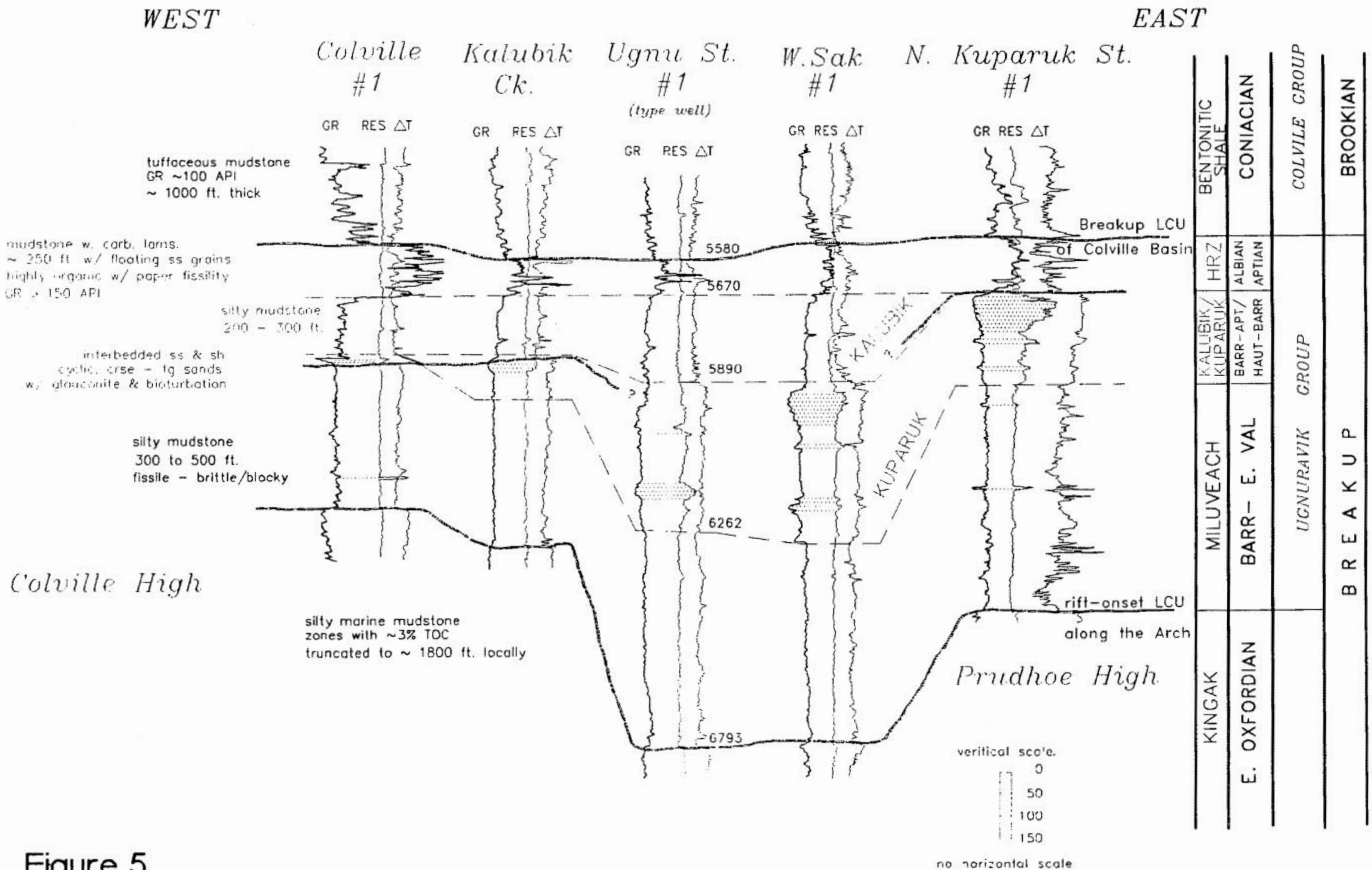



Figure 5.

Log correlation section across Kuparuk River field
showing Breakup sequence stratigraphy (Ugnuravik Group) and unconformities

and Gaynor and Scheihing (1988).

More thin and interbedded sandstones and siltstones overlie the Nuiqsut sand (7,087-6,898 ft.). An interval consisting of mostly hard, black to brown, fissile and partially pyritic material overlies the Nuiqsut Unit (figure 4). This correlates stratigraphically to the Pebble Shale Unit described in NPRA, and the Kalubik Formation (Barremian-Aptian) of the Kuparuk area. The upper 200 feet is highly radioactive and correlates to the Gamma Ray Zone of the Pebble Shale Unit (GRZ) of regional North Slope usage, or the Aptian-Albian High Radioactive Zone (HRZ) of the Kuparuk area (Carman and Hardwick, 1983).

Lower Brookian (Aptian-Albian) clastics of the Torok Formation overlie the Breakup Sequence. The basal unit at the Nechelik well (6,602-5,508 ft.) is a turbidite fan type of deposit. It consists of thin and interbedded shale, gray to brown partially laminated siltstones, and very-fine grained lithic and quartz sandstones. Sandstones between about 6,070 and 6,165 feet are stacked/amalgamated into thick units (figure 4). Core #1 shows that the siltstones are laminated (banded), featuring quartz grains and carbonaceous material. Both the silts and sands are typically deformed and show dewatering features (load or sole structures). Cross bedding is common. The cuttings description records brown oil staining. The Torok lithology becomes soft to fissile gray shale and claystone to 4,240 feet, typical for distal lithologies of the Torok.

The Torok is overlain by interbedded, nonmarine siltstones, shale and sandstone of the Nanushuk Group (Albian). The sandstones are gray, very fine-to fine-grained, with dark gray lithic fragments (mostly chert). Coaly materials are locally abundant.

Middle Brookian shale and claystone of the Colville Group (upper Cretaceous-Paleocene) overlies the Nanushuk. These are light-to dark-gray shales and claystones. There are a few sands or silts thick enough to appear on the logs in this section between 3,050-2,495 feet. In addition, three zones have relatively high gamma log radioactivity between 2,620-1,930 feet. Regionally, the Colville Group becomes coarse grained upsection.

In the Nechelik well, the approximately 1,130 foot depth level marks the base of the unconsolidated gravels and soft siltstone. Lithological similarities and the lack of induration suggest it may be the base of the Sagavanirktok Formation. However, paleontological data are not available to determine whether the uppermost unit belongs to the Colville Group (Maestrichtian-Paleocene) or the upper Brookian Sagavanirktok Formation (Eocene and Younger).

# 3. General Summary of Results

### Nuiqsut Unit

Petrographic examination and modal analysis of eighteen samples over the depth interval 7113-7216 feet show that almost all are rather low in visible porosity (the sample from 7126 feet exhibits 9%, as the significant exception). The samples are composed principally of fine-grained or very fine-grained (7213, 7216 feet), well-very well sorted quartz sand, with appreciable clay size material present as well. The latter occurs as laminae (persistent-irregular-discontinuous) and intergranular matrix, some of which, at least, is apparently bioturbated material. Thus, in overall aspect most of these samples are poorly sorted, on the scale of the entire thin-section.

The little recognizable porosity present in general (<5% in all samples except the thin-section representing the 7126 foot depth interval, which showed 9% visual porosity) is patchy (10-20% within these patches), with little/no apparent interconnection between the small and rather sparse patches. This restricted porosity appears to represent areas in which otherwise pervasive intergranular clay material is absent, perhaps due to effects of bioturbation (burrows relatively purged of clays, for example) and/or diagenesis (paragenetically early carbonate cementation, for example) within the sediments. In fact, an indeterminate portion of this apparent visible porosity may well represent artefacts of sample preparation, making the actual in-situ porosity in these rocks even lower than evaluated here. In addition, the substantial amounts of clay materials present (9-34%), particularly in persistent-irregular-discontinuous laminae, as well as interstitial to framework grains- occluding potential pore space, results in samples possessing relatively poor apparent fluid storage or transmissive qualities.

The framework grains are principally (78 to 95%) quartz- some of which exhibit reworked/somewhat rounded overgrowths of quartz, with lesser proportions of rock fragments (5 to 22%; principally sedimentary- cherts, carbonate grains, siltstone-shale clasts) and minor amounts of feldspars (TR-1%; potassium feldspars- including microcline, and plagioclase). Trace amounts of fossil fragments (carbonate), tourmaline, glauconite- some as deformed intergranular material, some as rounded grains, and zircon were also noted. The thin-section from 7136 feet features excellent large pelecypod fragments.

Diagenetic pyrite is common (2 to 16%), interstitial to framework grains, replacive of fossil materials, and in a general association with organic materials and clays. Quartz cement- some at least apparently pre-dating clays/carbonates- is common as overgrowths on detrital quartz grains, though difficult to resolve microscopically with sufficient consistency to permit meaningful modal analysis. Carbonate minerals - siderite, calcite; based on somewhat ineffective staining of these thin-sections- constitute a not uncommon cement phase as well. Some thin-sections (7118, 7126, 7136, 7142 feet) feature patches/appreciable amounts of microcrystalline to poikilotopic carbonate cements, of apparent early paragenesis-though at least some might, alternatively, represent replacement of matrix and/or framework grains.

The clay materials appear to be principally detrital in nature, although at least in part reworked and redistributed, apparently as a result of bioturbation. Clay as intergranular matrix is essentially ubiquitous. The optical characteristics and vaguely discernible morphologies suggest that at least much of this clay is illitic-micaceous, with some recognizable kaolinitic clay present as well.

The framework quartz grains are mostly subangular-subrounded, some are angular or rounded, and generally well sorted, or better.

These samples can be designated as sandstones: sublithic arenites/wackes, sublithic arenites (7118, 7136 feet), or quartz arenite/wacke (7117 feet), based on the relative proportions of the various sand size framework grain constituents, together with the abundance of detrital/bioturbated clay components. The classification scheme used here is modified from Pettijohn, et al., 1987 (a copy of figure 5-1 from this reference is attached as Appendix 1 to the present report). The assignment of a rock name to each of these samples is somewhat ambiguous, given the mode of occurrence and distributions of the clay-sized materials, and the uncertainty as to their origins and relationships to the sand size framework grains. The samples clearly are sandstones; whether "wacke" or "arenite" is appropriate in each case is less clear.

Relationships such as those observed in these samples, wherein a well sorted sand-sized framework is associated with appreciable clay-sized material, have been termed "textural inversions" (cf. Pettijohn, et al., 1987, p. 82-3). Bioturbation is a common cause of such texture, although other sedimentologic processes- generally somewhat unique combinations of particular circumstances (for example, during a storm a well-sorted marine shelf sand might be mixed with clay in much deeper water)- may result in similar textural relationships (Blatt, et al., 1980, pp. 372ff.). Dark opaque-semiopaque organic (presumably) materials are also common, principally in association with clay materials. Some of this could be hydrocarbon material.

A report presenting analytical data regarding some organic geochemical parameters for some samples from the Nechelik #1 well was obtained from the Geological Materials Center, State of Alaska, and is included in the present report as Appendix 2. Chemical analyses of total organic carbon content for some of the intervals studied in thin-section in the present investigation are in the range of 1.06-2.74% by weight.

Core descriptions from the well file archived as public information with the State of Alaska Oil and Gas Conservation Commission indicate appreciable manifestations of oil-staining/hydrocarbon shows throughout the horizons studied here. These core descriptions are also quite informative with regard to lithologies, sedimentary structures, fractures, and other gross aspects of these samples. The core descriptions from the well file are attached to the present report as Appendix 3.

**Torok Formation**

Petrographic examination and modal analysis of two thin-sections from the depth intervals 6382 and 6387 feet show that the former sample exhibits 12% (18% within the lower two-thirds of the sandstone layer), and the latter also 12% visible porosity; an appreciable proportion consists of, or is associated with, microporosity. The samples are composed principally of very fine- to fine-grained, well sorted, subequal amounts of lithic fragments and quartz sand framework grains (77, 79%, of total rock), with subordinate amounts (9, 11%) of matrix material of somewhat ill-defined argillaceous character. Appreciable amounts of the lithic grains are deformed into "pseudomatrix" between more competent quartz and other lithic grains. Each of these samples is slightly feldspathic, with both plagioclase and potassium feldspar present.

Most of the visible porosity in both thin-sections represents the effects of partial to complete secondary dissolution of pre-existing framework grains- principally cherts, feldspars, and carbonate fragments, as well as other rather ill-defined rocks. Appreciable clay material, much of which appears to be kaolinitic in nature, is associated with this porosity, likely as derivative reaction products of the dissolution of the silicates, in particular.

In these two samples, the framework grains are principally (50%) lithic fragments- comprised of cherts (7,20%), argillaceous rocks (12,16%), carbonate materials (12,15%) including rhombs (some are at least in part ferroan calcite) and other fragments, as well as other less-well-defined rocks (6%), together with quartz grains (45-48%). The feldspars are present in minor (2, 5%) amounts. Trace amounts of organic debris, weathered iron-titanium oxides, muscovite, biotite amd chlorite are present. Cements as such are either poorly-defined, or essentially absent from these rocks, probably because of such detrital clay matrix (9,11%) as is present, the moderate degree of compaction, and the extensive development of pseudomatrix materials among the framework grains. Minor/trace amounts of diagenetic pyrite are present. Trace amounts of quartz overgrowth cement were noted, in one instance as euhedra projecting into apparent primary intergranular pore space in the thin-section representing the 6382 foot interval. These samples thus can be designated as sandstones: litharenites, using the classification discussed above (cf. Appendix 1).

The structural and textural features, especially those exhibited by the thin-section representing the 6382 foot interval, as discussed in the detailed description of this sample, below, are indicative of a probable turbidite mode of origin. These sandstones are appreciably less quartzose, thinner, and probably not as areally extensive as the Nuiqsut sands. Nor are they likely as extensive as the thicker sandstone intervals higher in the Torok Formation.

Appendix 3 contains core descriptions of these intervals, from the well file archived with the State of Alaska Oil and Gas Conservation Commission.

## 4. Detailed Analytical Results

The results of the petrographic analytical work done are summarized in Table 2. Figures 6, 7 and 8 are ternary diagrams showing the relative abundances of framework sand size grains of quartz, feldspars, and lithic fragments (including chert, metaquartzite, other rock-types) for each sample analyzed. The box on each diagram includes information on detrital matrix, authigenic, and diagenetic/introduced materials. The rock classification used is modified from Pettijohn, et al., 1987, and Dott, 1964. Numerous photomicrographs were taken, and are on file with the first author.

Selected photomicrographs are also presented here, as Plates 1-4. Regarding the photomicrographs, the apparent magnification, expressed as "...X", is that of a measured linear distance on a Leitz micrometer slide on the microscope stage, as compared to the linear dimension of that same distance on the finished photographic print.

The photomicrographs were taken in plane-polarized light, unless otherwise noted. "XSP" indicates a photomicrograph taken with "crossed polarizers" in the optical path of the microscope.

Plate 1 features: (A-D) aspects of rock fabric, framework grains, carbonate cementation, intergranular clays, and minor porosity as exhibited by the thin-section from the 7118 foot interval. Nuiqsut unit samples.

Plate 2 features: (A) an overall view of the fabric and character of these bioturbated samples, as represented by the 7131 foot thin-section; (B, C) show aspects of this, including minor porosity, in the 7164 foot sample; (D) shows porosity development adjacent to extensive carbonate cementation in the sample from 7126 feet. Nuiqsut unit samples.

Plate 3 features: (A-C) aspects of rock fabric, framework grains, and carbonate cementation, as well as a portion of a large pelecypod fragment, as shown in the sample from 7136 feet; (D) a portion of the thin-section from the 7142 foot sample, showing apparent siderite as well as calcite occurring as intergranular cements, with some of the framework quartz grains exhibiting apparent quartz overgrowth cements. Nuiqsut unit samples.

Plate 4 features: (A-D) aspects of rock fabric, framework grains, matrix materials, and porosity- much apparently secondary in character-, as seen in the sample from 6382 feet. Torok Formation samples.

Appendix 3 should be consulted for additional information on various gross aspects of each sample interval examined: lithologies, sedimentary structures, fractures, hydrocarbon staining/shows.

## 5. Petrographic Descriptions

### A. Nuiqsut Unit

7113 feet

Sandstone: sublithic arenite/wacke. Framework grains (64% of the total rock): predominantly fine sand-sized, with a trace amount of medium sand; well-very well sorted, angular/subangular; consisting of quartz (93%)- a few of which exhibit evidence of rounded overgrowths, trace amount

# SANDSTONES : BRIEF DESCRIPTION OF THIN SECTIONS

| SAMPLE NO. AND/OR DEPTH | WHOLE ROCK 100 % | | | | GRAINS 100 % | | | CEMENT TYPES | | | | | POROSITY TYPES | | | AVERAGE GRAIN SIZE mm. | | | | | | SORTING | | | | ROUNDNESS | | | | OTHER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GRAINS | MATRIX | CEMENT | PORES | QTZ. | FELDSPAR | LITHIC FRAGS. | QUARTZ | CALCITE | DOLOMITE | | PRESSURE SOLUTION | INTERGRAN. | DISSOLUTION | FRACTURE | VC > 1.0 | C 0.5 - 1.0 | M 0.25-0.5 | F 0.13-0.25 | VF 0.06-0.13 | SILT < 0.06 | EXCELLENT | WELL | MODERATE | POOR | ROUNDED | SUBROUNDED | SUBANGULAR | ANGULAR | PYRITE | GLAUCONITE | |
| 7113' | 64 | 27 | 7 | 2 | 93 | TR | 7 | X | X | | | | | X | | | | TR | X | | | | SAND | | X | | X | X | | X | X | |
| 7114' | 65 | 25 | 9 | TR | 94 | TR | 6 | X | X | | | | | X | | | | | X | | | | SAND | | X | | X | X | | X | X | |
| 7117' | 59 | 26 | 15 | — | 95 | — | 5 | X | X | | | | | | | | | TR | X | | | | SAND | | X | X | X | X | | X | | |
| 7118' | 66 | 14 | 17 | 3 | 94 | TR | 6 | X | X | | | | | X | | | | TR | X | | | | SAND | | X | X | X | X | | X | X | |
| 7119' | 70 | 19 | 7 | 4 | 91 | — | 9 | X | X | | | | | X | | | | TR | X | | | | SAND | | X | X | X | X | X | X | X | |
| 7120' | 62 | 30 | 7 | TR | 94 | TR | 6 | X | X | | | | | | | | | | X | | | | SAND | | X | | X | X | X | X | X | |
| 7123' | 59 | 24 | 14 | 3 | 91 | — | 9 | X | X | | | | | X | | | | TR | X | | | | SAND | | X | | X | X | X | X | X | |
| 7126' | 67 | 17 | 7 | 9 | 93 | — | 7 | X | X | | | | | X | | | | | X | | | | SAND | | X | X | X | X | X | X | X | |
| 7130' | 65 | 22 | 9 | 4 | 84 | — | 16 | X | | | | | | X | | | | TR | X | | | | SAND | | X | | X | X | | X | X | |
| 7131' | 63 | 29 | 7 | 2 | 86 | TR | 14 | X | | | | | | X | | | | TR | X | | | | SAND | | X | X | X | X | | X | X | |
| 7136' | 62 | 9 | 29 | 1 | 85 | TR | 15 | X | X | | | | | X | | | | | X | | | | SAND | X | X | | X | X | X | X | X | |
| 7138' | 71 | 26 | 3 | — | 90 | — | 10 | X | | | | | | | | | | TR | X | | | | SAND | | X | | X | X | X | X | X | |
| 7140' | 60 | 26 | 10 | 3 | 87 | TR | 13 | X | X | | | | | X | | | | TR | X | | | | SAND | | X | X | X | X | X | X | | |

Table 2.

## SANDSTONES: BRIEF DESCRIPTION OF THIN SECTIONS

| SAMPLE NO. AND/OR DEPTH | WHOLE ROCK 100 % | | | | GRAINS 100 % | | | CEMENT TYPES | | | | POROSITY TYPES | | | AVERAGE GRAIN SIZE mm. | | | | | | SORTING | | | | ROUNDNESS | | | | OTHER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GRAINS | MATRIX | CEMENT | PORES | QTZ. | FELDSPAR | LITHIC FRAGS. | QUARTZ | CALCITE | DOLOMITE | PRESSURE SOLUTION | INTERGRAN. | DISSOLUTION | FRACTURE | VC > 1.0 | C 0.5 - 1.0 | M 0.25-0.5 | F 0.13-0.25 | VF 0.06-0.13 | SILT < 0.06 | EXCELLENT | WELL | MODERATE | POOR | ROUNDED | SUBROUNDED | SUBANGULAR | ANGULAR | PYRITE | GLAUCONITE | |
| 7142' | 66 | 15 | 17 | 3 | 88 | TR | 12 | X | X | | | | X | | | | TR | X | | | | SAND | | X | | X | X | X | X | X | |
| 7144' | 70 | 21 | 7 | 2 | 83 | — | 17 | X | X | | | | X | | | | | X | | | | SAND | | X | | X | X | X | X | X | |
| 7164' | 67 | 20 | 9 | 4 | 78 | — | 22 | X | X | | | | X | | | | TR | X | | | | SAND | | X | X | X | X | X | X | X | |
| 7213' | 62 | 34 | 3 | — | 82 | — | 18 | X | X | | | | | | | | | X | X | | | SAND | | X | | | X | X | X | | |
| 7216' | 64 | 33 | 3 | — | 88 | — | 12 | X | X | | | | | | | | | X | X | | | SAND | | X | X | X | X | X | X | X | |
| 6382' | 79 | 9 | ? | 12 | 45 | 5 | 50 | TR | | | | | X | | | | | X | X | | | X | | | | X | X | X | X | X | |
| 6387' | 77 | 11 | ? | 12 | 48 | 2 | 50 | TR | | | | | X | | | | | X | X | | | X | | | | X | X | X | X | X | |

Table 2. (continued)

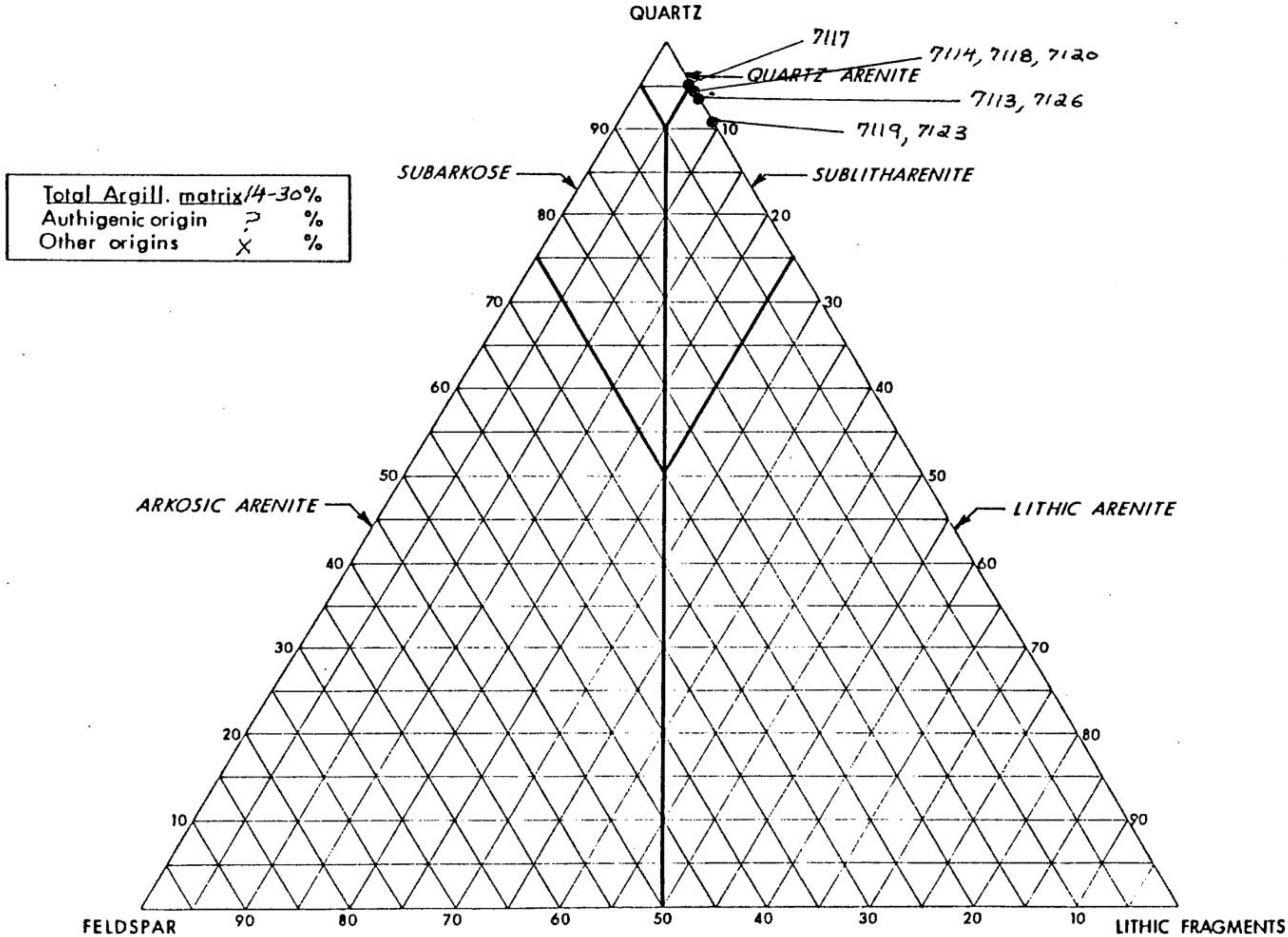



Figure 6. Nuiqsut; Upper Horizons (7113-7126 feet)

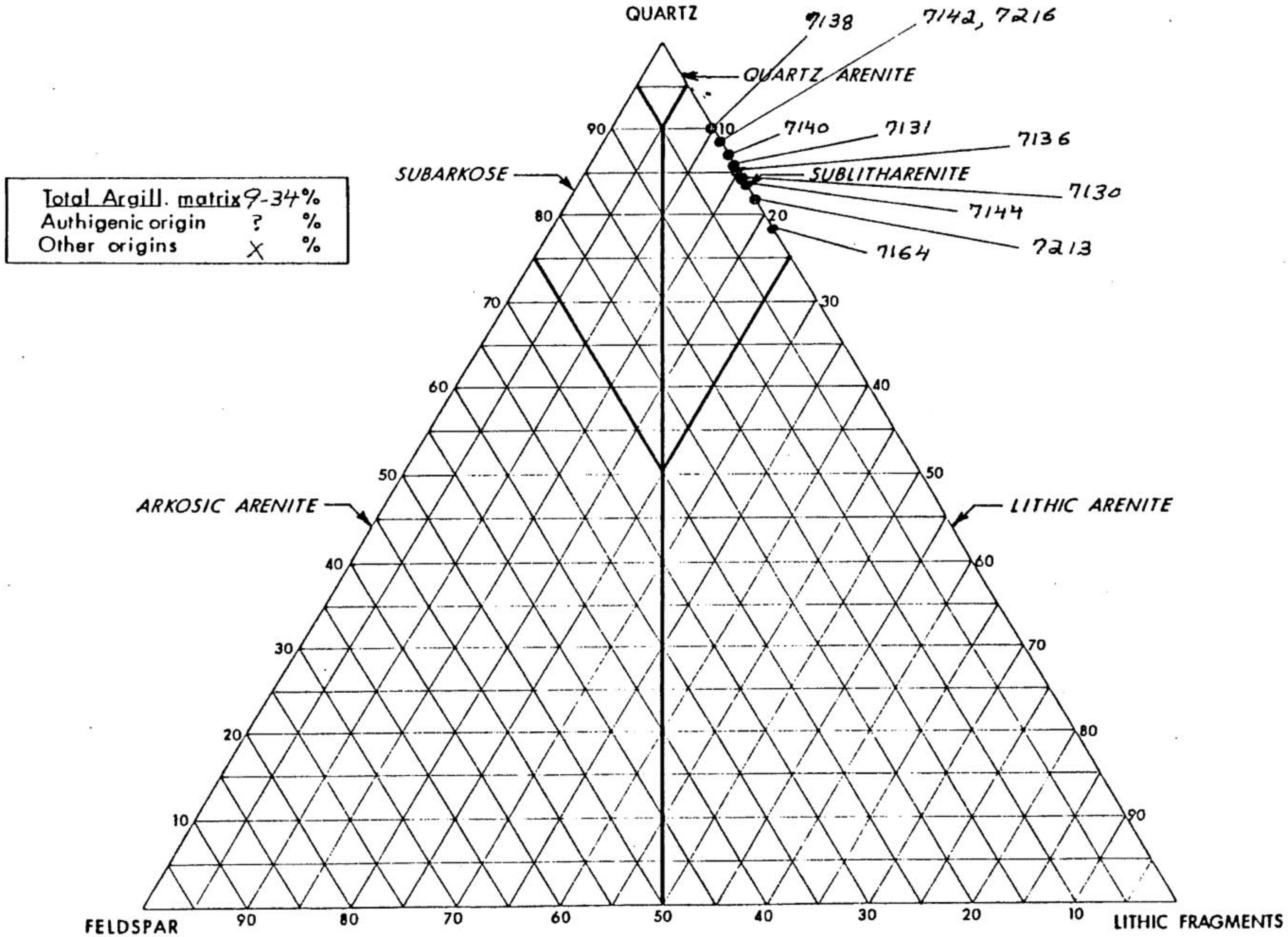



Figure 7. Nuiqsut; Lower Horizons (7130-7216 feet)

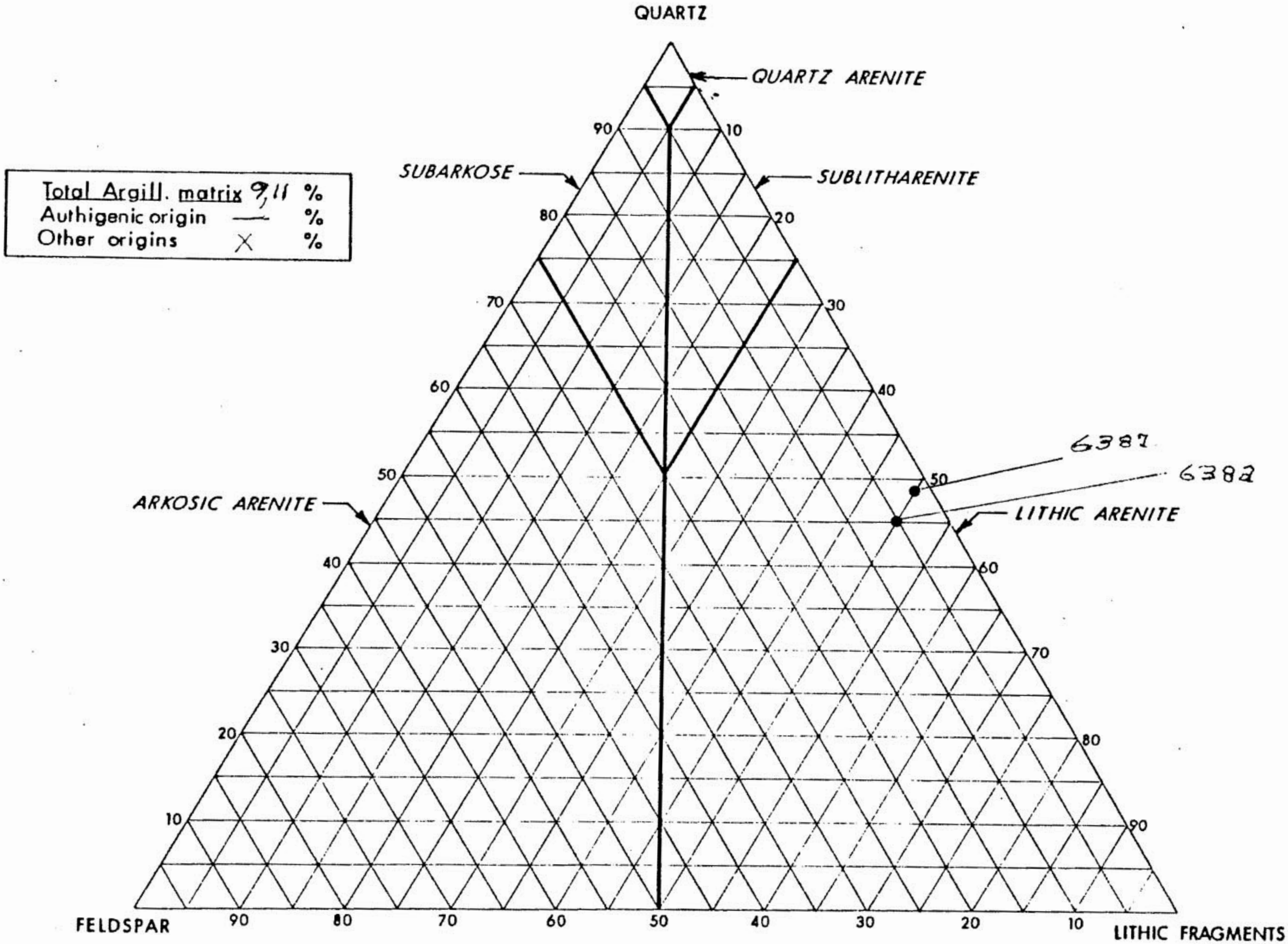



Figure 8. Torok; (6382, 6387 feet)

of feldspar (plagioclase, with albite twinning), and lithic fragments (7%)- principally cherts. Trace amount of green glauconite. Matrix, in large part at least apparently detrital, is on the order of 27% of total rock. Argillaceous, patchy, in irregular laminae, streaks, and interstitial to framework grains. Organic material is associated, at least some of which appears to represent staining by hydrocarbons. The clays appear to be micaceous-illitic in nature, with some kaolinite as well.

Visible porosity 2% or less, principally as sparse patches of vestigial intergranular porosity, perhaps associated with secondary dissolution of eogenetic carbonate cements, and/or detrital lithic fragments/feldspars (?). Some microporosity may be present as well.

Cements comprise at least 7% of this thin-section. There are traces of carbonate, and at least trace amounts of quartz overgrowths. Diagenetic pyrite (6% of sample) occurs intergranular to framework grains, as well as in association with organic materials and clays.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality is essentially nil as is, with poor/fair (?) potential for improvement elsewhere, via diagenetic means (in particular, dissolution of cherts, pyrite).

7114 feet

Sandstone: sublithic arenite/wacke. Framework grains (65% of the total rock): predominantly fine sand-sized; well-very well sorted, subangular/subrounded; consisting of quartz (94%), trace amounts of feldspar (plagioclase, exhibiting albite twinning), and lithic fragments (6%)- cherts, carbonate fragments (some recognizably fossil material). Traces of glauconite and tourmaline occur.

Matrix, in large part at least aparently detrital, is on the order of 25% of the total rock. Argillaceous, patchy, in irregular laminae, streaks, and interstitial to framework grains. Organic materials are associated, at least some of which may well represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity essentially nil, principally as microporosity.

Cement constitutes a minimum of 9% of the total thin-section. Diagenetic pyrite (8% of total thin-section) occurs intergranular to framework grains, as well as in association with clays and organic materials. Quartz overgrowths occur in indeterminate but relatively small amount, and there are traces of carbonate as well. This sample has undergone a moderate degree of apparent compaction, as well as bioturbation.

Reservoir quality is poor as is, with poor potential for improvement diagenetically.

7117 feet

Sandstone: quartz arenite/wacke. Framework grains (59% of total rock): predominantly fine sand-sized, with minor amounts of medium sand-sized materials, well-very well sorted, subangular/subrounded/rounded; consisting of quartz (95%)- a few of which exhibit rounded overgrowths, lithic fragments (5%)- consisting predominantly of cherts, and other constituents (TR%), including argillaceous rock fragments, tourmaline and fossil fragments (carbonate).

Matrix, at least in large part apparently detrital, is on the order of 26% of the total rock. Argillaceous, patchy in irregular laminae, streaks, and interstitial to framework grains. Associated organic material, at least some of which appears to represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity is essentially absent. Some microporosity may be present.

Cement comprises a minimum of 15% of the total thin-section. Diagenetic pyrite (15%) occurs intergranular to framework grains, as well as in association with organic materials and clays. There are also at least trace amounts of quartz overgrowth and carbonate cements.

The sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality is poor as is, with poor /fair potential for improvement elsewhere, via diagenetic means.

7118 feet

Sandstone: sublithic arenite. Framework grains (66% of the total rock): predominantly fine sand-sized, with trace amount of medium sand; well-very well sorted, subangular/subrounded/rounded; consisting of quartz (94%), feldspars (trace- plagioclase, exhibiting albite twinning), and lithic fragments (6%)- cherts. Glauconite occurs in trace amount.

Matrix at least in large part apparently detrital, is on the order of 14% of the total rock. Argillaceous, patchy, in irregular laminae, streaks, and interstitial to framework grains. Organic materials are associated, some of which may represent hydrocarbon staining. The clays appear to be micaceous-illitic in nature, with some kaolinite as well.

Visible porosity 3% or less, principally as secondary development after certain framework grains. Much of this is microporosity.

Cements comprise at least 17% of the thin-section. Patches of generally poikilotopic carbonate (calcite) make up most of this, with subordinate amounts of microcrystalline (siderite ?) concentrated along the margins of some framework grains. Diagenetic pyrite (4% of the thin-section) occurs intergranular to framework grains, as well as in association with organic materials and clays. Quartz overgrowths also occur, in indeterminate amount; some of these seem to be paragenetically prior to carbonate, and to clay influx, as observed in several portions of the thin-section. This is somewhat at odds with the observed overall textural relationships. Perhaps this quartz represents reworked overgrowth material. Alternatively, replacement by carbonates is a possibility, although such an explanation lacks generality with regard to the clays/ quartz cement relationships observed.

This sample has undergone a moderate degree of apparent compaction, as well as bioturbation.

Reservoir quality poor as is. Fair-good potential for improvement, via dissolution of carbonate cements, as well as other potentially reactive materials (cherts, pyrite). However, the patchy nature of the zones of poikilotopic carbonate might militate against the net likelihood of development of significantly interconnected porosity throughout appreciable volumes of rock.

*Plate 1 depicts salient features of the above sample.*

7119 feet

Sandstone: sublithic arenite/wacke. Framework grains (70% of the total rock): predominantly fine sand-sized, with trace amount of medium sand; well-very well sorted, angular/subangular/subrounded/ rounded; consisting of quartz (91%) and lithic fragments (9%)- cherts, carbonate rhombs/fragments, argillaceous rock fragments, as well as traces of glauconite (?).

Matrix, at least in large part apparently detrital, comprises 19% of the thin-section.

Argillaceous, patchy, in irregular laminae, lenses, streaks, and interstitial to framework grains. Organic material is associated, at least some of which appears to represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity 4% or less, principally as secondary development after certain framework grains. Some is microporosity.

Cements comprise at least 7% of this thin-section. Diagenetic pyrite (5% of total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. An indeterminate amount of quartz cement occurs as overgrowths on detrital quartz grains, and trace amounts of carbonate cement are noted as well.

This sample has undergone a moderate degree of apparent compaction, as well as bioturbation.

Reservoir quality poor as is. Poor/fair (?) potential for improvement, via secondary dissolution of reactive materials (lithic fragments, pyrite; carbonate cement).

7120 feet

Sandstone: sublithic arenite/wacke. Framework grains (62% of total rock): predominantly fine sand-sized, well sorted, angular/subangular/subrounded; consisting of quartz (94%)- a few of which exhibit reworked overgrowths, feldspars (trace; plagioclase, with albite twinning, and potassium feldspar, with microcline twinning), lithic fragments (6%)- principally cherts, carbonate fragments. Traces of tourmaline and glauconite.

Matrix, at least in large part apparently detrital, comprises 30% of the total rock. Argillaceous, patchy, in irregular-continuous laminae, and interstitial to framework grains. Associated organic material, at least some of which appears to represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity in trace amount, principally as microporosity.

Cements comprise at least 7% of this thin-section. Diagenetic pyrite (7%) occurs intergranular to framework grains, as well as in association with organic materials and clays. An indeterminate amount of quartz overgrowths, and trace amounts of carbonate cement are also present.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality is essentially nil as is, with poor potential for improvement elsewhere, via diagenetic means.

7123 feet

Sandstone: sublithic arenite/wacke. Framework grains (59% of the total rock): predominantly fine sand-sized, with trace amount of medium sand, well-very well sorted, angular/subangular/subrounded, consisting of quartz (91%), lithic fragments (9%)- principally cherts, carbonate fragments. Traces of tourmaline and glauconite.

Matrix, at least in large part apparently detrital, comprises 24% of the total rock. Argillaceous, patchy, in irregular laminae, streaks, and interstitial to framework grains. Associated organic material, with some possibly representing hydrocarbon staining. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity 3%, or less. Principally as secondary development after certain framework grains. Some may represent sparse patches of vestigial intergranular porosity, perhaps associated with secondary dissolution of eogenetic carbonate cements. Microporosity is present as well.

Cements comprise at least 14% of the total thin-section. Diagenetic pyrite (14% of total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. An indeterminate amount of quartz overgrowth material also is present, as well as traces of carbonate cement.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality is poor as is, with poor/moderate (?) potential for improvement elsewhere, via diagenetic means (in particular, in this case, via dissolution of pyrite, and/or lithic grains).

7126 feet

Sandstone: sublithic arenite/wacke. Framework grains (67% of the total rock): predominantly fine sand-sized; well-very well sorted, angular/ subangular/ subrounded/rounded; consisting of quartz (93%), lithic fragments (7%)- cherts. Trace of glauconite.

Matrix, at least in large part apparently detrital, comprises 17% of this thin-section. Argillaceous, patchy, and interstitial to framework grains. Organic materials are associated, some of which may represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity comprises 9% of this thin-section. Patchy development, principally secondary in nature, perhaps most likely via dissolution of eogenetic carbonate cement. Some microporosity also is present.

Cements comprise at least 7% of this thin-section. Diagenetic pyrite (4% of total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. Also noted are patches of intergranular "beadwork" crystalline carbonate, associated with more extensive/ poikilotopic carbonate, with the sum of such carbonate amounting to some 3% of the total rock analyzed. Within a typical patch modal analysis demonstrates the presence of approximately 65% detrital framework grains, generally in mutual contact, surrounded by 30% carbonate cements, with some 5% porosity associated. Although rigorous definition is generally somewhat ambiguous in thin-section, there seems to be no compelling evidence of appreciable replacement of framework grains by carbonates here. Some of the carbonate may be siderite (particularly the apparently paragenetically earlier "beadwork"), while the more extensively developed material likely is calcite. An indeterminate but lesser amount of quartz cement occurs, as overgrowths which seem to have been early in the paragenetic sequence, since they are surrounded/covered over by carbonate or clays. Alternatively, these may, rather, represent reworked overgrowths.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality is fair as is, although there is uncertainty as to the degree of interconnectedness, hence the effectiveness, of the porosity present, over any appreciable volume of rock in-situ. Fair/good potential for further improvement in reservoir quality seems to exist, via diagenetic dissolution of reactive materials (carbonate, pyrite, cherts).

*Plate 2 depicts salient features of the above sample.*

7130 feet

Sandstone: sublithic arenite/wacke. Framework grains (65% of the total rock): predominantly fine sand-sized, with trace of medium sand; well-very well sorted, subangular/subrounded; consisting of quartz (84%), lithic fragments (16%)- cherts, carbonate fragments and rhombs. Traces of glauconite and tourmaline. Some of the relatively clay-free patches are lens-shaped/round, suggestive of burrows.

Matrix, at least in large part apparently detrital, comprises 22% of the total rock. Argillaceous, patchy, and interstitial to framework grains. Organic materials are associated, some of which may represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity 4% or less. Includes secondary development after certain framework grains, as well as microporosity.

Cements comprise at least 9% of this thin-section. Diagenetic pyrite (9% of total rock) occurs intergranular to framework grains, and replacive of fossils, as well as in association with organic materials and clays. An indeterminate amount of quartz overgrowth cements occur, in patchy distributions throughout the thin-section, generally in regions relatively devoid of clays.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality poor as is. Poor/fair (?) potential for improvement diagenetically; dissolution of pyrite and/or lithic fragments (cherts, carbonates) would seem to offer some possibilities.

7131 feet

Sandstone: sublithic arenite/wacke. Framework grains (63% of the total rock): predominantly fine sand-sized, with trace amounts of medium sand; well-very well sorted, subangular/subrounded/rounded; consisting of quartz (86%)- a few grains feature reworked overgrowths, feldspars (trace; plagioclase and potassium feldspars— at least in part microcline), lithic fragments (14%)- principally cherts, carbonate fragments. Traces of glauconite, tourmaline.

Matrix, at least in large part aparently detrital, comprises 29% of the total rock. Argillaceous, patchy, in irregular-continuous laminae, streaks, and interstitial to framework grains. Associated organic material, some of which may represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with perhaps some kaolinite as well.

Visible porosity 2% or less. Principally as sparse patches of vestigial intergranular (?) porosity, perhaps associated with secondary dissolution of eogenetic carbonate cements. Some microporosity.

Cements comprise at least 7% of this thin-section. Diagenetic pyrite (7% of total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. An indeterminate amount of quartz overgrowth cements occur, in patches throughout the rock which are relatively free of clays.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality poor as is, with poor/fair (?) potential for improvement elsewhere, via diagenetic means (in particular, dissolution of pyrite, lithic grains, feldspars).

*Plate 2 depicts salient features of the above sample.*

7136 feet

Sandstone: sublithic arenite. Framework grains (62% of the total rock): predominantly fine sand-sized; well-very well sorted, angular/subangular/subrounded; consisting of quartz (85%), feldspars (trace; plagioclase, and potassium feldspar), lithic fragments (15%)- cherts, carbonate fragments (including large pieces of Pelecypods, in the form of shell fragments made up of prismatic calcite). Traces of glauconite, tourmaline. The glauconite is concentrated to some degree in discontinuous streaks, and is often deformed somewhat.

Matrix, at least in large part apparently detrital, comprises 9% of this thin-section. Argillaceous, patchy, lens-like, streaks, and interstitial to framework grains. Organic materials are associated, some of which may (?) represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with perhaps some kaolinite as well.

Visible porosity 1% or less, including microporosity.

Cements comprise at least 29% of this thin-section. Carbonate, principally as poikilotopic areas, makes up 22% of the rock, and likely is related to the occurrence of large calcareous fossil fragments (not counted in the modal analysis) elsewhere in this sample. Within a typical poikilotopic patch, modal analysis reveals the presence of 64% framework grains, generally in mutual contact, surrounded by 36% carbonate. Again, as mentioned above in the discussion of the sample from 7126 feet, there seems to be no compelling evidence of appreciable replacement of framework grains by carbonates here. Most of this carbonate appears to be calcite. Diagenetic pyrite accounts for another 7% of the total rock, occurring intergranular to framework grains, as well as in association with organic materials and clays. An indeterminate amount of quartz overgrowth cements occur sporadically in small patches. At least some of this material appears to pre-date the carbonate cement, which is difficult to reconcile with the observed overall textural relationships, as well as theoretical aspects of the geochemistry of these phases. Perhaps the apparent quartz cement actually represents reworked overgrowths, although the evidence seems somewhat less-than-definitive here.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality poor as is. Excellent potential for improvement, diagenetically, via secondary dissolution of the extensive poikilotopic carbonate cements, as well as the shell fragments, pyrite, and cherts.

*Plate 3 depicts salient features of the above sample.*

7138 feet

Sandstone: sublithic arenite/wacke. Framework grains (71% of the total rock): predominantly fine sand-sized, with trace of medium sand; well-very well sorted, angular/subangular/subrounded, consisting of quartz (90%), lithic fragments (10%)- principally cherts, carbonate fragments, argillaceous rock fragments. Traces of glauconite, tourmaline, zircon.

Matrix, at least in large part apparently detrital, comprises 26% of the total rock. Argillaceous, patchy, irregular-continuous laminae, streaks, and interstitial to framework grains. Associated organic material, at least some of which may (?) represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, with perhaps some kaolinite as well.

Visible porosity not evident. Some microporosity may be present.

Cement comprises at least 3% of this thin-section. Diagenetic pyrite (3% of total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. An indeterminate amount of quartz overgrowth cement occurs, principally in patches relatively free of clays.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality is nil as is, with poor/moderate (?) potential for improvement elsewhere, via diagenetic means (dissolution of lithic grains, pyrite).

7140 feet

Sandstone: sublithic arenite/wacke. Framework grains (60% of the total rock): predominantly fine sand-sized, with trace of medium sand; well sorted, angular/subangular/subrounded/rounded; consisting of quartz (87%), feldspars (trace; potassium feldspars), lithic fragments (13%)-cherts, argillaceous rocks, carbonate fragments (including shell material). Trace of tourmaline.

Matrix, at least in large part apparently detrital, comprises 26% of this thin-section. Argillaceous, patchy, irregular, interstitial to framework grains. Organic materials are associated, some of which may (?) represent hydrocarbon staining. The clays appear to be micaceous-illitic in character, perhaps with some kaolinite as well.

Visible porosity 3% or less, apparently as secondary development after certain framework grains. Microporosity is present.

Cements comprise at least 10% of this thin-section. Diagenetic pyrite (8% of the total rock) occurs intergranular to framework grains, and replacive of fossils, as well as in association with organic materials and clays. Carbonate cement makes up 2% of the total rock. There is also an indeterminate amount of quartz overgrowth cement.

This sample has undergone a moderate degree of apparent compaction, as well as bioturbation.

Reservoir quality is poor as is. Poor/fair (?) potential for improvement diagenetically, via dissolution of reactive materials (lithic fragments, pyrite, carbonate cement).

7142 feet

Sandstone: sublithic arenite/wacke. Framework grains (66% of the total rock): predominantly fine sand-sized, with trace of medium sand; well sorted, angular/subangular/subrounded; consisting of quartz (88%), feldspar (trace; plagioclase, with albite twinning), lithic fragments (12%)-argillaceous rocks, cherts, carbonate fragments. Traces of glauconite, tourmaline.

Matrix, at least in large part apparently detrital, comprises 15% of this thin-section. Argillaceous, patchy, and interstitial to framework grains. Organic materials are associated; the clays appear to be micaceous-illitic in nature, with perhaps some kaolinite as well.

Visible porosity 3% or less. Apparently from secondary development after certain framework grains, and/or carbonate cement. Microporosity is present.

Cements comprise at least 17% of this thin-section. Carbonate (13% of the total rock) occurs as "beadwork" crystalline (siderite ?) material adjacent to many framework grains, with paragenetically subsequent extensive/poikilotopic patches (calcite) comprising the rest of the carbonate surrounding the framework grains. Diagenetic pyrite (4% of the total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. There is also an indeterminate amount of quartz overgrowth cement, principally in patches relatively free of clays. As discerned petrographically, this appears to pre-date the carbonate cements, as well as clay materials, which is difficult to reconcile with the observed overall textural relationships, as well as theoretical aspects of the geochemistry of these phases. Perhaps these apparent quartz cements actually represent reworked overgrowths, although their aspect is somewhat less-than-definitive as to this. Replacement of pre-existing matrix and/or framework grains by carbonate is another alternative, but compelling evidence for this seems lacking here; in any case this explanation begs the question of the clays/quartz cement relationships observed.

This sample has undergone a moderate degree of apparent compaction, as well as bioturbation.

Reservoir quality poor as is. Fair/good potential for improvement, diagenetically, via dissolution of carbonate cement, pyrite, lithic fragments.

*Plate 3 depicts salient features of the above sample.*

7144 feet

Sandstone: sublithic arenite/wacke. Framework grains (70% of the total rock): predominantly fine sand-sized; well sorted, angular/subangular/subrounded; consisting of quartz (83%), lithic fragments (17%)-carbonate fragments, cherts, and traces of glauconite, tourmaline.

Matrix, at least in large part apparently detrital, comprises 21% of this thin-section. Argillaceous, interstitial to framework grains. Organic materials are associated; the clays appear to be micaceous-illitic in character, with perhaps some kaolinite as well.

Visible porosity 2% or less. Apparently as secondary development after certain framework grains and carbonate cement. Microporosity is present.

Cements comprise at least 7% of this thin-section. Diagenetic pyrite (4% of the total rock) occurs intergranular to framework grains, as well as associated with organic materials and clays. Carbonate (2% of the total rock) also occurs as intergranular cement. There is an indeterminate amount of quartz overgrowth cement developed, especially in areas relatively free of clays.

This sample has undergone a moderate degree of apparent compaction, and also appears to have undergone bioturbation.

Reservoir quality poor as is. Poor/fair (?) potential for improvement diagenetically, via dissolution of lithic fragments, pyrite, and carbonate cement.

7164 feet

Sandstone: sublithic arenite/wacke. Framework grains (67% of the total rock): predominantly fine sand-sized, with trace of medium sand; well sorted, angular/subangular/subrounded/rounded; consisting of quartz (78%), lithic fragments (22%)-cherts, carbonate fragments. Traces of glauconite, tourmaline.

Matrix, at least in part apparently detrital, comprises 20% of this thin-section. Argillaceous, somewhat patchy; most matrix in this rock is intergranular to framework grains, rather than as discrete laminae, perhaps attesting to more thorough bioturbation in this sample. Organic materials are associated with the apparently micaceous-illitic and, perhaps, kaolinitic clays.

Visible porosity 4% or less. Secondary in nature, after carbonate cement. Microporosity is present. The porosity appears to have developed as the result of secondary dissolution of paragenetically early carbonate cement which, in turn, precluded the entry of clay matrix material into such regions of original primary pore space during bioturbation.

Cements comprise at least 9% of this thin-section. Carbonate (6% of total rock) occurs intergranular to framework grains. Diagenetic pyrite (3% of total rock) occurs intergranular to framework grains, with traces of organisms, as replacements of fossils, and in a general association with organic materials and clays. There is an indeterminate amount of quartz overgrowth cement as well.

This sample has undergone moderate apparent compaction, as well as apparently extensive bioturbation.

Reservoir quality poor as is. Fair potential for improvement, diagenetically, via secondary dissolution of reactive materials (carbonate cement, lithic fragments, pyrite).

*Plate 2 depicts salient features of the above sample.*

7213 feet

Sandstone: sublithic arenite/wacke. Framework grains (62% of the total rock): predominantly fine to very fine sand-sized; well sorted, angular/subangular; consisting of quartz (82%), and lithic fragments (18%)- principally chert, carbonate fragments.

Matrix, at least in large part apparently detrital, comprises 34% of the total rock. Argillaceous, patchy, laminated-regular/discontinuous, irregular, streaks, and interstitial to framework grains. Associated organic material. The clays apear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity not evident. Some microporosity may be present.

Cements comprise at least 3% of this thin-section. Diagenetic pyrite (3% of total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. Minor carbonate, in regions relatively free of clays. There is an indeterminate amount of quartz overgrowth cement, also concentrated in areas relatively devoid of clays. This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality nil as is, with poor/fair (??) potential for improvement elsewhere, via diagenetic means (dissolution of lithic grains, carbonate cement, pyrite). Framework grain sizes, and the substantial amount of clay materials also present militate against significant improvement, however.

7216 feet

Sandstone: sublithic arenite/wacke. Framework grains (64% of the total rock): predominantly fine to very fine sand-sized, moderately-well sorted; angular/subangular/subrounded/rounded; consisting of quartz (88%), and lithic fragments (12%)- principally cherts, carbonate fagments (including fossil/shell fragments). Traces of glauconite, tourmaline.

Matrix, at least in large part apparently detrital, comprises 33% of the total rock. Argillaceous, laminated-irregular to regular, streaks, patches, and interstitial to framework grains. Associated organic material. The clays appear to be micaceous-illitic in character, with some kaolinite as well.

Visible porosity not evident. Some microporosity may be present.

Cements comprise at least 3% of this thin-section. Diagenetic pyrite (3% of total rock) occurs intergranular to framework grains, as well as in association with organic materials and clays. Minor amounts of carbonate occur intergranular to framework grains.There is an indeterminate amount of quartz overgrowth cement as well.

This sample has undergone moderate apparent compaction, as well as bioturbation.

Reservoir quality nil as is, with poor potential for improvement elsewhere, via diagenetic means (dissolution of lithic grains, carbonate cement, pyrite). Framework grain size, as well as the abundance of clays militate against such improvement, however.

**Torok Formation**

6382 feet

Sandstone: litharenite. Framework grains (79% of the total rock): predominantly very fine to fine sand-sized; well sorted, angular/subangular/subrounded. Consist of quartz (45%), feldspars (5%)- [plagioclase, with albite twinning (albite-andesine), and potassium feldspar (some with microcline twinning)], and lithic fragments (50%)- [carbonate rhombs/other materials- some are at least in part ferroan calcite (15% of grains), argillaceous rocks (16% of grains), cherts (7% of grains), other poorly-defined rocks (6% of grains)]. Minor/trace amounts of muscovite, chlorite, biotite, iron-titanium oxides, glauconite (?), black-brown-reddish organic materials/debris.

This thin-section shows a degree of graded bedding (through an interval on the order of 0.6 mm thick) between the upper portion (3.1 mm thick) of the sandstone layer (8.8 mm total thickness) and an overlying siltstone-silty shale horizon, while the sandstone is also seen to be in relatively sharp sedimentary contact with an underlying shale horizon. This lower contact features loading structures comprised of projections of sandstone into the underlying shale. The thin-section shows these features quite nicely; apparently an excellent example, on the scale of a standard petrographic thin-section, of relationships indicative of a "turbidite" type of deposition.

Argillaceous matrix of likely detrital origin comprises some 9% of the total rock. The appreciable amount of pseudomatrix developed via deformation of argillaceous rock fragments and other materials makes rigorous delineation of true detrital matrix difficult at best here, using only the optical microscope. The authigenic clays (principally kaolinitic, apparently) developed attendant upon the reactions leading to dissolution of framework grains add to this uncertainty.

Visible porosity is developed only within the lower 5.7 mm of the sandstone layer in this thin-section; the visible porosity is 18% of the sandstone in this lower interval. Visible porosity is on the order of 12%, for the total 8.8 mm thick sandstone layer. Principally as the result of secondary dissolution of framework grains- cherts, feldspars, carbonates, other rock fragments, biotite. Dissolution is partial-total, generally with appreciable development of authigenic clays within the resultant porosity. Much of this clay material appears to be kaolinitic in nature, as "books"/vermiform aggregates. Hence, an appreciable component of the extant porosity in this thin-section is, or is associated closely with, microporosity. Interestingly, determinations of an "ambient helium porosity" value of 13.6%, with an "ambient bulk density" of 2.39 g/cc, and a "grain density" value of 2.76 g/cc were reported from a core plug cut from this sample by other investigators (Geologic Materials Center Data Report 70, 1987).

Cements as such are either essentially absent, or optically indeterminate, due to the combined factors of authigenic clay development, appreciable pseudomatrix development, and presence of original detrital matrix. In a sense, of course, the authigenic clays might be considered as a type of cement, but they were not analyzed as such here. Traces of euhedrally terminated quartz overgrowth cement were recognized projecting into pores which may well represent vestigial intergranular porosity. Minor proportions of the total porosity observed in this thin-section appear to represent such primary porosity. Diagenetic pyrite also occurs (<1% of total thin-section).

This sample has undergone a moderate degree of apparent compaction. Reservoir quality is adjudged to be fair, at best, as is. Although there is a moderate amount of visible porosity, much is, or is associated with, microporosity. Effective porosities/permeabilities would perhaps be somewhat suspect, laterally within the sandstone. They would seem to be even more problematic vertically over any appreciable interval, given the silty/shaly horizons above and below the sandstone. The potential for improvement in terms of reservoir quality might be considered as poor/fair (?), via secondary dissolution of the abundant reactive materials of various types-principally feldspars, carbonates, cherts, and other rock fragments. However, the observed relationships regarding the development of authigenic clays attendant upon much of the secondary dissolution, the degree of apparent compaction of the rock, the appreciable development of pseudomatrix, the very-fine sand-sized framework grains, and the argillaceous detrital matrix are negative factors.

*Plate 4 depicts salient features of the above sample.*

6387 feet

This thin-section was of relatively poor quality, with only patches representing less than 20% of the total area usable for optical microscopy.

Sandstone: litharenite. Framework grains (77% of the total rock): predominantly very fine to fine sand-sized; well sorted, angular/subangular/subrounded. Consist of quartz (48%), feldspars (2%)- [plagioclase, with albite twinning (albite-andesine), and potassium feldspar, with microcline twinning], and lithic fragments (50%)- [argillaceous rocks (12% of grains), carbonate materials/rhombs (12% of grains)- some ferroan, cherts (20% of grains), other rocks (6% of grains)]. Minor/trace amounts of black-brown-reddish organic materials/debris, chlorite, muscovite, iron-titanium oxides.

Argillaceous matrix of apparently detrital origin comprises some 11% of this sample. As discussed above in the description of the 6382 foot sample, rigorous delineation of this is dubious via optical microscopy. There is extensive development of pseudomatrix, via intergranular deformation of relatively incompetent framework grains.

Visible porosity 12%, apparently essentially all as the result of the development of secondary, partial to complete, dissolution of framework grains- principally feldspars, cherts, carbonates, and other rocks. As discussed above for the other Torok Formation sample, as part of such dissolution reactions, appreciable formation of authigenic clays, featuring kaolinitic materials in "books"/vermiform aggregates, occurs within the resultant pores. Thus, a considerable proportion of the porosity either consists of, or is closely associated with, microporosity. An "ambient helium porosity" of 14.7%, an "ambient bulk density" of 2.38 g/cc, and a "grain density" value of 2.79 g/cc were reported from a core plug from this sample by other investigators (Geologic Materials Center Data Report 70, 1987).

Cements are either essentially absent, or are optically indeterminate, as discussed for the 6382 foot sample, above. Quartz overgrowths were only apparent in trace amounts in the 6387 foot sample, and some diagenetic pyrite (<1% of total area analyzed) also is present.

This sample has undergone a moderate degree of apparent compaction. Reservoir quality fair (?) as is. Poor/fair (?) potential for improvement, via secondary dissolution of the abundant reactive materials of various types- feldspars, carbonates, cherts, other rocks. The framework grain size, degree of apparent compaction, appreciable development of pseudomatrix, presence of argillaceous detrital matrix, and the likelihood of the development of pore-associated authigenic clays as the result of secondary dissolution reactions are all negative factors.

## 6. 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 1984) perspectives, in the 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 significantly "enhanced" overall porosity/reservoir quality in rocks has, however, been tempered somewhat by a seeming paucity of demonstrable examples of extensive effects of this sort, other than in relatively specific (cf. Kuparuk Field, discussed below) 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. An excellent example, in which the title of the paper itself nicely summarizes the situation, is presented by Bjorlykke (1984)- "Formation of secondary porosity: how important is it?"

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, effective 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.

It was pointed out some time ago (Mowatt, 1980, 1983, 1984a,b), and reviewed more recently (Mowatt and Mowatt, 1990, 1991), that secondary dissolution porosity in fact does exist, and potential for development was rather to be expected, in rocks of the type exemplified by Torok Formation and Nanushuk Group samples from a number of wells from the National Petroleum Reserve-Alaska (NPRA) studied by them at that time. For example, Mowatt and Mowatt (1991) comment (p. 16-17):

> In Wolf Creek Test Well 3, examples of the development of secondary dissolution porosity are clearly discernible.

> Porosity is developed in a sequence including intervals enriched in organic matter, and varying degrees of dissolution of carbonate and other minerals can be seen, apparently related to stratigraphic distance from the organic-rich zones, in interlayered sandstones and siltstones. In this case, presumably the generation of carbon dioxide acompanying thermal maturation of the organic materials was sufficient, perhaps in concert with other geochemical-physical factors (e.g., organic acids), for the development of an environment conducive to dissolution on a relatively local scale.
>
> Under regionally dominant similar conditions, presumably such secondary porosity development, in precursorial rocks of appropriate character, would be developed on a more extensive basis, pervading appreciable volumes of the sediments involved. Somewhat similar features were also noted, to various extents, in petrographic examination of materials for each of the other wells studied.

They also add (p.12):

> There is no question that the deleterious effects of diagenetic processes on reservoir rock qualities may indeed be very significant in many instances. In particular, reactions involving feldspars and/or other labile silicates, resulting in the ultimate (local, proximal, distal) formation of other solid reaction products (i.e., clay minerals, quartz, plus or minus zeolites, other feldspars, especially) may well be quite influential in this type of resultant state of affairs, within the immediate neighborhood of dissolution and/or elsewhere within the subsurface.

In a subsequent reconnaisance study of reservoir quality and potential, based on examination of available petrographic thin-sections from nine wells within the NPRA, Mowatt and Dygas (1991) reported the occurrence of secondary dissolution porosity within horizons equivalent to the Kuparuk Sandstone, the Torok Formation, the Nanushuk Group, and other stratigraphic units, including the Ivishak, Kingak, Pebble Shale, and Walakpa intervals. These authors comment:

> At some risk of perhaps endeavoring to invoke a 'Deus ex machina' (Bloch, et al., 1990), it should be noted that secondary dissolution porosity development seems not uncommon in many of the samples studied by us. Admittedly, per the comments of our friend and colleague Dr. Bloch, the proportional contribution to total porosities remains to be rigorously determined, quantitatively, as does its real importance- or lack thereof- relative to hydrocarbon accumulation. This is a key feature of emphasis in our present work. We have been concerned for many years with the presence/absence/origins(s) of discernible secondary dissolution porosity (in the classic sense so well-presented by Schmidt and McDonald, 1979a,b), and its possible role in reservoir quality, as well as potential significance to hydrocarbon accumulation in various subsurface environments, particularly northern Alaska (Mowatt and Mowatt, 1990). This is most important, of course, vis-a-vis 'prediction' of 'potential' reservoir qualities elsewhere, in rocks similar to those from which such prognostications are to be attempted. It is, in one sense, the crux of the matter, in terms of the attempted 'assessment' of reservoir potential in the subsurface, prior to testing with the drill.

The occurrence and significance of secondary dissolution porosity development in Kuparuk River Formation hydrocarbon reservoirs within the Kuparuk Field have been described in the technical literature (e.g., Paris, 1981; Eggert, 1987; Masterson and Paris, 1987; Gaynor and Scheihing, 1988). This porosity is principally related to the partial dissolution of the rather abundant carbonate (esp. siderite) cements associated with these rocks. These cements have been investigated in some detail by Mozley and Carothers (1992), who, among other findings in their excellent paper, corroborate the early paragenesis of much of this cement. Masterson and Paris comment in discussing their "C-4" stratigraphic interval (1987; p. 103):

> Interval C-4 can be up to 60 feet (18m) thick and can be almost entirely cemented by siderite. Up to 40 feet (12m) of reservoir sandstone is present in areas where secondary porosity was created by dissolution of siderite and framework grains (Paris, 1981; Eggert, this volume). The presence of detrital siderite clasts within C-4 sandstone implies that siderite cement precipitated at very shallow depths and was subsequently ripped up and redeposited by marine currents.

Gaynor and Scheihing (1988) observe with regard to their stratigraphic "unit C" (p.333):

> The reservoir in unit C is characterized by a blanket-like geometry. Sandstone geometries within unit C are poorly defined because of syndepositional faulting and erosional truncations within the unit. The C sandstones are massive due to bioturbation and are highly glauconitic. The best reservoir-quality sandstones occur in the basal and uppermost intervals. Both intervals have unconformities at their base. In the case of the basal interval, this is a major erosional unconformity within the Kuparuk River formation. These subunits are characterized by intense siderite cementation and subsequent partial dissolution. The distribution of reservoir properties is directly related to diagenesis and indirectly to depositional facies.

It seems worth pointing out here that the existence of appreciable carbonate cements and, not infrequently, their subsequent secondary dissolution is a not uncommon association in or near the basal and/or uppermost portions of many sandstone horizons, worldwide, based on scrutiny of the technical literature, as well as personal experience.

Collectively, this earlier work seems to have been borne out once again in the Nechelik #1 well. It is most interesting to observe both the enhancing and the deleterious aspects of diagenesis as related to reservoir rock quality apparently demonstrated in the Nechelik #1 well horizons studied in the present work. There seem to be obvious implications regarding the Torok and Nuiqsut samples from the Nechelik #1 well described in the present report, as well as for the possible existence and potential character of hydrocarbon reservoir rocks in horizons of similar aspect elsewhere within the region.

Exemplifying his continued careful consideration of these matters, 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 evolu-

> tion 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" here needs remain rather simplistic, hence the approach adopted above. We are continuing our studies of diagenetic relationships in various wells, with the view to obtaining more comprehensive appreciation of controls on reservoir properties.

# 7. Conclusions

### Torok Formation

Since only two thin-sections, representing horizons just five feet apart vertically in the subsurface, were available for investigation here, extensive further discussion beyond that already offered above seems unwarranted. These horizons are informative in terms of obtaining geological insights regarding these supposedly "turbidite" sequences in the lower Torok Formation, and characterization of diagenetic relationships, as well as for evaluation of reservoir qualities and potentials.

The 6382 foot sample demonstrates rather convincingly the likely "turbidite" nature of at least that particular horizon, on the scale of a standard thin-section. Both samples provide the fundamental mineralogy-fabric information requisite to an appreciation of the depositional and post-depositional relationships within these intervals.

The composition (sedimentary rock lithic fragments, and quartz, principally) of the sand size framework grains indicates predominance of sedimentary rocks as sources. These very fine to fine sand size, well sorted grains are also consistent with sedimentary sources, and with deposition in a distal turbidite environment.

The nature, amount, distribution, and likely effectiveness of the extant porosity suggest that these rocks presently represent at least fair reservoir rocks, in situ. Taken collectively, the mineralogic, fabric, and petrophysical attributes of these materials would suggest a fair degree of potential for further improvement of reservoir quality, under appropriate physical and geochemical conditions. The caveats, however, are several, as discussed above.

### Nuiqsut Unit

With nineteen thin-sections available for study, representing eighteen horizons within some one hundred and three feet of stratigraphic interval, the opportunity is afforded for a somewhat detailed evaluation of this sequence, in terms of geologic and reservoir characteristics in the Nechelik #1 well, and with regard to potential relationships elsewhere in the subsurface.

A relatively minor amount of the visible porosity apparent in these thin-sections seems to represent the secondary dissolution of certain more reactive framework grains. Additionally, some minor amounts of porosity (featuring appreciable microporosity, often) are associated with patches of sand relatively devoid of clays, perhaps representing bioturbation features in which burrows were somewhat "purged" of clays. However, the more significant visible porosity recognized in the samples studied from the Nechelik #1 well appears most likely, ultimately, to represent vestigial intergranular porosity. It occurs in patchy zones not appreciably affected by input of clay materials due to bioturbation or other processes. The good sorting of the sand size framework grains suggests that the original sediments may have possessed good intergranular porosity initially. The appreciable amounts of clay size material now in the rocks were unlikely to have been directly associated, via original sedimentation, with such porosity.

There are scattered occurrences of carbonate mineral(s) cements, associated with visible porosity, observable in the thin-sections. This might be representative of previously existing somewhat more pervasive cement, formed during early diagenesis (eogenetic; cf. Mozley and Carothers, 1992), perhaps as patches or poikilotopic crystals possibly formed around nucleii of, and/or via dissolution of calcareous fossil fragments in at least portions of the primary intergranular, and/or bioturbated/"purged of clay" porosity. Such early cement might well have been "porosity-protective," in the sense of preventing subsequent influx of clay size materials into these cemented zones of the sediment, attendant to the bioturbation which seems to have occurred. The well-developed carbonate cements exhibited in several of the thin-sections investigated here are supportive of such a course of events.

This bioturbation resulted in irregular-discontinuous laminae-patches-streaks-zones rich in clay materials. These regions are oriented at various angles to one another, apparently reflecting biologic activities in the sediments, and attendant redistribution of clay size materials from initially more continuous laminae of clays which were originally deposited as discrete horizons by other physical processes of sedimentation. The essentially ubiquitous presence of intergranular clay size materials (apparently of non-diagenetic origin, based on textural relationships) interstitial to the well sorted sand size framework grains is most likely the result of bioturbation.

The few patches of porosity presently observed among framework grains are, thus, most likely due to the inability of such clays to enter this porosity during bioturbation. As suggested above, perhaps the most probable reason for this is the presence of porosity-occluding cement, likely occurring as patchy-poikilotopic carbonate(s), which has subsequently undergone mesogenetic dissolution, leaving the presently observed generally sparse porosity.

Thus, the present visible porosity might best be interpreted as relict-residual intergranular, resulting from secondary dissolution of early diagenetic cement. This seems to accord best with observations possible with the petrographic microscope alone, on rather limited amounts of sample materials. Additional analyses, including more definitive thin-section staining, luminesence petrography, scanning electron microscopy/x-ray emission, and x-ray diffraction could provide further information potentially useful in refining this interpretation.

In terms of reservoir rock properties, however, it is evident that almost all of these samples (the thin-section representing the rock at 7126 feet being an apparent exception) exhibit rather poor characteristics, regardless of more esoteric aspects of sedimentologic-diagenetic histories, etc. There is little total porosity apparent in most of these rocks, and such as does exist may not be well interconnected in three dimensions. Noteworthy, however, is the presence of apparent hydrocarbon staining in a number of these samples, as well as the common occurrence of shows throughout the interval studied.

The apparent persistent occurrence, over some one hundred feet of stratigraphic interval, of essentially fine-grained, originally well-very well sorted framework sands might be considered encouraging, in terms of the possible existence of similar sands elsewhere in the region, equivalent to this interval, which might have retained greater degrees of their original intergranular porosities, under somewhat different (particularly with respect to bioturbation) post-depositional circumstances.

The predominance of quartz framework grains (some showing reworked / somewhat rounded secondary quartz overgrowths), the essentially exclusively sedimentary character (predominantly cherts, carbonate fragments, with minor amounts of siltstone-shale-mudstone clasts) of the decidedly subordinate proportions of associated lithic framework grains, the paucity of feldspars, and the trace amounts of accompanying tourmaline grains collectively indicate a source terrane of predominantly sedimentary rocks for these components of the rocks in the depth interval studied.

The essentially ubiquitous trace amounts of glauconite grains observed could have been similarly derived, although their overall aspect, including morphologies and apparent lack of appreciable oxidation effects, suggests, rather, that they more likely were formed within the sedimentary environment contemporary with the sediments as presently constituted. Such primary glauconite is generally considered evidence of a marine depositional setting (Selley, 1978, p. 26-29; among numerous other authors).

The relatively high degree of sorting of the sand size framework grains could indicate a degree of energy in the immediate depositional environment sufficiently great to effect such sorting. Alternatively, such sorting could be attributable to the erosion of well sorted sedimentary rocks in the source terrane. The moderate (subangular-subrounded, generally) degree of rounding, for these generally fine-grained sands, might be interpreted as supporting evidence for the latter situation.

In any event, in circumstances such as those mentioned above, it would not seem unlikely that occasional changes in physical conditions of the local energy regime could result in alternating layers richer or poorer in various size ranges of detrital materials, including clays. Such materials, when subjected to subsequent biological activities / bioturbation, would tend toward the type of irregular redistribution-mixing apparent in the samples studied.

Alternatively, of course, relationships involving clay- and sand-size sediments such as observed in these samples may be attributable to other complexities of sedimentation, sediment sources and depositional environments. Perhaps the simplest explanation might be that of multiple sources for the sediments.

Interpretation of the cause(s) of textural inversion, from limited amounts of sample as in the present instance, is generally rather subjective / ambiguous. However, in the present case, there does seem to be evidence of disturbance most likely attributable to bioturbation.

Although we realize that unreserved use of any interpretive scheme of purportedly wide-ranging character is fraught with uncertainties, the following comments are put forward here in hopes of at least catalyzing further thought, rather than with any compelling degree of assurance as to rigorous applicability to these samples from the Nechelik #1 well.

The thoughtful contributions of R. L. Folk to the development of the science of sedimentary petrology over a number of years are well known. Folk's syllabus *Petrology of Sedimentary Rocks* has become a classic in the field. In his inimitable fashion, Folk has compiled, developed, synthesized, and presented an enormous amount of information, as exemplified by the summarization presented in the 1980 edition of this syllabus. Ranging the gamut of description, interpretation, and genesis, his approach includes incisive further attempts—*a la* P. D.

Krynine and other subsequent workers—to derive additional fundamental geologic perspectives as to source terrains, tectonics, paleoclimates, sedimentary processes and depositional environments, etc. from the present character of the resultant sedimentary rocks.

It seems useful here to consider the Nechelik #1 well samples which are the subject of the present work in the context of Folk's scheme (1980; p. 100-155, especially). According to this approach, these rocks would all be considered as "immature" (ie., containing >5% clay size materials). However, considering just the sand size framework grains, on the basis of the sorting (well-very well) the rocks would be termed "mature," while on the basis of rounding (angular/subangular/subrounded/rounded; principally subangular/subrounded) the rocks would be termed at least "submature-mature." In terms of the mineralogical composition of the sand size grains (ie., predominant quartz, subordinate lithic fragments- principally cherts and carbonate rocks/fragments, and at most mere trace amounts of feldspars), most of these rocks would be designated as "chert sublithic arenites" (the sample from 7117 feet would be a "chert quartzarenite").

Sandstones with such framework grain characteristics would be considered petrologically as attributable to "an older sedimentary source" (Folk, 1980, p.140-144), with the attendant other geologic implications as discussed by Folk (1980, p. 100-155). According to this view (Folk, 1980, p.140-143):

> Since no period of tectonic stability and no period of beach-dune action is required to attain a quartzarenite by reworking older, already quartz-rich sediments, these can form under any tectonic framework and almost any environment...Maturity is generally low (because, again, beach-dune action is not necessary for their production), and they are characterized primarily by many textural inversions (poor sorting and high rounding; or, more commonly, a lack of correlation between roundness and size, with mixture of angular and rounded grains within the same size, or small round grains plus large angular ones)...Abundant chert is the chief diagnostic material; it is quite commonly angular and associated with rounded and reworked quartz grains. There may be a very little feldspar, mica, etc., so that these are not quartzarenites of high purity.

The "immature" aspect represents the dilemma of textural inversions (Folk, 1980, p.103-106), which may be rationalized in a number of ways. As Folk states, "These are very valuable in interpretation because they indicate mixing of the products of two energy levels". Among the various combinations of sedimentological circumstances which may be invoked to explain textural inversions, bioturbation appears to perhaps best explain the relationships observed in these samples from the Nechelik #1 well. It seems appropriate here to let Folk (1980, p. 103) have the next-to-last word:

> Some textural inversions may be caused by burrowing organisms; for example, pelecypods or worms could burrow through a nicely interlayered series of well-sorted sands and interbedded clean clays, and make the whole thing into a homogeneous mass of clayey, immature sand. But the presence of these immature sands would indicate that the final environment was one of low energy, or else the currents would have re-sorted the material after burrowing.

## 8. Postscript

The implications of any/all of this in terms of the potential existence, character, and recognition of undiscovered hydrocarbon reservoir rocks within the region remain to be elucidated.

With this in mind, we finish here with some remarks by an erstwhile colleague, and venerable sage of petroleum geology-Parke A. Dickey. Somewhat ahead of his time, as he often was, in 1958 Dr. Dickey, writing in the Tulsa Geological Society Digest, offered this insightful piece of geopoetry:

"We usually find oil in new places with old ideas. Sometimes, also, we find oil in an old place with a new idea, but we seldom find much oil in an old place with an old idea. Several times in the past we have thought that we were running out of oil, whereas actually we were only running out of ideas."

# 9. References


Banet, A. C., 1990, Petroleum geology of the Arctic National Wildlife Refuge 1002 area; U. S. Bureau of Land Management, Alaska State Office Technical Report 12, 33p.

Banet, A. C., 1992, Bedrock geology of the northernmost bulge of the Rocky Mountain Cordillera; U. S. Bureau of Land Management, Alaska State Office Technical Report 13, 62 p.

Bjorlykke, K., 1984, Formation of secondary porosity: how important is it?; p. 277-286 in Clastic Diagenesis, McDonald, D. and Surdam, R. (eds.), American Association of Petroleum Geologists Memoir 37, Tulsa, 434 p.

Blatt, H., Middleton, G. and Murray, R., 1980, Origin of Sedimentary Rocks, Prentice-Hall, Englewood Cliffs, N. J., 782 p.

Bloch, S., McGowen, J. H. and Duncan, J. R., 1990, Porosity enhancement from chert dissolution beneath Neocomian unconformity: Ivishak Formation, North Slope Alaska: Discussion; American Association of Petroleum Geologists Bulletin, v. 74, p. 85-88.

Bloch, S., 1991, Empirical prediction of porosity and permeability in sandstones; American Association of Petroleum Geologists Bulletin, v. 75, no. 7, p. 1145-1160.

Carman, G. J. and Hardwick, P., 1983, Geology and regional setting of Kuparuk oil field; American Association of Petroleum Geologists Bulletin, v. 67, no. 6, p. 1014-1031.

Craig, J. D., Sherwood, K. W. and Johnson, P. P., 1985, Geologic report for the Beaufort Sea planning area, Alaska: regional geology, petroleum geology, environmental geology; U. S. Minerals Management Service OCS Report MMS 85-0111, 192 p.

Dickey, P. A., 1958, Oil is found with ideas; Tulsa Geological Society Digest, v. 26, p. 84-101.

Dott, R. H. Jr., 1964, Wacke, graywacke and matrix- what approach to immature sandstone classification?, Journal of Sedimentary Petrology, v. 34, p. 625-632.

Eggert, J. T., 1987, Sandstone petrology, diagenesis and reservoir quality, Lower Cretaceous Kuparuk River Formation, Kuparuk River Field, North Slope, Alaska; in Tailleur, I. and Weimer, P. (eds.), Alaskan North Slope Geology; Society of Economic Paleontologists and Mineralogists, Pacific Section, and Alaska Geological Society, v. 50.

Folk, R. L., 1980, Petrology of Sedimentary Rocks; Hemphill Publishing Company, Austin, Texas, 184 p.

Gaynor, G. C. and Scheihing, M. H., 1988, Shelf depositional environments and reservoir characteristics of the Kuparuk River Formation (Lower Cretaceous), Kuparuk Field, North Slope, Alaska; in Lomando, A. J. and Harris, P. M. (eds.),Giant Oil and Gas Fields; Society of Economic Paleontologists and Mineralogists Core Workshop No. 12, Tulsa, v. 1.

Geologic Materials Center, 1987, Core permeability determinations and other related physical analyses of the following 20 North Slope wells; State of Alaska, Division of Geological and Geophysical Surveys, Eagle River, Alaska, Geologic Materials Center Data Report 70, 20 p.

Giles, M. R. and de Boer, R. B., 1990, Origin and significance of redistributional secondary porosity; Marine and Petroleum Geology, v. 7, p. 378-397.

Hubbard, R. J., Edrich, S. P. and Rattey, R. P., 1987, Geologic evolution and hydrocarbon habitat of the Arctic Alaska Microplate; in Tailleur, I. L. and Weimer, P. (eds.), Alaskan North Slope Geology; Pacific Section of the Society of Economic Paleontologists and Mineralogists, and the Alaska Geological Society, volume 2, p. 797-830.

Lerand, M., 1973, Beaufort Sea, in McCrossmam, R. G., (ed.), The future petroleum provinces of Canada—their geology and potential; Canadian Society of Petroleum Geologists Memoir 1, p. 315-386.

Masterson, W. D. and Paris, C. E., 1987, Depositional history and reservoir description of the Kuparuk River Formation, North Slope, Alaska; in Tailleur, I. and Weimer, P. (eds.), Alaskan North Slope Geology; Society of Economic Paleontologists and Mineralogists, Pacific Section, and Alaska Geological Society, v. 50.

Moore, T. E., Wallace, W. K., Bird, K. J., Karl, S. M., Mull, C. G. and Dillon, J. T., 1992, Stratigraphy, structure and geologic synthesis of Northern Alaska; U. S. Geological Survey Open File Report 92-330, 183 p.

Mowatt, T. C., 1980, Characteristics of some Cretaceous sedimentary rocks, northern Alaska, in relation to diagenesis and potential for secondary porosity development; U. S. Bureau of Mines Open File Report (Draft, unpublished), Alaska Field Operations Center, Juneau.

Mowatt, T. C., 1983, Cretaceous sedimentary rocks and petroleum resource potential, National Petroleum Reserve in Alaska; presented at the Canadian Society of Petroleum Geologists Conference "The Mesozoic of Middle North America", Calgary; abstract in Canadian Society of Petroleum Geologists Memoir 9,Calgary, 1984, p.559.

Mowatt, T. C., 1984a, Diagenetic relationships and hydrocarbon resource implications, Nanushuk Group and Torok/Topagoruk Formations, National Petroleum Reserve, Alaska (abs.); American Association of Petroleum Geologists Bulletin, v. 68, p. 510.

Mowatt, T. C., 1984b, Reservoir potential of Cretaceous rocks, National Petroleum Reserve, Alaska (abs.); American Association of Petroleum Geologists Bulletin, v. 68, p. 944.

Mowatt, T. C., Banet, A. C. and Reeder, J. W., 1992, Petrographic analyses of selected horizons, Aurora 089 No. 1 OCS-Y-0943 well, offshore northeast Alaska, U. S. Bureau of Land Management, Alaska State Office Open-File Report 42, 48p.

Mowatt, T. C. and Dygas, J. A., 1991, Petrographic survey and appraisal of reservoir quality and potential, National Petroleum Reserve-Alaska; U. S. Bureau of Land Management, Alaska State Office Open-File Report 36.

Mowatt, T. C. and Mowatt, June C., 1990, Diagenetic relationships and reservoir quality potential, Brookian clastic sequences, National Petroleum Reserve in Alaska; presented at the Fifth Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii.

Mowatt, T. C. and Mowatt, June C., 1991, Diagenetic relationships and reservoir quality implications in Brookian clastic sequences, National Petroleum Reserve, Alaska; U. S. Bureau of Land Management, Alaska State Office Open File Report 40, 40p.

Mozley, P. S. and Carothers, W. W., 1992, Elemental and isotopic composition of siderite in the Kuparuk Formation, Alaska: effect of microbial activity and water/sediment interaction on early pore-water chemistry; Juornal of Sedimentary Petrology, v. 62, p. 681-692.

Paris, C. E., 1981, Petrography, lithofacies, and depositional setting of the Kuparuk River Formation, North Slope, Alaska; unpublished M. S. thesis, University of Alaska-Fairbanks, 95 p.

Pettijohn, F., Potter, P. and Siever, R., 1987, Sands and Sandstone, Springer-Verlag, New York, 553 p.

Schmidt, V. and McDonald, D. A., 1979a, The role of secondary porosity in the course of sandstone diagenesis; in SEPM Special Publication 26, p. 175-207.

Schmidt, V. and McDonald, D. A., 1979b, Texture and recognition of secondary porosity in sandstones; in SEPM Special Publication 26, p. 209-225.

Selley, R. C., 1978, Ancient Sedimentary Environments; Cornell University Press, Ithaca, New York, 287 p.

Surdam., R. C., Boese, S. W., and Crossey, L. J., 1984, The chemistry of secondary porosity; in American Association of Petroleum Geologists Memoir 37, p. 127-149.

Surdam. R. C., Crossey, L. J., Hagen, E. S., and Heasler, H. P.,1989, Organic-inorganic interactions and sandstone diagenesis; American Association of Petroleum Geologists Bulletin, V. 73, p. 1-23.

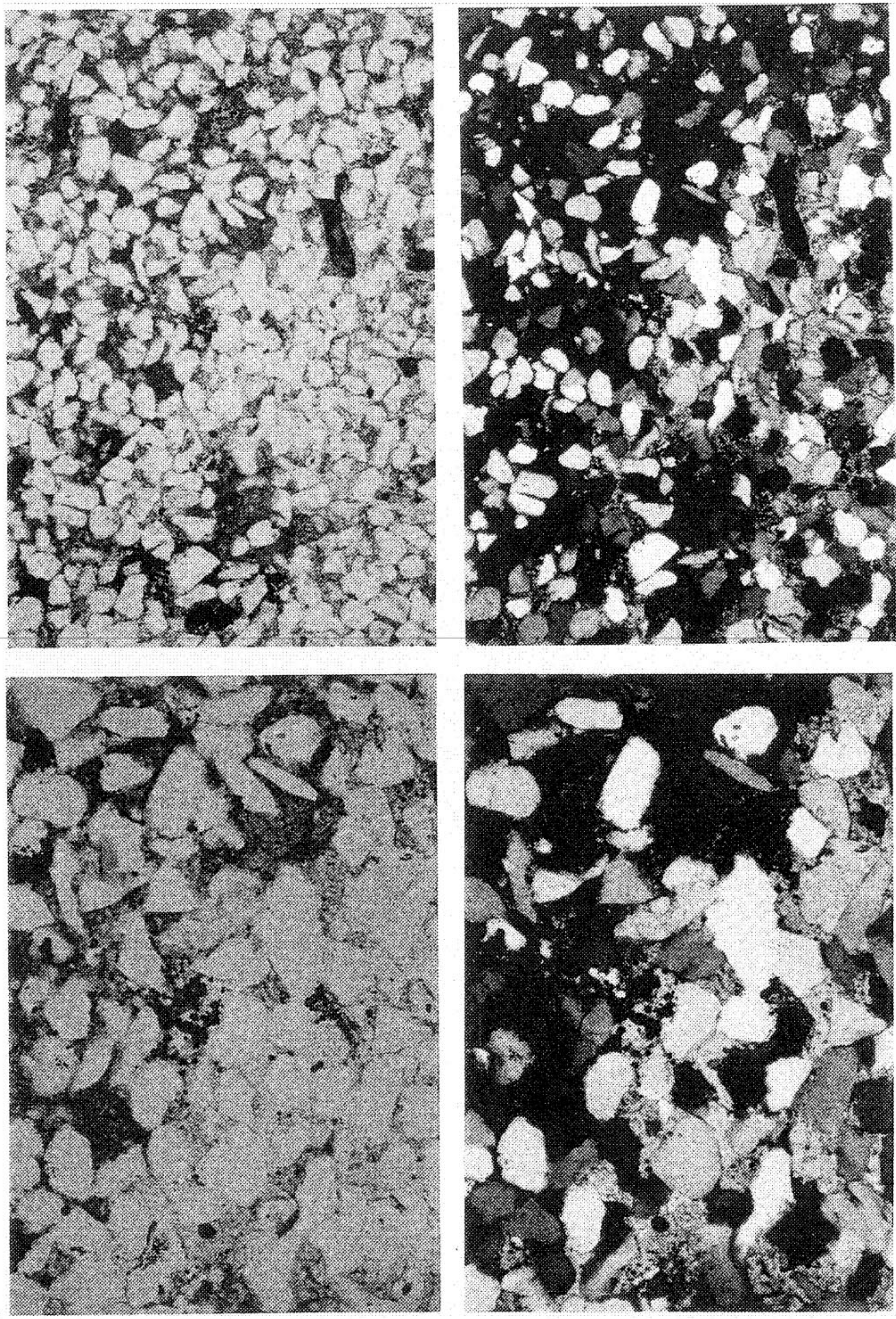
## PLATE 1

A. 7118 feet. Photographed at 12.5X. Printed photograph = 50X magnification. Much of the field of view features carbonate cemented framework grains; the darker intergranular areas include appreciable clay and associated organic material. Traces of porosity are present (blue). Note shape, sorting, and packing of framework grains.

B. 7118 feet. Photographed at 12.5X magnification, using crossed polarizing filters ("XSP"). Printed photograph = 50X magnification. Same field of view as A. Note especially the well-developed carbonate cement (orange-brown-golden, left side of photograph).

C. 7118 feet. Photographed at 25X magnification. Printed photograph = 100X magnification. Close-up of central portion of field of view shown in B. Indications of quartz overgrowths are also discernible.

D. 7118 feet. Photographed at 25X magnification, using crossed polarizing filters ("XSP"). Printed photograph = 100X magnification. Same field of view as C. Note carbonate cement (orange-brown-golden, left side of photograph), as well as traces of quartz overgrowths.



A. B C. D

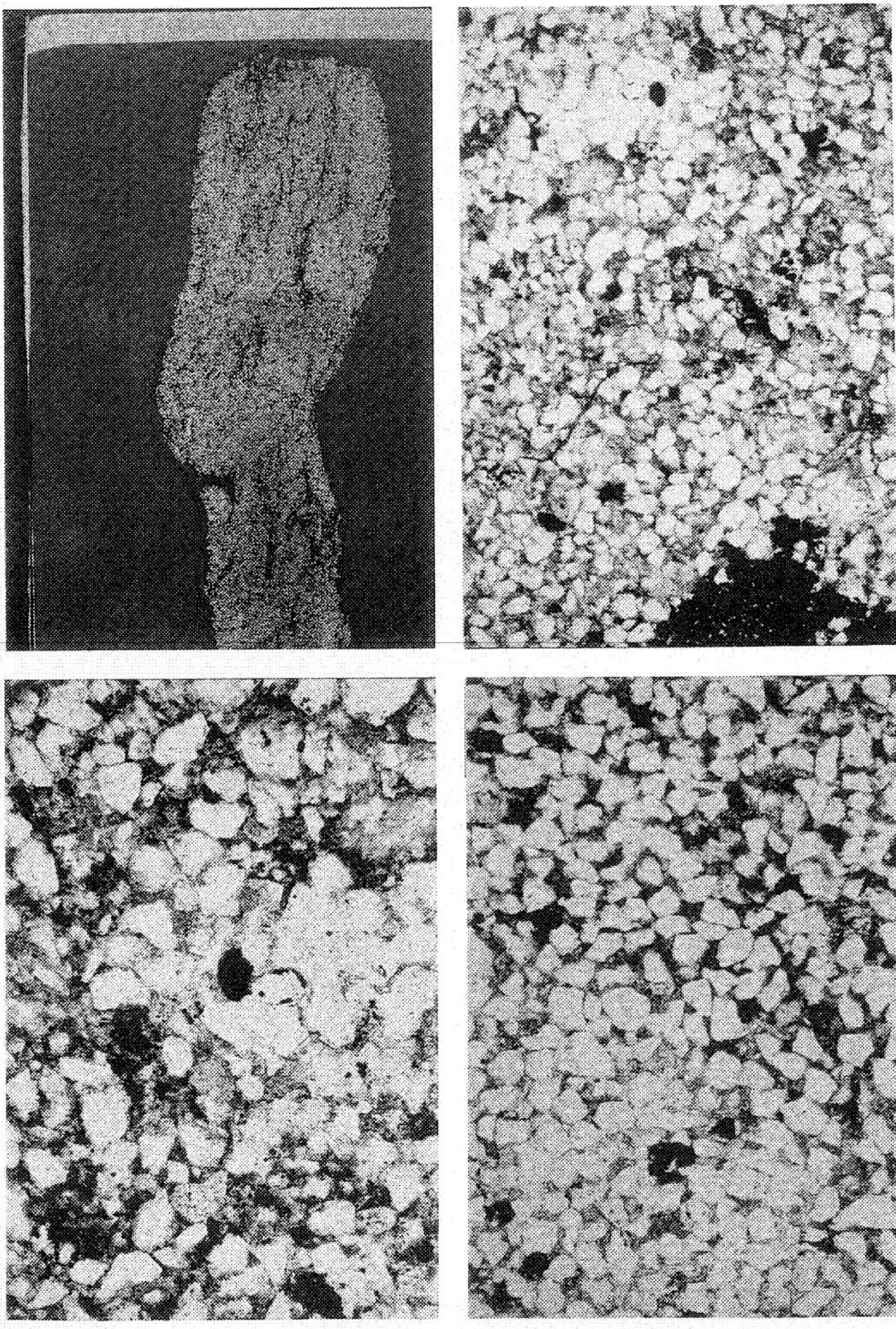
## PLATE 2

A. 7131 feet. Photographed at 1X magnification. Printed photograph = 4X magnification. Presents an overview of the typical character of these Nuiqsut unit samples. Note rock fabric, irregular/discontinuous/patchy nature of the lamellae and the coarser areas. Evidence of bioturbation throughout specimen.

B. 7164 feet. Photographed at 12.5X magnification. Printed photograph = 50X magnification. Note rock fabric, framework grains with appreciable intergranular clay material, one pale greenish glauconite grain (just to right of, and above, center of photograph), a portion of a pyrite-filled burrow (black, bottom of photograph), and a portion of a relatively clay-free burrow (white area, upper left of photograph).

C. 7164 feet. Photographed at 25X magnification. Printed photograph = 100X magnification. Close-up view of relatively clay-free burrow shown in B; note some porosity development (blue), quartz overgrowths, and general aspects of framework grains, inteergranular clays (and associated organic materials).

D. 7126 feet. Photographed at 12.5X magnification. Printed photograph = 50X magnification. View of porosity development (blue, principally at the top of the photograph) in an area adjacent to a thin zone of clay/organic materials (dark, across upper-middle portion of field of view), with the remainder (lower one-half) of the field of view showing extensive intergranular carbonate cementation. Note also general aspects of rock fabric, in particular the shape, sorting, and packing of the framework grains.



A.

B

C.

D

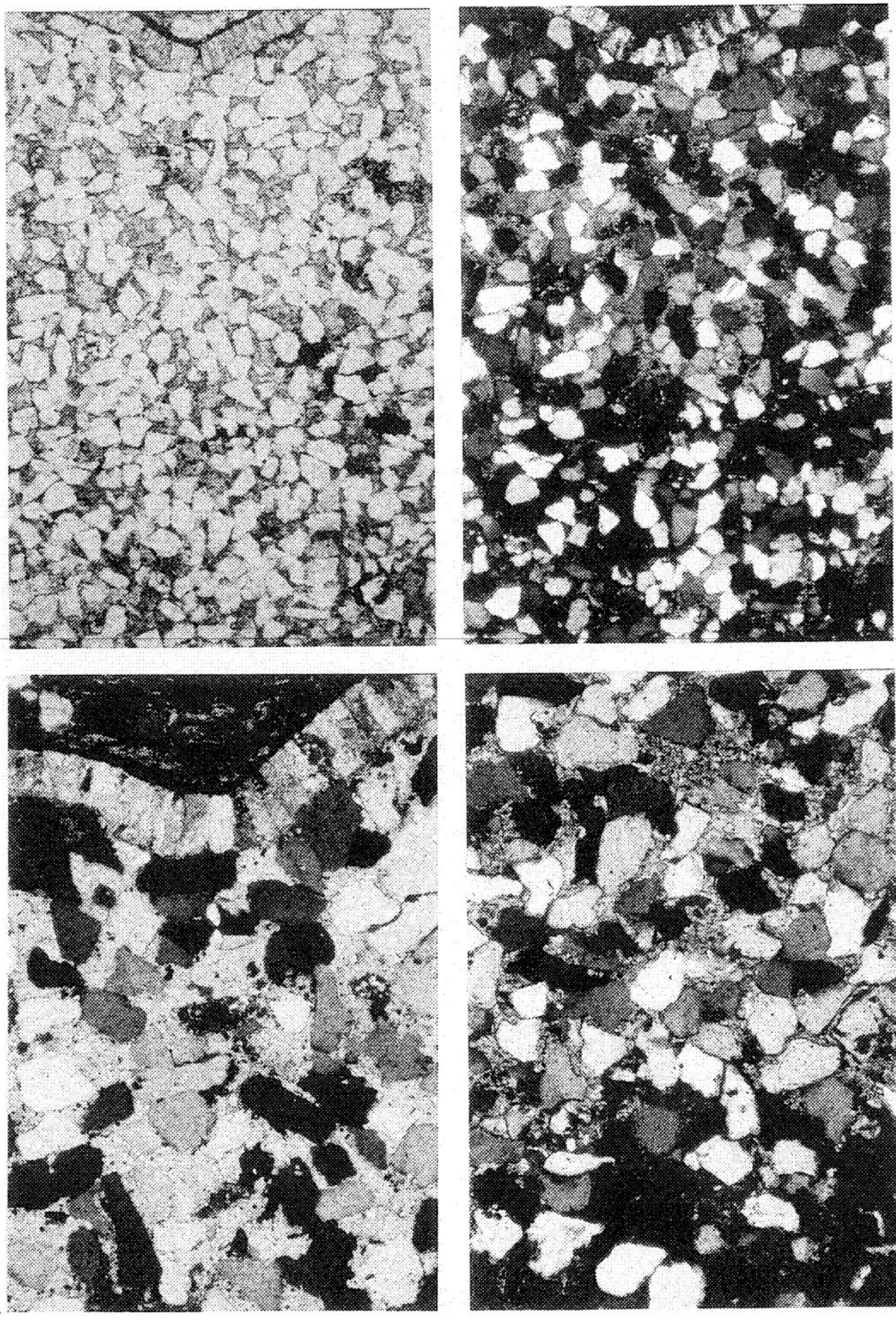
## PLATE 3

A. 7136 feet. Photographed at 12.5X magnification. Printed photograph = 50X magnification. Well-developed carbonate cementation intergranular to framework grains (predominantly quartz). A portion of a Pelecypod shell fragment, showing prismatic structure, is visible at the top of the photograph. Note rock fabric, especially the shape, sorting, and packing of the framework grains.

B. 7136 feet. Photographed at 12.5X magnification, using crossed polarizing filters ("XSP"). Same field of view as A. Note carbonate cement, as well as prismatic calcite in Pelecypod fragment (orange-brown-golden).

C. 7136 feet. Photographed at 25X magnification, using crossed polarizing filters ("XSP"). Printed photograph = 100X magnification. Upper portion of the field of view shown in B. Close-up view of carbonate cement, framework grains, Pelecypod fragment.

D. 7142 feet. Photographed at 25X magnification, using crossed polarizing filters ("XSP"). Printed photograph = 100X magnification. Note carbonate cements (orange-brown-golden) comprised of apparent siderite (small crystals) and more extensive calcite, intergranular to framework grains (principally quartz, some with overgrowths).



A. B

C. D

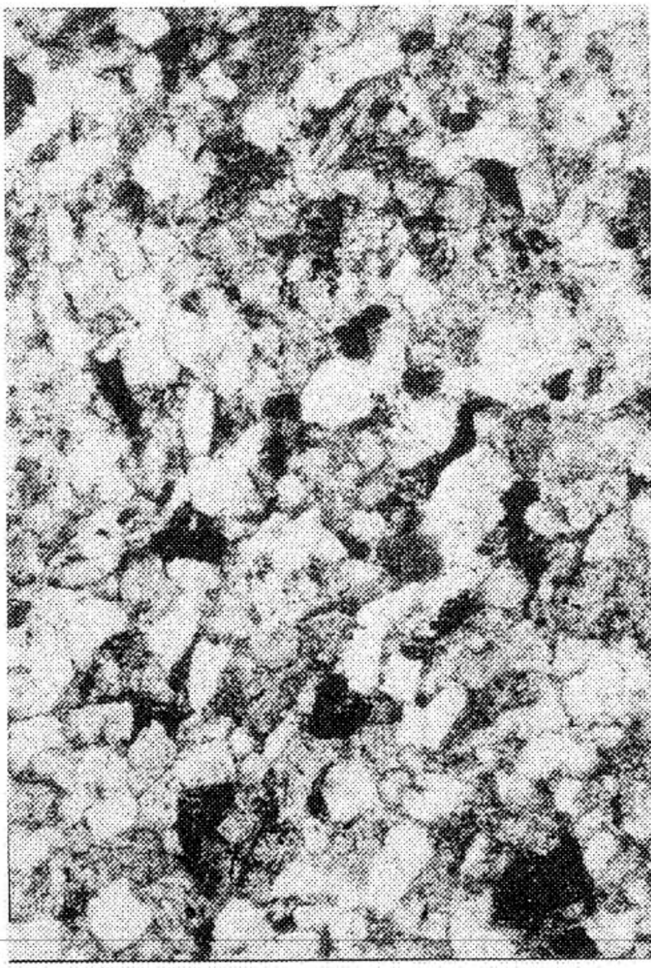
## PLATE 4

A. 6382 feet. Photographed at 25X magnification. Printed photograph = 100X magnification. General view of rock fabric elements. Note in particular size, shape, sorting of framework grains, and porosity development (shown in blue).

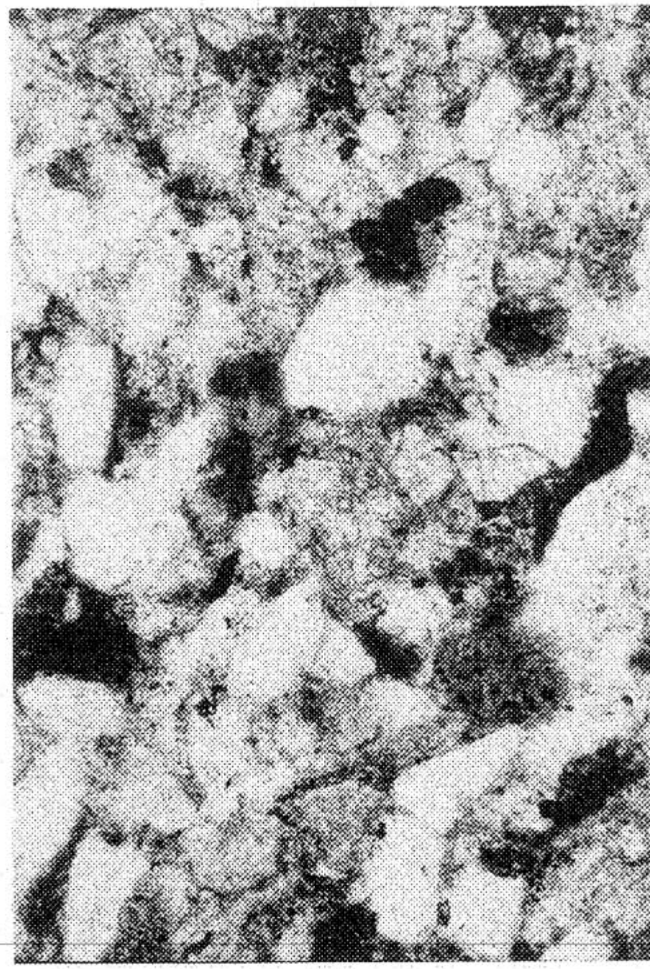
B. 6382 feet. Photographed at 50X magnification. Printed photograph = 200X magnification. Close-up view of central portion of field of view in A. Note nature of porosity- much secondary, with appreciable microporosity.

C. 6382 feet. Photographed at 50X magnification. Printed photograph = 200X magnification. Features view of porosity, and evidence of development via secondary dissolution of framework grains (particularly feldspars, and lithic fragments). Appreciable microporosity is apparent as well within the field of view.

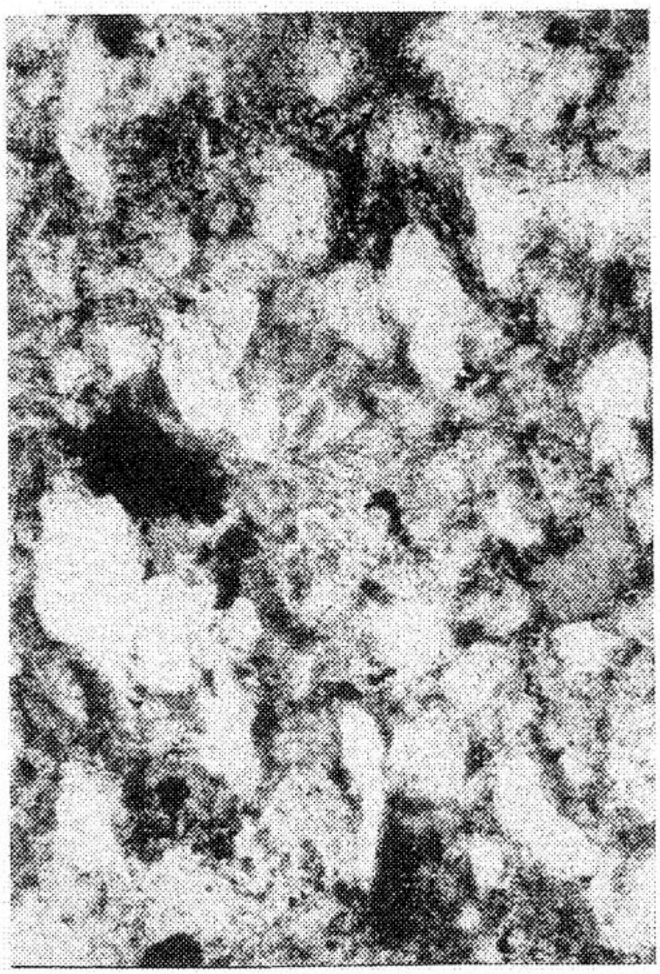
D. 6382 feet. Photographed at 50X magnification, using crossed polarizing filters ("XSP"). Printed photograph = 200X magnification. Note especially the remnants of a plagioclase feldspar grain which has undergone partial secondary dissolution (just above the center of the field of view).



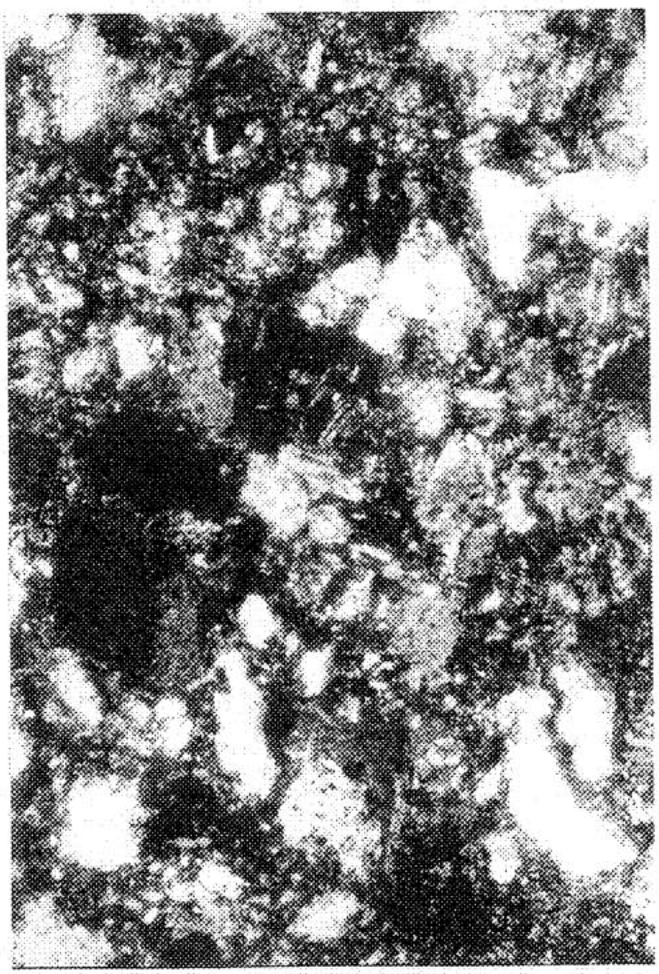
A.



B



C.



D

APPENDIX 1

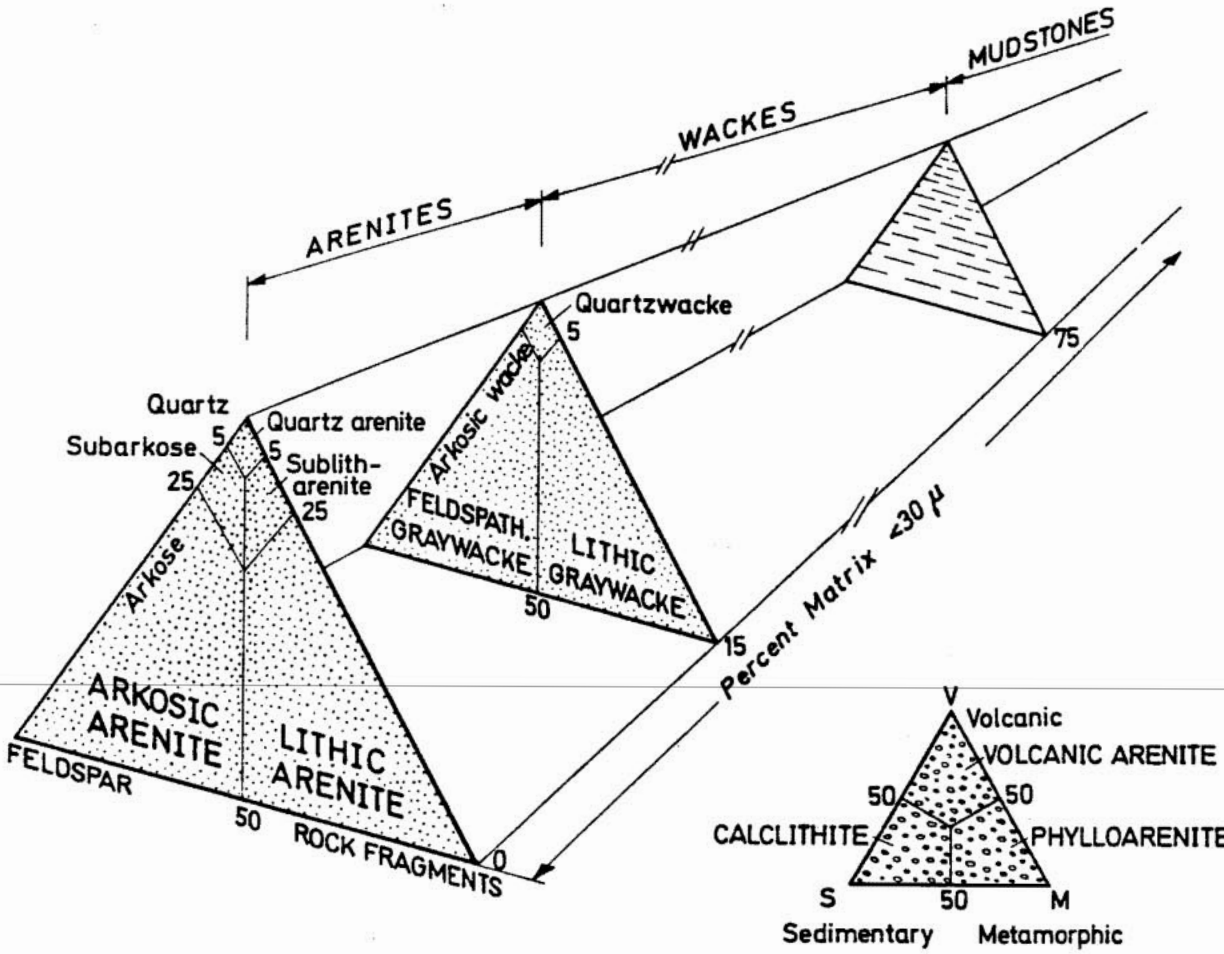



Figure 5-1. Classification of terrigenous sandstones.
(Modified from Dott, 1964, Fig. 3)

From Pettijohn, et al., 1987

# APPENDIX 2

Total Organic Carbon, Rock-eval Pyrolysis, and Vitrinite Reflectance Geochemical Data for the Sohio Alaska Petroleum Company Nechelik No. 1 Well

20 June 1985

Total of 4 pages in report

Geologic Materials Center Data Report 60

SOHIO NECHELIK NO. 1

| a DEPTH (ft) | TOC (%) | ROCK-EVAL S1 mg/g | S2 mg/g | S3 mg/g | Tmax C | VR % |
|---|---|---|---|---|---|---|
| 510 | 0.85 | . | . | . | . | . |
| 570 | 0.50 | . | . | . | . | . |
| 630 | 0.75 | . | . | . | . | . |
| 690 | 0.26 | . | . | . | . | . |
| 750 | 1.16 | . | . | . | . | . |
| 780 | 1.94 | 0.13 | 0.47 | 2.00 | 403 | 0.29 |
| 810 | 2.44 | 0.13 | 0.82 | 2.48 | 428 | . |
| 870 | 0.61 | . | . | . | . | . |
| 930 | 1.50 | 0.13 | 0.51 | 2.24 | 422 | . |
| 990 | 1.04 | . | . | . | . | . |
| 1050 | 0.84 | . | . | . | . | 0.48 |
| 1110 | 0.39 | . | . | . | . | . |
| 1170 | 0.93 | . | . | . | . | . |
| 1230 | 0.62 | . | . | . | . | . |
| 1290 | 0.67 | . | . | . | . | . |
| 1350 | 0.88 | . | . | . | . | 0.43 |
| 1410 | 0.80 | . | . | . | . | . |
| 1470 | 0.78 | . | . | . | . | . |
| 1530 | 0.86 | . | . | . | . | . |
| 1590 | 0.77 | . | . | . | . | . |
| 1650 | 0.72 | . | . | : | . | 0.35 |
| 1710 | 0.51 | . | . | . | . | . |
| 1770 | 0.62 | . | . | . | . | . |
| 1830 | 0.70 | . | . | . | . | . |
| 1890 | 0.71 | . | . | . | . | . |
| 1950 | 0.78 | . | . | . | . | 0.44 |
| 2010 | 0.80 | . | . | . | . | . |
| 2070 | 1.07 | . | . | . | . | . |
| 2130 | 1.04 | . | . | . | . | . |
| 2190 | 1.57 | 0.19 | 2.01 | 1.33 | 416 | . |
| 2250 | 1.63 | 0.17 | 1.79 | 1.38 | 417 | 0.36 |
| 2310 | 0.91 | . | . | . | . | . |
| 2370 | 0.69 | . | . | . | . | . |
| 2430 | 1.07 | . | . | . | . | . |
| 2490 | 0.83 | . | . | . | . | . |
| 2550 | 0.76 | . | . | . | . | 0.46 |
| 2610 | 0.93 | . | . | . | . | . |
| 2670 | 2.35 | 0.75 | 13.13 | 3.00 | 431 | . |
| 2730 | 1.30 | 0.13 | 0.89 | 1.96 | 425 | . |
| 2790 | 1.06 | . | . | . | . | . |
| 2850 | 0.98 | . | . | . | . | 0.42 |
| 2910 | 1.00 | . | . | . | . | . |
| 2970 | 0.90 | . | . | . | . | . |
| 3030 | 1.20 | . | . | . | . | . |
| 3090 | 1.11 | . | . | . | . | . |
| 3150 | 0.98 | . | . | . | . | 0.43 |
| 3210 | 1.39 | 0.38 | 1.79 | 1.87 | 426 | . |
| 3270 | 1.26 | . | . | . | . | . |
| 3330 | 1.10 | . | . | . | . | . |
| 3390 | 1.15 | . | . | . | . | . |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3450 | 1.19 | . | . | . | . | 0.38 |
| 3510 | 1.18 | . | . | . | . | . |
| 3570 | 1.16 | . | . | . | . | . |
| 3630 | 1.06 | . | . | . | . | . |
| 3690 | 1.90 | 0.18 | 3.11 | 1.33 | 416 | . |
| 3750 | 1.48 | 0.17 | 1.77 | 1.30 | 421 | 0.41 |
| 3810 | 1.48 | 0.13 | 1.86 | 1.23 | 419 | . |
| 3870 | 1.23 | . | . | . | . | . |
| 3930 | 1.79 | 0.20 | 2.59 | 1.48 | 415 | . |
| 3990 | 1.35 | 0.10 | 0.84 | 1.70 | 417 | . |
| 4050 | 1.51 | 0.18 | 1.36 | 1.76 | 421 | 0.42 |
| 4110 | 1.63 | 0.57 | 2.82 | 1.28 | 419 | . |
| 4170 | 1.22 | . | . | . | . | . |
| 4230 | 1.18 | . | . | . | . | . |
| 4290 | 1.76 | 0.33 | 1.48 | 1.97 | 422 | . |
| 4350 | 1.36 | 0.80 | 1.75 | 1.57 | 419 | 0.50 |
| 4410 | 1.52 | 0.28 | 1.52 | 1.77 | 424 | . |
| 4470 | 1.58 | 0.34 | 1.71 | 1.79 | 422 | . |
| 4530 | 1.45 | 0.42 | 1.11 | 2.04 | 420 | . |
| 4590 | 1.50 | 0.40 | 1.42 | 1.57 | 421 | . |
| 4650 | 2.03 | 0.26 | 1.75 | 2.05 | 424 | 0.49 |
| 4710 | 1.03 | . | . | . | . | . |
| 4770 | 1.27 | . | . | . | . | . |
| 4830 | 1.17 | . | . | . | . | . |
| 4890 | 1.16 | . | . | . | . | . |
| 4950 | 1.20 | . | . | . | . | 0.48 |
| 5010 | 1.41 | . | . | . | . | . |
| 5050 | 1.12 | . | . | . | . | . |
| 5100 | 1.27 | . | . | . | . | . |
| 5150 | 1.30 | . | . | . | . | . |
| 5200 | 1.32 | . | . | . | . | 0.49 |
| 5250 | 1.38 | . | . | . | . | . |
| 5300 | 1.28 | . | . | . | . | . |
| 5350 | 1.42 | . | . | . | . | . |
| 5400 | 1.40 | . | . | . | . | . |
| 5450 | 1.47 | . | . | . | . | 0.46 |
| 5580 | 43.60 | 77.68 | 63.55 | 65.53 | 329 | . |
| 5680 | 38.63 | 72.49 | 48.16 | 52.85 | 327 | . |
| 5730 | 45.19 | 80.24 | 63.82 | 66.13 | 331 | . |
| 5780 | 6.91 | 20.36 | 11.57 | 18.58 | 366 | 0.46 |
| 5830 | 38.04 | 75.67 | 55.33 | 57.15 | 330 | . |
| 5880 | 2.99 | 4.24 | 4.43 | 8.23 | 419 | . |
| 5930 | 7.94 | 23.27 | 15.37 | 20.99 | 325 | . |
| 5980 | 2.03 | 1.50 | 2.65 | 3.69 | 423 | . |
| 6030 | 1.77 | 1.12 | 2.24 | 2.45 | 425 | 0.44 |
| 6080 | 1.68 | 1.05 | 2.61 | 2.32 | 424 | . |
| 6130 | 1.35 | . | . | . | . | . |
| 6180 | 1.41 | . | . | . | . | . |
| 6230 | 1.43 | . | . | . | . | . |
| 6280 | 1.41 | . | . | . | . | . |
| 6330 | 8.75 | 20.42 | 14.77 | 16.93 | 326 | . |
| 6350 | 1.93 | 0.42 | 2.23 | 1.22 | 426 | 0.42 |
| 6380 | 3.56 | 5.57 | 5.76 | 7.64 | 411 | . |
| 6397 | 0.83 | . | . | . | . | . |
| 6430 | 1.32 | . | . | . | . | . |
| 6480 | 1.16 | . | . | . | . | . |
| 6530 | 1.21 | . | . | . | . | . |
| 6580 | 1.10 | . | . | . | . | 0.47 |
| 6630 | 4.68 | 0.51 | 15.30 | 1.91 | 423 | . |
| 6680 | 4.37 | 0.39 | 10.12 | 2.68 | 427 | . |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6730 | 3.11 | 0.27 | 4.11 | 1.68 | 429 | . |
| 6780 | 2.71 | 0.21 | 2.58 | 1.21 | 431 | 0.44 |
| 6830 | 2.35 | 0.29 | 2.60 | 1.20 | 431 | . |
| 6880 | 1.91 | 0.23 | 1.75 | 1.47 | 431 | . |
| 6930 | 1.62 | 0.24 | 1.73 | 1.43 | 430 | . |
| 6980 | 1.40 | . | . | . | . | . |
| 7030 | 1.52 | . | . | . | . | . |
| 7080 | 2.04 | 0.57 | 3.14 | 3.01 | 428 | . |
| 7113 | 1.06 | . | . | . | . | 0.40 |
| 7130 | 1.67 | . | . | . | . | . |
| 7150 | 1.22 | . | . | . | . | . |
| 7180 | 2.74 | 0.30 | 3.28 | 2.24 | 430 | . |
| 7200 | 1.37 | . | . | . | . | 0.54 |
| 7230 | 1.35 | . | . | . | . | . |
| 7280 | 1.39 | . | . | . | . | . |
| 7330 | 1.65 | . | . | . | . | . |
| 7380 | 1.81 | . | . | . | . | . |
| 7430 | 2.12 | 0.45 | 3.47 | 2.71 | 430 | . |
| 7480 | 1.95 | . | . | . | . | . |
| 7530 | 1.63 | . | . | . | . | 0.52 |
| 7580 | 1.65 | . | . | . | . | . |
| 7630 | 2.66 | 0.43 | 7.66 | 1.17 | 428 | . |
| 7680 | 2.29 | 0.27 | 5.04 | 1.08 | 431 | . |
| 7730 | 2.18 | 0.41 | 6.67 | 1.19 | 430 | 0.48 |
| 7780 | 2.13 | 0.27 | 6.30 | 1.16 | 433 | . |
| 7830 | 2.27 | 0.20 | 5.57 | 1.24 | 433 | 0.53 |
| 7880 | 2.01 | 0.25 | 4.40 | 1.07 | 432 | . |
| 7930 | 1.80 | . | . | . | . | . |
| 7980 | 1.79 | . | . | . | . | . |
| 8030 | 2.00 | 0.25 | 5.38 | 0.91 | 437 | . |
| 8080 | 1.81 | . | . | . | . | . |
| 8130 | 2.80 | 0.59 | 13.34 | 0.77 | 436 | . |
| 8180 | 2.80 | 0.35 | 9.46 | 1.17 | 433 | . |
| 8230 | 2.36 | 0.55 | 7.51 | 1.42 | 435 | . |
| 8280 | 2.29 | 0.22 | 6.22 | 1.11 | 436 | 0.48 |
| 8330 | 2.43 | 0.44 | 7.83 | 1.08 | 437 | . |
| 8380 | 3.31 | 0.70 | 13.41 | 1.14 | 437 | . |
| 8430 | 2.75 | 0.77 | 11.18 | 1.20 | 437 | . |
| 8480 | 1.86 | . | . | . | . | . |
| 8530 | 2.35 | 0.59 | 9.33 | 1.21 | 437 | 0.49 |
| 8580 | 2.06 | 0.52 | 3.81 | 5.65 | 437 | . |
| 8630 | 1.01 | . | . | . | . | . |
| 8680 | 1.95 | . | . | . | . | . |
| 8730 | 2.42 | 0.77 | 7.54 | 1.87 | 436 | . |
| 8763 | 0.97 | . | . | . | . | . |
| 8780 | 18.45 | 2.58 | 18.96 | 20.20 | 428 | . |
| 8810 | 0.65 | . | . | . | . | 0.59 |
| 8830 | 4.13 | 0.32 | 2.42 | 6.45 | 436 | . |
| 8860 | 0.57 | . | . | . | . | . |
| 8880 | 3.39 | 0.87 | 2.96 | 5.54 | 434 | . |
| 8910 | 0.26 | . | . | . | . | . |
| 8930 | 1.38 | . | . | . | . | . |
| 9000 | 0.21 | . | . | . | . | . |
| 9030 | 14.35 | 1.03 | 14.15 | 17.93 | 432 | . |
| 9042 | 0.22 | . | . | . | . | . |
| 9080 | 1.97 | . | . | . | . | . |
| 9100 | 0.15 | . | . | . | . | . |
| 9130 | 0.67 | . | . | . | . | . |
| 9138 | 0.08 | . | . | . | . | . |
| 9180 | 0.50 | . | . | . | . | . |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9230 | 0.40 | . | . | . | . | . |
| 9280 | 0.35 | . | . | . | . | . |
| 9310 | 0.28 | . | . | . | . | . |
| 9330 | 0.35 | . | . | . | . | . |
| 9350 | 0.12 | . | . | . | . | . |
| 9380 | 0.31 | . | . | . | . | . |
| 9400 | 0.23 | . | . | . | . | . |
| 9430 | 0.37 | . | . | . | . | . |
| 9480 | 0.28 | . | . | . | . | . |
| 9528 | 0.60 | . | . | . | . | 1.02 |
| 9530 | 0.48 | . | . | . | . | . |
| 9580 | 0.64 | . | . | . | . | . |
| 9630 | 0.56 | . | . | . | . | . |
| 9680 | 0.63 | . | . | . | . | . |
| 9725 | 0.92 | . | . | . | . | 0.95 |
| 9730 | 0.54 | . | . | . | . | . |
| 9780 | 1.05 | . | . | . | . | . |
| 9830 | 2.15 | 0.13 | 1.15 | 2.27 | 436 | . |
| 9840 | 0.64 | . | . | . | . | . |
| 9880 | 0.68 | . | . | . | . | . |
| 9895 | 0.58 | . | . | . | . | . |
| 9930 | 0.44 | . | . | . | . | . |
| 9980 | 0.34 | . | . | . | . | . |

a Depth given is top of 30-foot interval

# APPENDIX 3

50-103-20020
NAME NECHELIK #1
1/31/82
1" = 2'
BY NOLAN/GODARD

#81-149

SOHIO
SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: TOROK
CORE NO: 1
INTERVAL: 6338.0 - 6398.0
CUT: 60'
RECOVERED: 60' (100%)
PAGE 1 OF 5

| DEPTH | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR / INTERMEDIATE / MAJOR) | FRACTURES | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 6338 | | | | | | | rubble | MUDSTONE, medium to dark grey, soft to firm, carbonaceous, micaceous, fissile, v. slightly calcareous |
| 6340 | | | | | | | | |
| | | | | | | | fractures @ 10° polished fracture planes | MUDSTONE, banded, dk gy, v. fissile, mic., carbonaceous bands, calcareous in spots, poss. dolomitic in others |
| 6342 | | | | | | | | |
| | 1 | | | | | | | |
| 6344 | | | | | | | numerous small fractures 5-10° | |
| 6346 | | | | | | | | MUDSTONE, a/a |
| 6348 | | | | | | | 10° | |
| 6350 | | | | | | | | |

CONFIDENTIAL INDEFINITELY

API NO. 50-103-20020
WELL NAME NECHELIK #1
DATE 1/31/82
SCALE 1" = 2'
DESCRIBED BY NOLAN/GODARD

SOHIO

SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION TOROK
CORE NO.: 1
INTERVAL 6338.0'-6398.0'
CUT: 60'
RECOVERED 60' (100%)
PAGE 2 of 5

| DEPTH (feet drilled) | CORE NO | FRACTURES | REMARKS |
| --- | --- | --- | --- |
| 6350 | | numerous fractures sub-hor. to 20° | MUDSTONE, dk gy, fm-hd, banded, carb, mic, occ silty lenses, ribbed appearance, harder bands are silica (?) cemented and less fissile, sli-mod calc. |
| 6352 | | slickensided surfaces # in two directions | |
| 6354 | 1 | | MUDSTONE, a/a sli silty w/traces of vfgrn qtz, carb material on fissility planes |
| 6356 | | high ∡ fractures up to 45° | |
| 6358 | | | MUDSTONE, hard, dk gy, unribbed, silty w/vfgrn qtz, mic, well cemented, mod calc. |
| 6360 | | | MUDSTONE, ribbed, a/a |
| 62 | | | |

CONFIDENTIAL INDEFINITELY

API NO. 50-103-20000
WELL NAME NECHELIK #1
DATE 1/31/82
SCALE 1″ = 2′
DESCRIBED BY NOLAN/GODARD

SOHIO

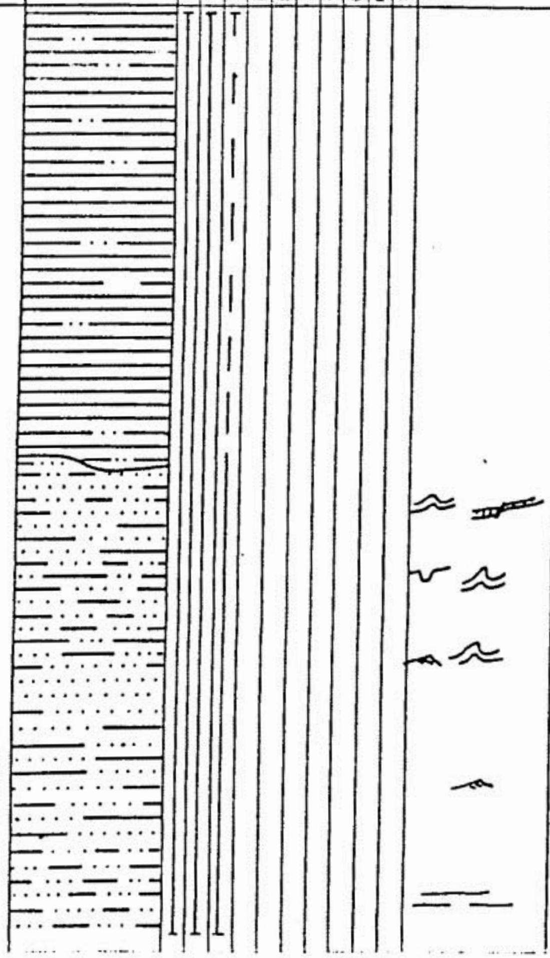
SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: TOROK
CORE NO.: 1
INTERVAL: 6338.0′ - 6378.0′
CUT: 60′
RECOVERED: [illegible] (100%)



| DEPTH (Feet Drilled) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS | FRACTURES | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 6362–6374 | 1 |  | | | | | | |

Grain size columns: Mud, Silt, Sand (VF, F, M, C, VC), Granule, Pebble, Cobble. Sediment trends: Minor, Intermediate, Major.

Fractures:
- 6362–6363: 10° polished fracture planes
- 6365: 10°
- 6368–6369: Slickensides 2 sets @ 60°
- 6372–6373: numerous microfractures, slickensided surfaces

Remarks:

MUDSTONE, silty, v mic, fiss, well cem, sli calc, dkgy-blk w/occ. f.grn qtz and carb. matl, soft v.fiss, ribs.

Chaotically deformed interval of interbedded and interlaminated:

SANDSTONE, ltgy-gybrn, vfgrn qtzose, sli-vsilty, sli mic, carb debris, calc and dol cement

SILTSTONE, dkgy-gybrn, sandy and argil, w/vfgrnqtz, carb, mic, grading to silty sandstone.

Abundant soft-sediment deformation structures including contorted bedding, convolute laminae, microfracturing, sole structures, deformed burrow fillings(?), load structures, cross lamination or cross bedding.

SOHIO

SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

API: 50-103-20002
WELL NAME: NECHELIK #1
DATE: 1/31/82
SCALE: 1" = 2'
DESCRIBED BY: GODARD/NOLAN

FORMATION: TOROK
CORE NO: 1
INTERVAL: 6338-6398'
CUT: 60'
RECOVERED: 60' (100%)



| DEPTH (FEET) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, Sand: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR, INTERMEDIATE, MAJOR) | FRACTURES | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 6374 | | | | | | | | |
| 6376 | | | | | | | | Highly deformed interbedded and interlaminated sequence of: SILTSTONE, sandy, dk gy, mic, carb, containing sandy lenses of vfgrn qtz and mudst partings, grades into silty mudstone, silty sandstone |
| | | | | 50° | | | | SANDSTONE, gy brn, vfgrn, qtzose, silty, mod sorted, tr. carb. debris, sli calc-dol cement, tight. |
| 6378 | 1 | | | | | | | Traces of min fluor - no cut fluor |
| 6380 | | | | | | | micro-fractures | |
| 6382 | | | | | | | | |
| 6384 | | | | 75° | | | | |
| 6386 | | | | | | | | |

API NO [illegible]-03-20020
WELL NAME NECHELIK #1
DATE 1/31/82
SCALE 1" = 2'
DESCRIBED BY GODARD/NOLAN

# SOHIO PETROLEUM COMPANY

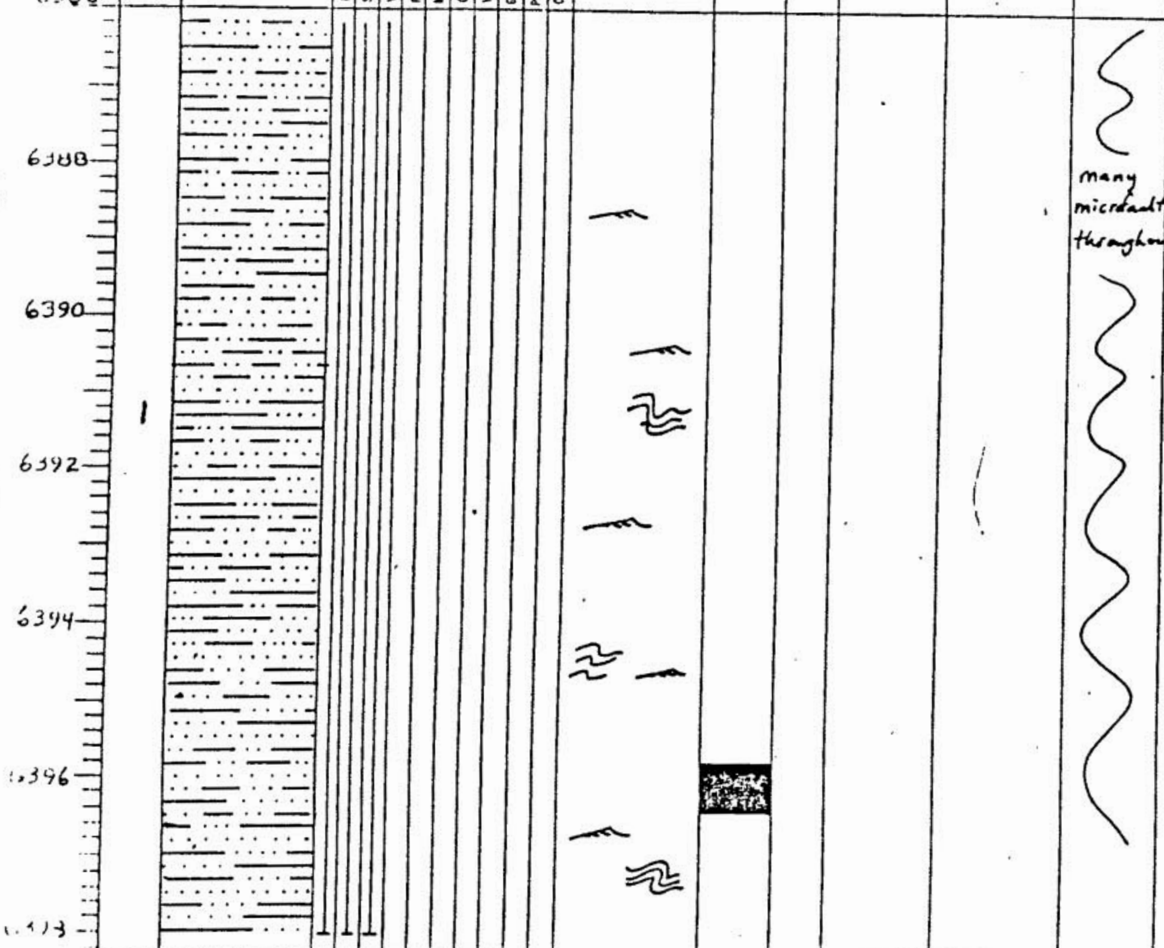
## CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION:
CORE NO: 1
INTERVAL 6338.0' - 6398.0'
CUT 60'
RECOVERED 60' (100%)



| DEPTH (feet drilled) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, SAND: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR, INTERMEDIATE, MAJOR) | FRACTURES | REMARKS |
|---|---|---|---|---|---|---|---|---|




Interlaminated sequence of SILTSTONE and vfn grn SANDSTONE, a/a, containing cross bedding/laminae and soft sed. deformation features, microfaulting abundant

Spotty mineral fluor - no cut fluor

API NO 50-103-20022
WELL NAME NECHELIK #1
DATE 2-3-82
SCALE 1" = 2'
DESCRIBED BY JUDSON / NOLAN

# SOHIO PETROLEUM COMPANY

## CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk
CORE NO: 2
INTERVAL: 7112 - 7172
CUT: 60'
RECOVERED: 60'6" (100%)
PAGE 1 of 5

| DEPTH (feet drilled) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR / INTERMEDIATE / MAJOR) | FRACTURES | Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7112 | | | | | | | | Bright yellow-green flour. instant strmg. milk white followed by slow strmg creamy white cut, straw cut | SANDSTONE - well sorted, subangular, grainstone to packstone texture, non to v. sli. calc. matrix, dolomitic in places, majority of matrix seems to be siliceous, grey. Brown oil stain throughout (saturated in places) carbonaceous and clay drapes present on bedding planes. There are waxy surfaces, possibly plant remains along which the core easily breaks. Abundant SIDERITE nodules. |
| 7114 | | | | | | | | Bright gold flour (90%) except through clay & carb. partings | |
| 7116 | 2 | | | ABUNDANT SOFT SED. DEFORMATION FEATURES | | | | Bright Orangy Gold flour. instant strmg. bright white cut, straw cut. | amount of siderite is increasing down core |
| 7118 | | | | | | | | | |
| 7120 | | | | | | | | | |
| 7122 | | | | | | | | Patchy dull to bright gold flour., inst. creamy cut flour. | Sand becoming more matrix supported. Clay - dark brown, non calc. |
| 7124 | | | | | | | | | |

CONFIDENTIAL INDEFINITELY

... 50-103-20005
WELL NECHELIK #1
DATE 2-3-82
SCALE 1" = 2'
LOGGED BY JUDSON / NOLAN

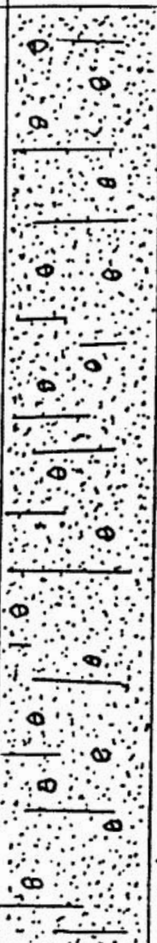
SOHIO

SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk
CORE NO: 2
INTERVAL: 7112 - 7172
CUT: 60'
RECOVERED: 60'6" (100%)
PAGE 2 of 5

| DEPTH | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, Sand: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (Minor, Intermediate, Major) | FRACTURES | Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7124 | 2 |  | | | | | | Bright gold flour., v. bright white creamy instant strong cut flour. | Clay drapes and banding present throughout sand. HAS A MOTTLED LOOK, possibly due to bioturbation. Lenses of sand surrounded by small beds of clay. |
| 7126 | | | | | | | | | |
| 7128 | | | | | | | | | Common Siderite Nodules .5mm - 7mm |
| 7130 | | | | | | | | Bright gold flour., v. bright inst. strong creamy white cut flour., straw cut | Some partings of dark green clay on bedding planes |
| 7132 | | | | | | | | | Bands of siderite ll to bedding planes |
| 7134 | | | | | | | | | Sandstone - Oil Stained - Lith a/a patchy dolomitic cement. |
| 7136 | | | | | | | | | |

API NO 50-103-2002
WELL NAME NECHELIK #1
DATE 2-3-82
SCALE 1" = 2'
DESCRIBED BY JUDSON / NOLAN

SCHIO

# SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION Kuparuk
CORE NO: 2
INTERVAL 7112 - 7172'
CUT 60'
RECOVERED 61'6" (100%)



| DEPTH (feet drilled) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, Sand: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (Minor, Intermediate, Major) | FRACTURES | Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7136 – 7148 (7138, 7140, 7142, 7144, 7146) | 2 |  | | Siderite nodules up to 2" across; lenticular-wavy manded | | | sub-horizontal | Gold flour, instant white streaming cut flour. | Sandstone - grey, brown oil stain, quartzose, subangular, tr. mica, trace carb., sli. pyritic, well cemented. w/ Dark grey Sandstone and wavy dark grey carb. partings. Siderite nodules are abundant. SST as above with mudstone part. SST. with patchy brown oil stain, pyritic, subangular, micaceous with a clay matrix. Interbedded w/ carb. partings and dark grey, pyritic Mud. |

API NO 50-103-20020
WELL NAME NECHELIK #1
DATE 2-3-82
SCALE 1" = 2'
DESCRIBED BY JUDSON / NOLAN

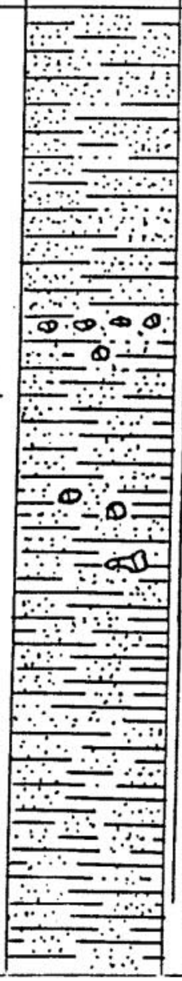
SOHIO

SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk
CORE NO: 2
INTERVAL 7112-7172
CUT 60'
RECOVERED 60'6" (100%)
PAGE 4 of 5

| DEPTH (Core Drilled) | CORE NO. | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, Sand: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (Minor, Intermediate, Major) | FRACTURES | Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7148 | |  | | | | | | | Mudstone with Laminae and Lenses of Sandstone |
| | | | | | | | | No flour. | Mudstone- brown hard, splintery, silty and sandy, with disseminated pyrite and pyrite veins. ssl. Laminations are < 1/8" |
| 7152 | | | | infilled Burrow | | | | | |
| | 2 | | | parallel band of siderite nodules | | | | | Siderite nodule - sandy center with waxy outer covering  fossil wood? center is siderite |
| 7154 | | | | | | | | | CONFIDENTIAL INDEFINITELY |
| 7156 | | | | | | | | no. flour. | Mudstone a/a Micaceous with Laminations and Lenses of a white crystaline material, and sand size grains in a white matrix, grains are soft and give a white streak. |
| 7158 | | | | | | | | | Carb. partings. |
| 7160 | | | | Lenticular wavy Bedding | | | | | |

WELL NO. 50-103-20020
WELL NAME NECHELIK #1
DATE 2-3-82
SCALE 1" = 2'
DESCRIBED BY JUDSON / NOLAN

SOHIO

SOHIO PETROLEUM COMPANY

CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk
CORE NO.: 2
INTERVAL: 7112'-7172
CUT: 60'
RECOVERED 60' 6" (100%
PAGE 5 of 5

| DEPTH (feet) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, Sand: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR, INTERMEDIATE, MAJOR) | FRACTURES | Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7162 | | | | Dissrupted Lenticular bedding | | | | Bright Gold Flour., fast string yellow/green cut flour., | Dark Red Brown Mudstone, subfissile, micaceous, pyritic. increase in Sand Content, still interlaminated SST. and Mudstone with sand being dominant. SST. - fine grained, quartzose, with clay, well cemented. MDST. - grey to grey brown, silty, sandy quartzose |
| 7164 | 2 | | | | | | | | |
| 7166 | | | | | | | | Bright gold flour., instant white cut from SST. | Dominately SST. ~~with wavy carb~~ Laminations, interlaminated w/ MDST |
| 7168 | | | | | | | | ↓ | |
| 7170 | | | | | | | | | (50/50) MDST. - brown, micaceous, silty, w/ frag of quartz, tr. carb. material, disseminated and vein pyrite. SST - fine grained, grey to brown, quartz, with clay matrix + sli dolomitic cement |
| 7172 | | | | | | | | | downward increase in MDST. |

CONFIDENTIAL INDEFINITELY

API NO 50-103-20020
WELL NAME Nechelik #1
DATE 2-4-82
SCALE 1" - 2'
DESCRIBED BY NOLAN / WILD / JUDSON

SOHIO

SOHIO PETROLEUM COMPANY

# CORE. DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk
CORE NO.: 3
INTERVAL. 7172 - 7231'9"
CUT- 59'9"
RECOVERED 100%
PAGE 1 of 5

| DEPTH | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR / INTERMEDIATE / MAJOR) | FRACTURES | Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7172 – 7175 | | | | wavy lam.; lenticular wavy bedding; burrow fill | | | | bright gold flour. from Light sst. Lenses white fast cut fluor. | Interlaminated dark grey Mudstone and light brown sandstone. Band of dark Brown Mdst. @ 7172'6" - 1" Th |
| 7175 – 7178 | 3 | | | Sigmoidal lenses; disrupted lam. bioturbated; Lenticular bedding | | | | | MDST. Brown, sandy, micaceous, subfissile with pyrite veins and crystals. SST. - fine grained, quartzose, sli. micaceous, coal frags., w/ clay matrix, poor vis. Φ, brown oil stain, non calc.. (~60% SST / 40% MDST) |
| 7179 | | | | | | | | | SST. - A/A but w/ sli. calcareous cement |
| 7180 – 7181 | | | | | | | fractures mud filled | | Dark brown very Carb. Laminations |
| 7182 – 7184 | | | | wavy lam | | | Mud filled Fractures | | Dominantly sst. a/a with mudstone partings. Increase in MUDSTONE @ 7183' |

CONFIDENTIAL INDEXED

API No. 50-...-20020
WELL NAME NECHELIK #1
DATE 2-4-'82
SCALE 1" = 2'
DESCRIBED BY NOLAN | WILD | JUDSON

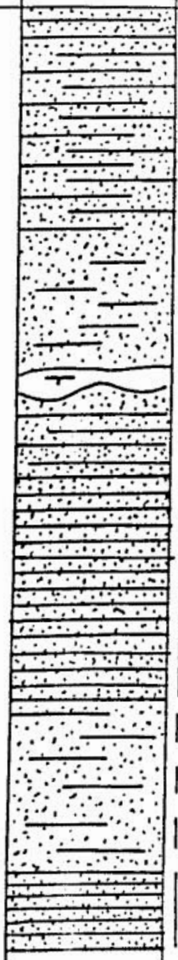
SOHIO

SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk
CORE NO: 3
INTERVAL: 7172' – 7231'9"
CUT: 59' 9"
RECOVERED: 100%


| DEPTH (Drilled) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, SAND: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR, INTERMEDIATE, MAJOR) | FRACTURES | SHOWS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7184 | |  | | | | | | Trace of pinpoint yellow fl. no cut. | MUDSTONE, brn, mic, sub fis, pyrite trails on bedding surfaces, tr vfg qtz. |
| 7165 | | | | | | | | | SANDSTONE, fg, qtzose, wh clay matrix, pkst-grst text, poor vis Φ. |
| 7186 | | | | laminated and lenticular structures. | | | | | |
| 7187 | | | | lenticular wavy bedding | | | | | Mudstone and sandstone are interlaminated, with varying proportions. The SST laminae are disrupted into lenses in part and flaser type bedding is formed. |
| 7188 | | | | | | | | | |
| 7189 | | | | | | | | | Dominantly Mudstone a/a with sandstone laminae and lenses. |
| 7190 | | | | | | | | | |
| 7191 | | | | shell debris | | | | | |
| 7192 | | | | | | | | | |
| 7193 | | | | | GEOLOGY | | | | Dominantly Sandstone a/a. |
| 7194 | | | | | | | | | |
| 7115 | | | | | | | | | Dominantly Mudstone a/a with sandstone laminae and lenses. |
| 7116 | | | | | | | | | |

CONFIDENTIAL

50-123-20020
NAME Nechelik #1
2-4-81
1" = 2'
DESCRIBED BY JUDSON / WILD / NOLAN

**SOHIO**

SOHIO PETROLEUM COMPANY

# CORE DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk
CORE NO.: 3
INTERVAL: 7172 - 7231'9"
CUT: 59'9"
RECOVERED: 100%
PAGE 3 of 5

| DEPTH (FEET) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, Sand: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS (MINOR, INTERMEDIATE, MAJOR) | FRACTURES | Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 7177 | | | | | | | | faint trace of Dull gold flour. In sst. Laminae | Mudstone w/ fine lenticular bands of fine Sand and silt. MDST - Brown, Micaceous, non fissile, pyrite veins. SST - v. fine grained, sub rounded, qtzose Sub parallel Laminae of fine Sand + silt the individual grains are surrounded by a white matrix, non to sli. calcareous |
| 7199 | | | | | | | | No flour. | |
| 7201 | 3 | | | | | | | | MDST - occasionally grades into a subfissile brown shale. w/ TR. pyrite |
| 7203 | | | | Parallel Bedding changes into convoluted beds associated with an Increase in sand | | | Breaks easily along bedding planes | No flour | Increasing amount of fine sand Laminae - (50/50 - mudst / sst) grading back to predominately mudstone @ 7207'. |
| 7205 | | | | | | | | | |
| 7207 | | | | | | | | Trace flour in sst. Laminae a/a | |

CONFIDENTIAL

WELL NO 50-103-20020
WELL NAME Nechelik #1
DATE 2-4-82
SCALE 1" = 2'
DESCRIBED BY Wild / Judson / Nolan

SOHIO

SOHIO PETROLEUM COMPANY

# CORE. DESCRIPTION

SOHIO CONFIDENTIAL

FORMATION: Kuparuk / L. Shale
CORE NO: 3
INTERVAL: 7172-7231'9"
CUT: 59'9"
RECOVERED: 100%
PAGE 4 of 5

| DEPTH (corrected) | CORE NO | GRAPHIC LITHOLOGY | GRAIN SIZE (Mud, Silt, Sand: VF, F, M, C, VC, Granule, Pebble, Cobble) | SEDIMENTARY STRUCTURES | SAMPLE LOC. | SEDIMENT TRENDS: MINOR | INTERMEDIATE | MAJOR | POROSITIES Shows | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 7209 | | | | | | | | | very occasional faint dull gold flourescence in SANDSTONE Laminae | Fine interlaminae (3-4mm) of very fine sandst. and brown grey Mudst., silty, micaceous. |
| | | | | | | | | | | Mostly parallel Laminations, occasionally slightly wavy. some evidence of worm casts, pyritised, but very little sign of bioturbation. |
| 7211 | | | | | | | | | | |
| 7213 | | | | | | | | | | Mudstone - brown-grey, silty micaceous with v. fine Sandstone - Laminae, white, argillaceous (30-40% by volume) |
| 7215 | | | | | | | | | | |
| 7217 | | | | | | | | | | Mudstone - darkbrown grey ~~very~~ firm w/ SANDSTONE - Lenses and Laminae, very fine, white, soft, clay matrix, slightly and variably calcareous. |
| 7219 | | | | | | | | | | Sandstone content 5-20% increasing up section from 7220 to 7215. |

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