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PETROGRAPHY OF THE NANUSHUK GROUP AND TOROK FORMATION

by

Susan Bartsch-Winkler and A. Curtis Huffman

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature

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Abstract

The Nanushuk Group, of Early and Late Cretaceous (Albian and Cenomanian) age, is a transitional unit containing deltaic, interdeltaic, and shallow marine sandstone and shale sequences that crop out in the western and central foothills belt and is widespread in the subsurface of the Arctic North Slope. The Lower Cretaceous Torok Formation, conformably underlying and laterally equivalent to the Nanushuk Group, is predominantly a shale sequence of deeper water origin than the Nanushuk Group. Sandstones collected from scattered outcrops, from eight measured sections, and from twenty wells drilled by the Navy and the U.S. Geological Survey in the Nanushuk Group and Torok Formation were examined for compositional differences. Results of the modal analyses show the suite of sandstones to be be lithic and quartz-rich when plotted on a O-F-L ternary diagram. Two depositional lobes (western and central) can be distinguished by variations in the lithic component of the sandstone modal analyses as well as paleontologic data.

Sandstones of the Nanushuk Group from scattered outcrops and from the Barabara syncline, Corwin Bluff, Tupikchak Mountain, and Carbon Creek sections in the western delta (the Corwin Delta) (Ahlbrandt and others, 1979) show an increased proportion of sedimentary lithic component, especially calcareous, argillaceous and carbonaceous grains, and thus are sedimentary litharenites (Folk, 1968). In contrast, sandstones of the Nanushuk Group from scattered outcrops, and from the Tuktu Bluff, Kurupa anticline, Arc Mountain, and Marmot syncline sections in the central delta (the Umiat Delta) (Ahlbrandt and others, 1979) contain more numerous volcanic rock fragments and metamorphic rock fragments (particularly quartzite and foliated quartz-mica). These sandstones are predominantly phyllarenite, though some samples may be categorized as sedimentary litharenite and volcanic litharenite (Folk, 1968). Samples from the more northerly subsurface occurrences of the Nanushuk Group and Torok Formation show modal plots which reflect subtle variations corresponding to those of the surface plots, possibly indicating a gradation, transition, or interfingering of lithic types in the subsurface.

Sources for the Nanushuk Group sandstone probably are different for the two deltas. The increased amounts of calcareous and argillaceous material found in the Corwin Delta were derived predominantly from the Lisburne Group of Mississippian and Pennsylvanian age, the Shublik Formation of Middle and Late Triassic age, and the Siksikpuk Formation, here of Early(?) Permian age. Material found in the Umiat Delta probably was shed from the Endicott Group, consisting of the Upper Devonian Hunt Fork Shale and Kanayut Conglomerate, and the Lower Mississippian Kayak Shale. The Endicott Group contributed increased proportions of quartzose and metamorphic rock fragments (phyllite and slate) to the eastern suite of Nanushuk sediments.

Matrix materials caused by compaction of ductile grains, and cementing minerals produced diagenetically and by weathering are ubiquitous in samples from the Nanushuk Group. Petrographic evidence for the development of secondary porosity exists, but is not common in the sandstones. Many samples, especially those from the subsurface, attain visible porosity values that are high enough to be of interest from a reservoir standpoint.

Introduction

Surface and subsurface sandstones from the Lower and Upper Cretaceous Nanushuk Group and the Lower Cretaceous Torok Formation were examined to determine the textural and mineralogical factors that might indicate their source and affect reservoir characteristics. The samples were collected from scattered outcrops (sample numbers 1075 through 5475), from measured sections in the western and central outcrop belts, and from the subsurface (Bartsch-Winkler, 1979; 1981; Bartsch-Winkler and Huffman, 1981; and Huffman, 1979) (Fig. 1). The stratigraphic sections in the Nanushuk Group range in depositional setting from fluvial to deltaic to shallow marine, and show variations in texture, composition, and diagenetic alteration. Samples of the Torok are believed by Bird and Andrews (1979) to be deeper water marine equivalents of Nanushuk sandstones; i.e., the two units are lateral equivalents of a single depositional system. Sampling was not systematic; rather, it concentrated on the coarser grained, thicker sandstones, which are of greater interest from a provenance and petroleum reservoir standpoint; most surface samples examined were from the fluvial or deltaic regimes; the thicker beds were frequently sampled at several horizons. The surface samples were collected by James E. Fox (South Dakota School of Mines) in July, 1975, from scattered outcrops of the Nanushuk Group so their depositional settings are known. The subsurface samples were obtained from cores stored at U.S. Geological Survey warehouses in Fairbanks and Anchorage. Some of the thin sections were made from the remains of "perm plugs" used to determine porosity and air permeability (Robinson, 1956, 1958, 1959a,b,c, 1964; Collins, 1958a,b, 1959). These samples, taken from the wells drilled by the U.S. Navy prior to 1975, include those from Kaolak-1, Topagoruk-1, Simpson, Meade-1, Oumalik-1, Titaluk-1, Wolf Creek 1 and 3, Grandstand, Knifeblade-2A, Square Lake, and Gubik-2. More recent wells were drilled by the U.S. Geological Survey, and samples analyzed from these wells include those from East Simpson, Dalton, Inigok, Seabee, Fish Creek, Tunalik, Peard, South Meade, and South Barrow 1 and 6. The relative stratigraphic positions of the subsurface samples are well known, but environments of deposition are not identified. Modal analyses were performed on a total of 199 thin sections, and observations on the textural details were made on many more samples. A preliminary petrographic study of the sandstones was reported in Circular 794 (Bartsch-Winkler, 1979, p. 61-76; Huffman, 1979, p. 77-88), Circular ______ (Bartsch-Winkler, 1981), and Circular 823-B (Bartsch-Winkler and Huffman, 1981). Krynine (1947, 1948), Krynine and Ferm (1952), Fox (1979, p. 42-53), and Fox and others (1979) did petrographic studies on rocks from the Umiat test wells, and their sandstone descriptions served as invaluable introductions to the complexities and nuances of the sandstones of the Nanushuk Group and Torok Formation examined in this study.

Methods of study

Sandstones were submitted for thin sectioning, staining, and impregnation, to commercial laboratories under contractual agreement with the U.S. Geological Survey. The thin sections were stained with sodium-cobaltinitrite to aid in identification of potassium feldspar and with

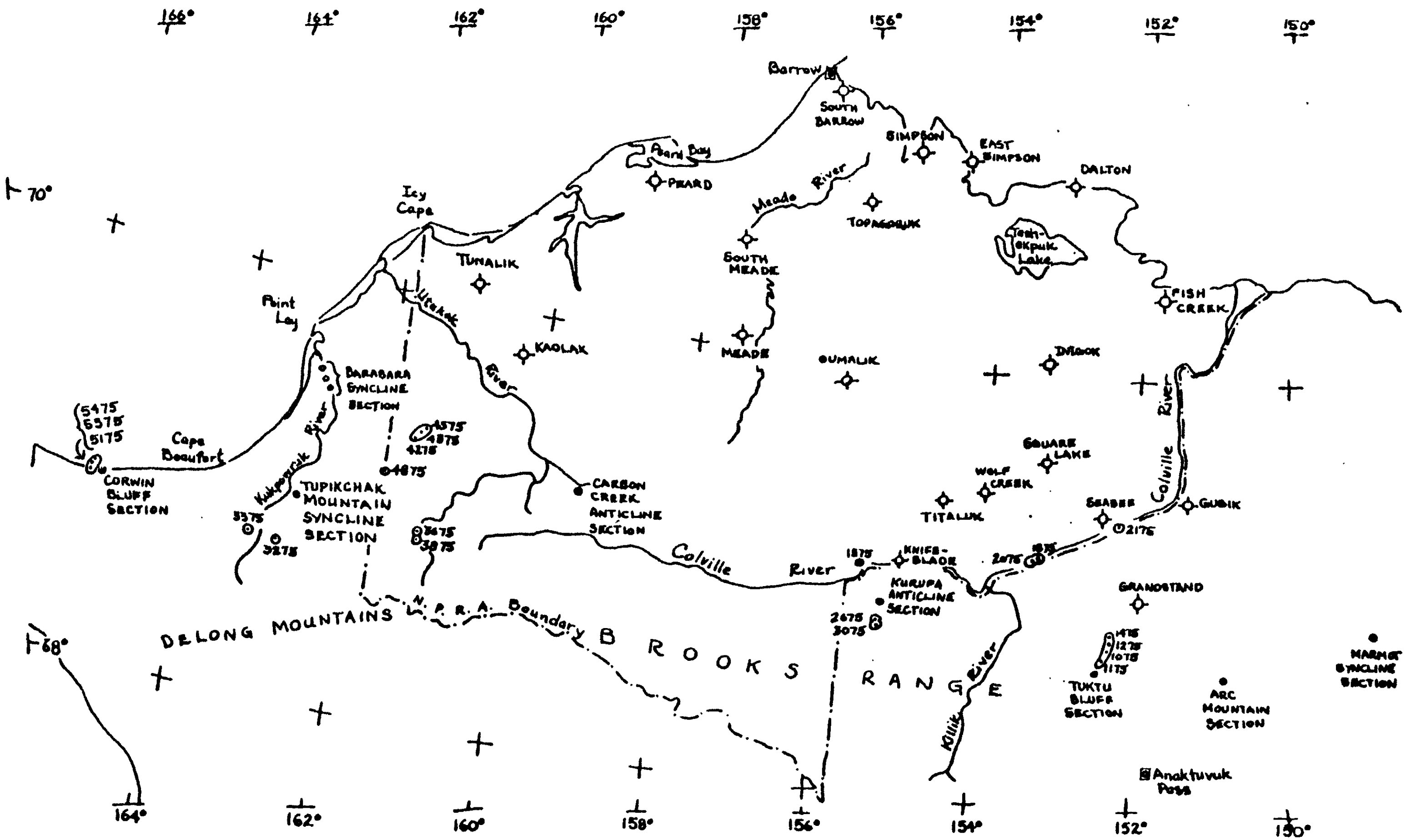


Figure 1. Locations of samples from the Nanushuk Group examined petrographically. Sandstones were collected from scattered outcrops (indicated by open circles), measured sections (indicated by black circles '), and wells (indicated by well symbols).

alizarin red to aid in identification of dolomite. Owing to the poor quality of the thin sections in all the samples except those from the post-1975 wells, especially in the impregnation and feldspar staining, modal data on visible porosity and potassium feldspar content is considered tentative. For modal analyses, a minimum of 300 grains were counted per thin section. Framework and matrix materials are categorized according to the definitions of Dickinson (1970), except for the chert grains (see the following discussion). Whole rock x-ray studies were conducted on some of the samples by Paul D. Blackmon and Harry C. Starkey, U.S. Geological Survey, Denver, to identify clay types and confirm major mineral constituents. With the assistance of Eve Sprunt, Stanford University, polished thin sections of selected samples were examined under cathodoluminescent light in order to determine cement relationships and possible grain overgrowths. Rock chips from the surface and subsurface samples were examined using the Cambridge 180 scanning electron microscope with an attached electron-dispersive analyzer located at the U.S. Geological Survey, Menlo Park, California, with the assitance of Robert L. Oscarson. Using the petrographic microscope, textural parameters were determined by estimation of sorting and type of grain contacts, measurement of grain size, and calculated percentages of cement, matrix, framework grains, and visible porosity from modal data. In the laboratory, porosity and air permeability measurements were made by Ira Pasternak (U.S. Geological Survey) and by contract laboratories on samples from the measured sections. Robinson and Collins reported results of measurements on samples from the wells drilled by the Navy (Robinson, 1956, 1958, 1959a, b, c, 1964; Collins, 1958a, b, 1959).

Mineralogy and grain types

Quartzose grains (Q) include monocrystalline quartz, polycrystalline quartz, chert, and quartzite. The monocrystalline grains (Qm) include undulose types as well as those with straight extinction angles. Quartzite grains are those with elongated crystalline morphologies, lacking any mica. Polycrystalline quartz (Qp) grains may have a wide range in crystalline dimensions, even in a single grain, and for this reason, grains with individual crystals smaller than 0.03 mm, which many workers would classify as chert (Dickinson, 1970) were not separated from the polycrystalline quartz category in this study. Chert grains include only fibrous types, which are rarely found in these rocks.

Feldspar (F) is not a significant component in the sandstones, averaging less than 10 percent of a typical sample. Potassium feldspar was stained yellow and thus was readily identifiable in most of the thin sections. Where feldspars are present they are typically altered, and identification of untwinned feldspars in some of the poorly stained thin sections was made on the basis of their significant alteration. Most feldspar grains are blocky and display albite and Carlsbad twinning; perthitic and myrmekitic feldspar types are also present.

Lithic grains (L) are typically altered by compaction because of their structural incompetence, and specific lithic types may be difficult to identify, not only because of their generally smaller grain size but also their apparent susceptibility to alteration and dissolution.

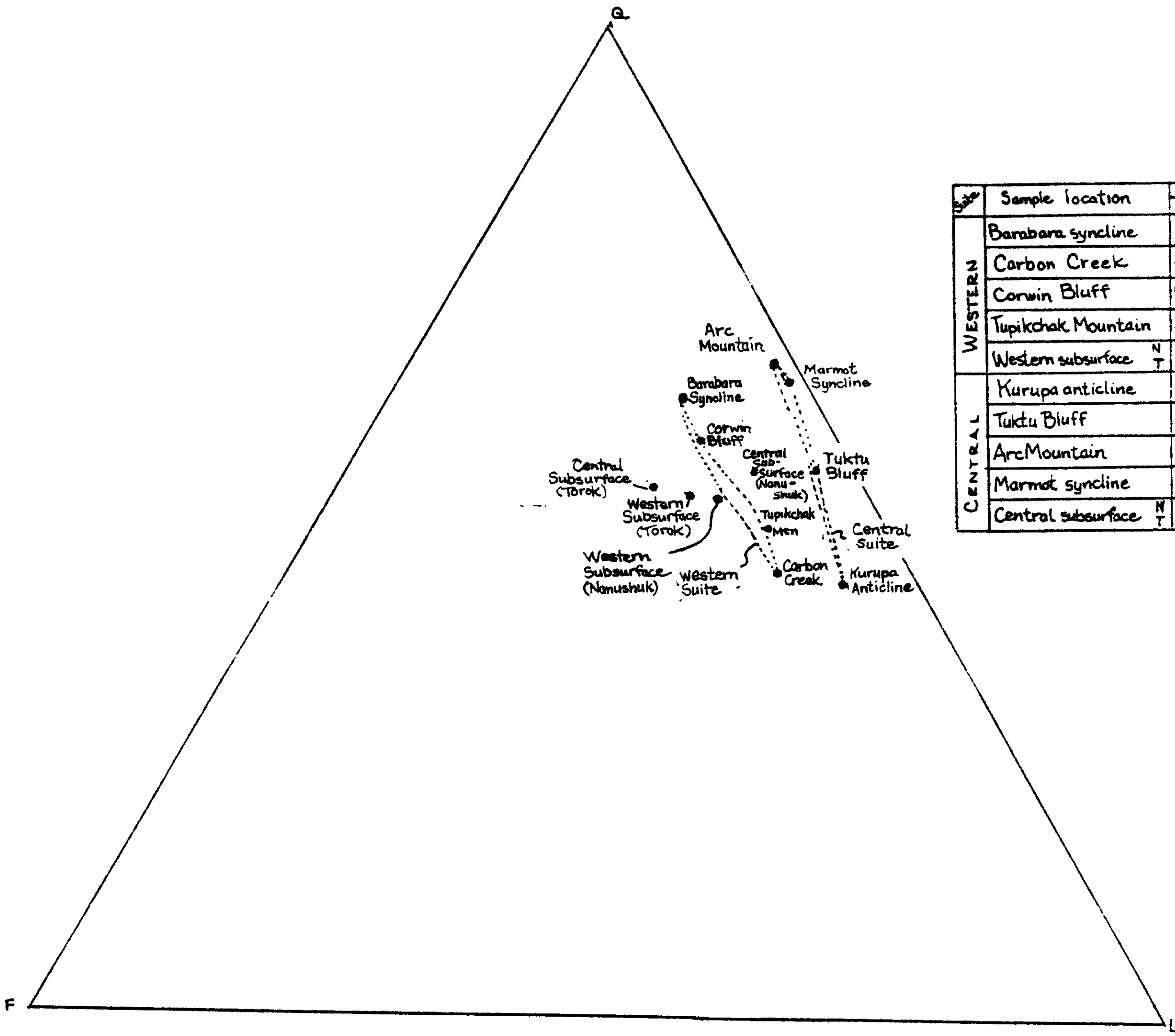
Metamorphic rock fragments (Lm) include quartzite and foliated quartz-mica (schist and phyllite) grains (Dickinson, 1970). Quartzite grains with only slightly elongate crystals are difficult to distinguish from polycrystalline quartz grains which are included in the quartzose grain category. Volcanic lithic grain types (Lv) include felsite, microlitic volcanic and microgranular-hypabyssal grains (Dickinson, 1970). Felsite grains may be confused with polycrystalline quartz grains if they are unaltered and untwinned, or with metamorphic grains if they show slightly elongate crystals.

Sedimentary rock fragments (Ls) include polycrystalline quartz (Qp) (see previous discussion), calcite clasts (Lcc), and argillaceous-carbonaceous fragments (Lac). The argillaceous-carbonaceous fragments in the sandstones studied are here treated together because of their close association in many grains and the difficulty of distinguishing them. Commonly though, the argillaceous fragments are laminated and may contain silt-size or smaller quartz grains, whereas the carbonaceous fragments and organic debris are massive and nearly opaque or deep orange along a very thin edge. Many of the sedimentary lithic fragments contain calcareous material which might vary from very finely crystalline to blocky sparry calcite. A few of the samples exhibit all stages of crystal development. Although some of this alteration may have taken place during diagenesis of the Nanushuk Group, much of it probably occurred prior to Nanushuk deposition in the source terrane. The resultant rounded, recycled clasts of recrystallized calcite(?) surrounded by blebs or coatings of dark-brown to reddish-brown clay material are characteristic, though not exclusively so, of the western area. Commonly these sedimentary lithic types are found associated with each other in various combinations in a single grain.

Most samples contain minor amounts of detrital muscovite, and a few contain small amounts of pleochroic straw-yellow to dark-brown detrital biotite in flakes which are nearly always bent and broken by compaction. Minor amounts of detrital chlorite(?) were also observed.

Results of Compositional Analyses - Provenance and Source Rocks

Complete results of the 199 modal analyses are shown in table 1 and table 4. When the sandstones were grouped according to their location on the map (table 4), compositional differences became apparent between samples from west of 157° W longitude (western suite) and samples from east of 157° W longitude (central suite). Samples from the western suite include those from Corwin Bluff, Tupikchak Mountain, Barabara Syncline and Carbon Creek measured sections and Tunalik, Peard, Kaolak, Meade, South Meade, Oumalik, and South Barrow wells. Samples from the Central suite include those from Kurupa Anticline, Tuktu Bluff, Arc Mountain, Marmot Syncline measured sections, and Simpson, East Simpson, Topagoruk, Dalton, Fish Creek, Inigok, Square Lake, Wolf Creek, Seabee, Gubik, Grandstand, Titaluk, and Knifeblade wells. Sandstones of the Nanushuk Group and Torok Formation are composed of abundant quartz and lithic grains (fig. 2). An average surface sample from the western suite contains 54 percent quartzose grains, 11 percent feldspar, and 35 percent lithic grains, whereas an average surface sample from the eastern suite is composed of 58 percent quartzose



Suite	Sample location		END MEMBER		
			Q	F	L
WESTERN	Barabara syncline		62.7	11.7	25.6
	Carbon Creek		45.1	11.8	43.1
	Corwin Bluff		58.5	12.0	29.5
	Tupikchak Mountain		49.6	10.3	40.1
	Western subsurface	N	53.5	13.1	33.4
		T	53.9	15.5	30.6
CENTRAL	Kurupa anticline		44.2	6.1	49.7
	Tuktu Bluff		55.6	3.2	41.2
	ArcMountain		66.6	1.8	31.6
	Marmot syncline		64.5	1.2	34.3
	Central subsurface	N	55.3	8.8	36.1
		T	53.5	18.8	27.6

Figure 2. Averages of quartz-feldspar-lithic (Q-F-L) modal analyses of sandstones of the Nanushuk Group from eight measured sections and from the Nanushuk Group (N) and Torok Formations (T) in the subsurface. Averages of sandstone samples from the western outcrop belt are enriched in feldspar grains and depleted in lithic grains when compared to samples from the central belt. Range in percentages of quartzose grains is the same for both suites. Subsurface Torok sandstones have increased numbers of feldspar grains compared to Nanushuk Group samples.

grains, 3 percent feldspar grains, and 39 percent lithic grains. Subsurface Torok sandstones have increased proportions of feldspar grains compared to Nanushuk Group samples.

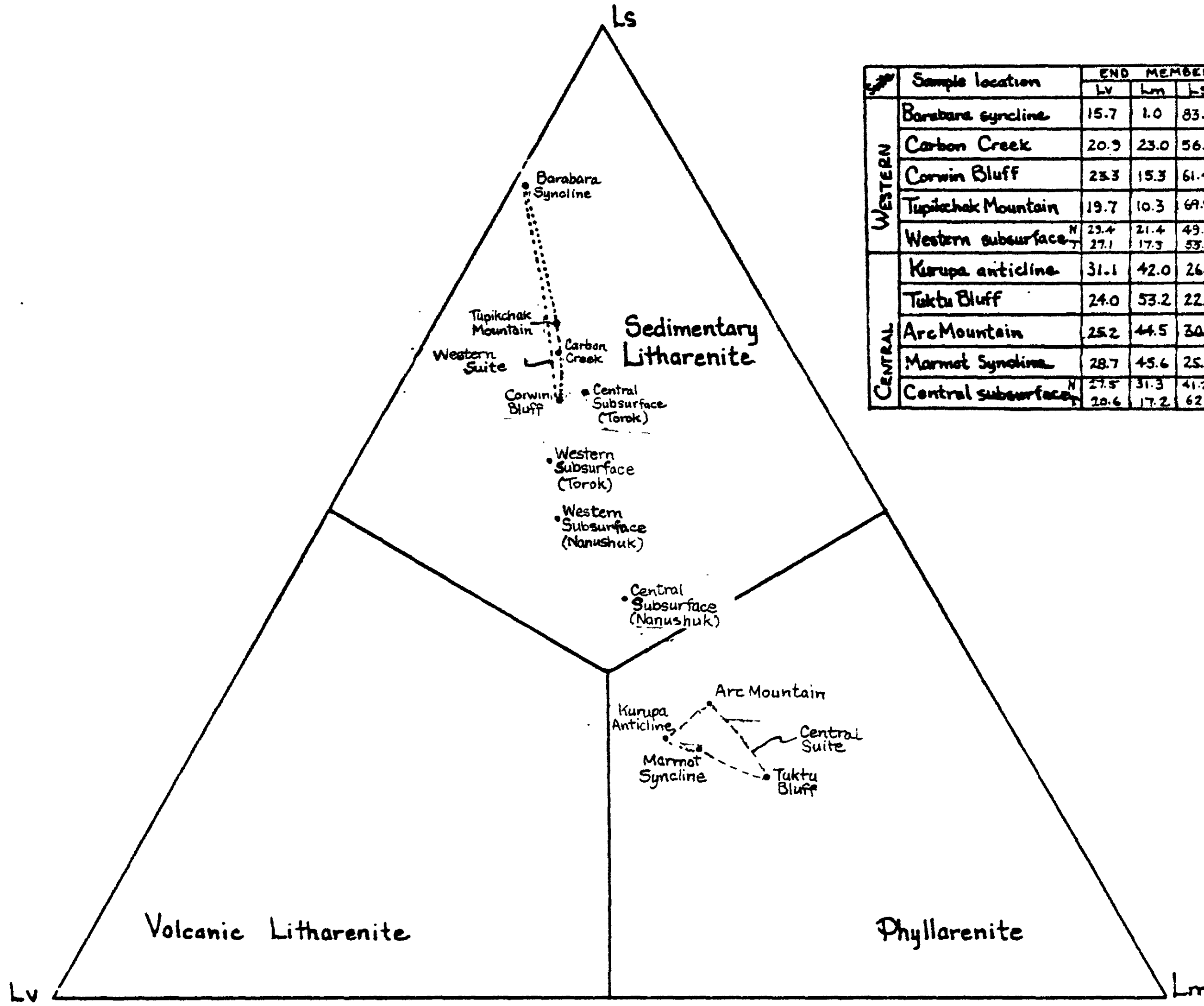
Proportions of detrital framework grains, particularly quartzose, feldspar, and lithic grains, determine the provenance of Nanushuk sandstones. Dickinson and Suczek (1979), using a series of modal plots, classified the sandstones of the Nanushuk Group with those from a "recycled orogen provenance" of uplifted, folded and faulted strata composed of recycled detritus of sedimentary or metasedimentary origin. They have further classified them as rocks derived from a foreland uplift associated with foreland fold-thrust belts with varied provenance characteristics, depending on the foreland setting.

The lithic grain compositions are the most useful modal tool in differentiating source areas of sandstones from the Nanushuk Group, as shown in Figure 3. Two groups of sandstones with differing relative lithic grain compositions can be distinguished. In the western area, sedimentary lithic fragments (especially carbonate and argillaceous-carbonaceous lithic clasts) constitute a larger percentage of the sandstones, and they are classified as sedimentary litharenites (Folk, 1968), whereas the sandstones from the central outcrop belt have an increased proportion of metamorphic rock fragments and they are classified as phyllarenites (Folk, 1968). Sandstones from the subsurface have compositions intermediate between the two surface suites. Subsurface sandstones of the Torok Formation are composed of a higher proportion of sedimentary lithic grains than the subsurface sandstones from the Nanushuk group.

Extensive carbonate outcrops of the Mississippian and Pennsylvanian and locally Permian Lisburne Group, along with the Silurian and Devonian and possibly Ordovician limestones making up the Baird Group (Tailleur and others, 1973), are probably primary sources for the calcareous clasts of the western province (the Corwin Delta of Ahlbrandt and others, 1979) of sandstones of the Nanushuk Group. Outcrops of these units occur in the Brooks Range to the south, the Tigara Uplift near Cape Lisburne (Payne, 1955), and probably the offshore extension of the uplift, the Herald Arch (Grantz and others, 1976; Mull, 1979). The Endicott Group, consisting of the Upper Devonian Hunt Fork Shale and Kanayut Conglomerate and of the Lower Mississippian Kayak Shale (Brosgé and Tailleur, 1971), has extensive outcrops in the central and eastern Brooks Range in the Endicott Mountains, and may be the source for the metamorphic lithic (phyllite and slate) and quartzose grains which predominate in the centrally located Umiat Delta (Ahlbrandt and others, 1979) of the Nanushuk Group.

Textural analysis

Primary factors thought by Fothergill (1955) and Fuchtbauer (1974) to contribute to the type and amount of interstitial matter in clastic rocks are (1) grain size, (2) thickness of beds, (3) amount of mixing of sediment layers by syndepositional processes such as burrowing by organisms, (4) proximity to shale beds, and (5) composition of framework grains. Secondary processes primarily responsible for the loss of



Suite	Sample location	END MEMBER Lv	Lm	Ls
WESTERN	Barabara syncline	15.7	1.0	83.3
	Carbon Creek	20.9	23.0	56.1
	Corwin Bluff	23.3	15.3	61.4
	Tupikchak Mountain	19.7	10.3	69.9
	Western subsurface N	29.4	21.4	49.2
	Western subsurface T	27.1	17.3	55.6
CENTRAL	Kurupa anticline	31.1	42.0	26.9
	Tuktu Bluff	24.0	53.2	22.8
	Arc Mountain	25.2	44.5	30.3
	Marmot Syncline	28.7	45.6	25.7
	Central subsurface N	27.5	31.3	41.2
	Central subsurface T	20.6	17.2	62.2

Figure 3. Averages of volcanic-metamorphic-sedimentary lithic (Lv-Lm-Ls) modal analyses of sandstones from the Nanushuk Group from eight measured sections and from the Nanushuk Group (N) and Torok Formation (T) in the subsurface. Plots determine compositional differences which constitute the central outcrop belt of phyllarenites having a higher percentage of metamorphic rock fragments, and a western outcrop belt of sedimentary litharenites, composed of increased proportions of sedimentary lithic grains. Samples from the subsurface have compositions intermediate between the two suites. Subsurface sandstones of the Torok Formation are composed of a higher proportion of sedimentary lithic grains than the subsurface sandstones of the Nanushuk Group. (Sandstone classification after Folk, 1968.)

porespaces in these sandstones are (1) weathering and (2) diagenetic alteration. Combinations of these primary and secondary factors are responsible for the reduction in porosity and permeability in sandstones of the Nanushuk Group and Torok Formation. Cement and matrix material are distinguished and tabulated according to the categories defined by Dickinson (1970); the results of the textural observations are shown in figure 11 and Table 4.

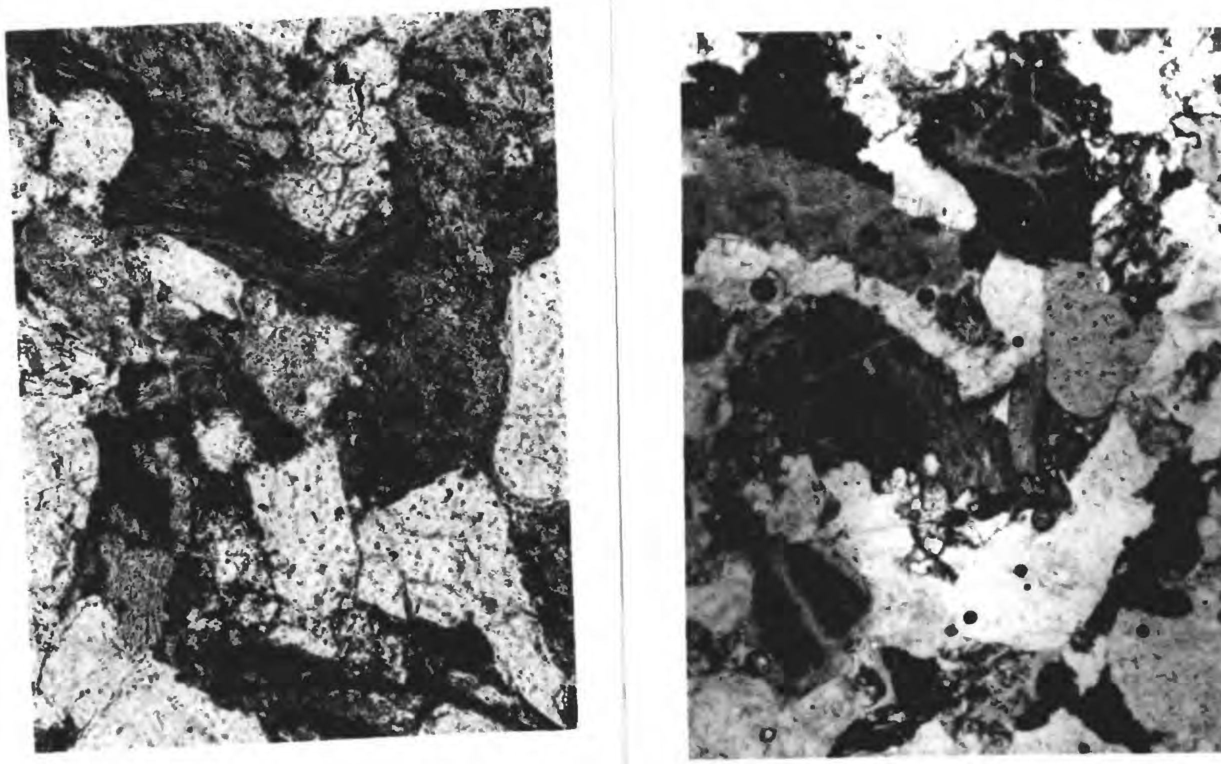
Matrix materials

A pseudomatrix (Dickinson, 1970), which probably results from the destruction of softer clastic grains, is the principle matrix material in the sandstones of the Nanushuk Group and Torok Formation which are not well cemented. Significant quantities of this material, which is composed of unsorted and randomly oriented silt and clay particles of quartz, chlorite, sericite, and much unidentifiable material, are found in the intergranular spaces in many of the sandstones. In many cases, less competent, but still recognizable (lithic?) grains are molded around adjacent grains (usually quartzose grains) which are more competent (fig. 4).

Cementing materials

Authigenic cements and alteration products due to diagenesis and weathering are common constituents in Nanushuk and Torok sandstones. Cementing materials in the samples are calcite, silica, kaolinite, and chlorite, and, rarely, feldspar, sericite, illite-montmorillonite, and chalcedony. X-ray studies of the outcrop samples and samples from the early (pre-1975) wells indicate that montmorillonite is present in only trace amounts (table 2). No zeolite minerals were observed petrographically or detected by x-ray analysis.

The most common and volumetrically most abundant cement is calcite, which constitutes as much as 45 percent and averages almost 8 percent in the thin sections from the Barabara syncline. All stages of cementation and replacement by calcite are observed, from only minor occurrences in some sandstones to pervasive recrystallization in others. Calcite cementation, which is more common in some sandstones in the western outcrop belt, is probably related to weathering and diagenesis of the sandstones. The amount of cementation can vary directly with the detrital calcite-clast content and commonly is observed growing out of these clasts (fig. 5). The calcite clasts, for the most part, were derived from crystalline limestone sources. The clasts, after Nanushuk deposition, became the focus of further calcareous cementation, obliterating original Nanushuk sandstone porosity and permeability. In some samples, ghosts of clastic calcite grains can be detected by relict outlines of clay material (fig. 6). When observed under cathodoluminescent light, the calcite grains luminesce red and orange, and often show internal crystal-growth outlines, whereas the surrounding calcite cement luminesces bright yellow, and is homogeneous, probably indicating an earlier origin for the calcite in the grains. In the most extreme examples, the sparry calcite cement completely replaces other detrital grains in the sandstone as well as the detrital calcite grains, except for a few remaining "floating" and deeply embayed



A B

Figure 4. "Typical tightly appressed sandstones from the Nanushuk Group show evidence of compaction. Less competent micaceous and lithic grains are squeezed and bent around more resistant quartzose grains. Quartz grains show evidence of suturing as a result of silica dissolution under high pressure. (A) sample 77 AAh21, Tuktu Bluff, 63x magnification; (B) sample 78AAh27, Arc Mountain, 25x magnification.

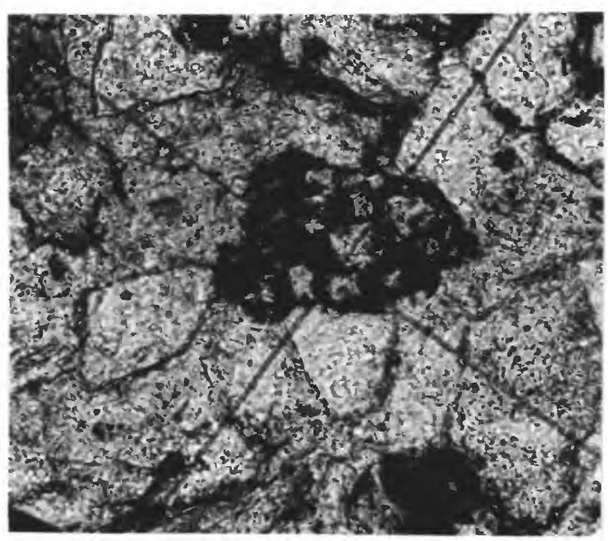


Figure 5. Opaque, brownish, ferruginous(?) coating outlines a reworked calcite grain, which is surrounded by secondary sparry calcite cement. Sample F3675, on the Utukok River, 160x magnification.

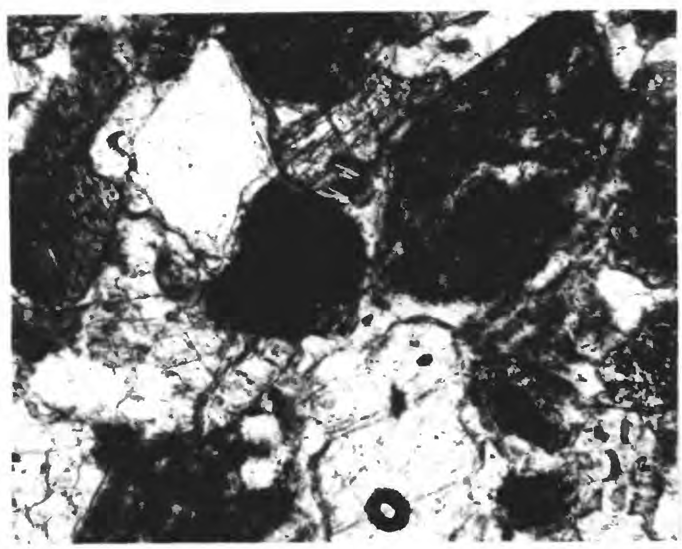


Figure 6. Sparry calcite cement replacement of clastic grains in sandstone leaves a relict "ghost" outline of the original grain (probably a reworked calcite grain). In addition, the cement infills the interstices between grains, eliminating any primary porosity that may have existed, and causing embayment of the remainder of the grains. Sample 78ACh35, Kurupa anticline, 63x magnification.

(partially replaced) quartz grains. Also present in many of the samples are small rhombohedrons of colorless dolomite.

Silica is probably mobilized for cementation by the compaction pressures and temperatures of the sandstones. The silica is thought to be produced from, or as a result of, pressure solution of framework grains (especially quartz), clay mineral alteration during burial, kaolinization of feldspar, dissolution of grains in adjacent shale beds, and replacement of quartz and silicate grains by carbonate (Jonas and McBride, 1977). The higher pressures caused by compaction along resistent quartz-grain surfaces causes silica to dissolve on projecting surfaces which are under higher pressure and to be redeposited as quartz overgrowths; these are observed petrographically as sutured, concave-convex, and long or straight grain boundaries. Silica cementation is widespread in sandstones of the Nanushuk Group, but is more typical of sandstones of the central outcrop belt. Siliceous cement is more readily observable in sandstones with visible porosity and lesser amounts of calcite cement and(or) pseudomatrix. Petrographic observations show a large number of quartz overgrowths which could be misinterpreted as being the result of a second cycle of deposition of the quartzose grains. However, the scanning electron microscope photographs reveal that many, if not all, the overgrowths have grown in place (fig. 7). Where detrital grains do not have clay "dust" rims, or where siliceous cementation is locally abundant, overgrowths and areas with significant siliceous cement may be difficult to distinguish from the angular detrital grains; petrographic techniques using cathodoluminescent light were unsuccessful in reliably determining the extent of quartz overgrowth development. Therefore, the amount of siliceous cementation in these sandstones may have been underestimated in the microscopic modal analyses.

Authigenic clays, such as sericite, chlorite, and kaolinite, are present as alterations of detrital feldspars, and also as secondary pore-filling masses of intergrown crystals (figs. 8, 9, 10). Kaolinite is the most abundant authigenic clay, followed by chlorite and then sericite. The clays were deposited after formation of quartz overgrowths resulting from compaction and dissolution of quartzose grains. Kaolinite commonly fills primary intergranular pores as well as secondary pores created from dissolution of framework grains. These platey minerals, due to their morphology, may give increased values of porosity and permeability in laboratory tests (Sarkisyan, 1971).

Textural observations and conclusions

Measurements were made of the maximum and modal <u>grain size</u> using the petrographic microscope and estimated in the field using the American Stratigraphic Company (Amstrat) grain size chart. <u>Sorting</u> was measured petrographically by referring to sorting images illustrated by Pettijohn, Potter, and Siever (1972, p. 585); field estimations of sorting (using the Amstrat chart) indicate better sorting than the petrographic estimates. <u>Type of grain contacts</u> (Taylor, 1950) include (1) sutured grains, mutual stylolitic interpenetration of two or more grains (which must be carefully distinguished from grains of polycrystalline quartz); (2) concave-convex grain contacts; (3) long or straight contacts; (4)

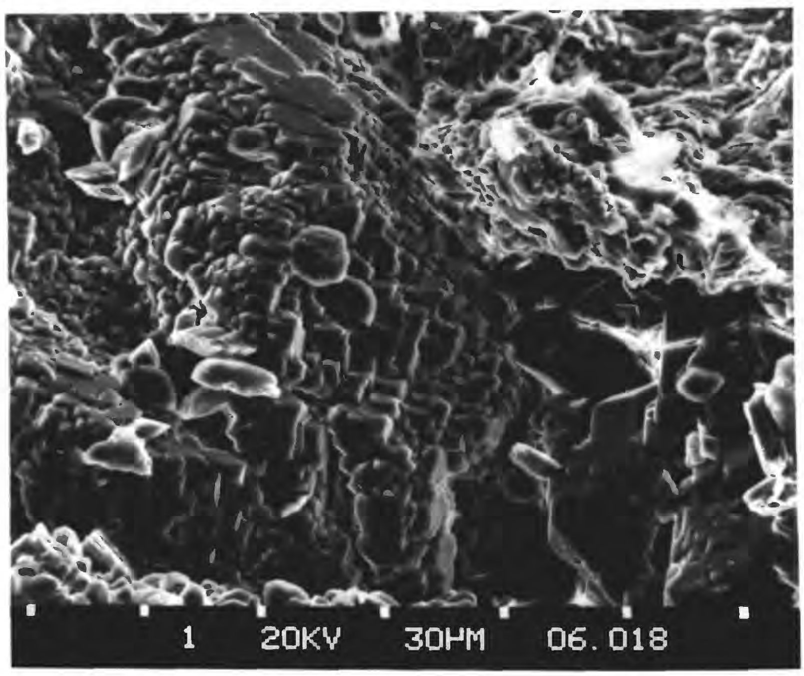


Figure 7. Scanning-electron-microscope photograph showing microcrystalline quartz overgrowth filling the interstices between detrital grains in a sandstone of the Nanushuk Group. Note the lack of kaolinite clay, and the retention of intergranular porosity. Sample 78ACh76, Kurupa anticline section, 1,000x magnification, distance between white ticks on bottom of photograph=30 microns.

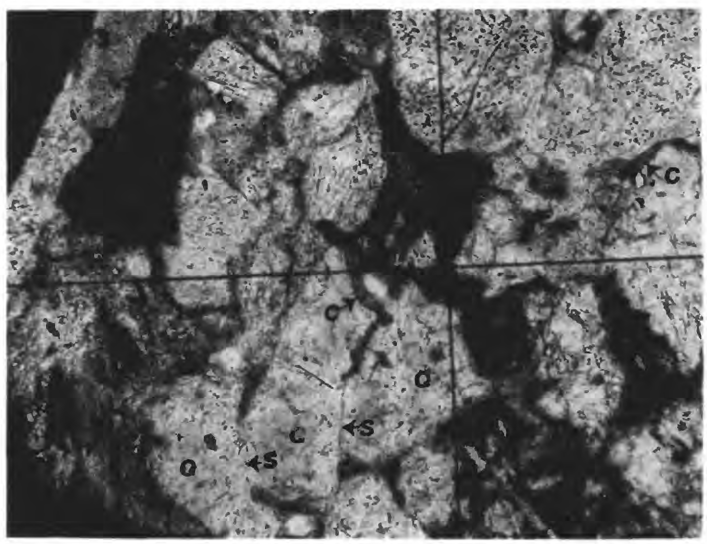


Figure 8. Diagenetic chlorite cement has grown around detrital grains but is notably absent where grains have been previously welded by compaction and dissolution of silica. C=chlorite; Q=quartz; s=sutured area. Sample 77AAh25, Tuktu Bluff, 63x magnification.

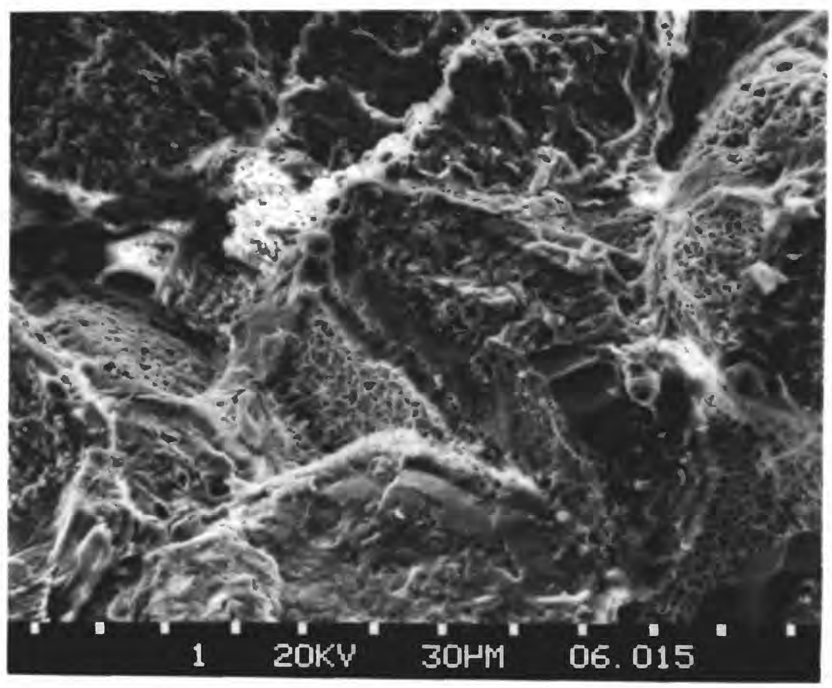


Figure 9. Scanning-electron microscope photograph showing the extensive development of chlorite cement in this sandstone from the Kurupa anticline section. The chlorite bridges intergranular spaces, completely obliterating any pores that may have previously existed. Sample 78ACh32, distance between white ticks on bottom of photograph=30 microns, 330x magnification.

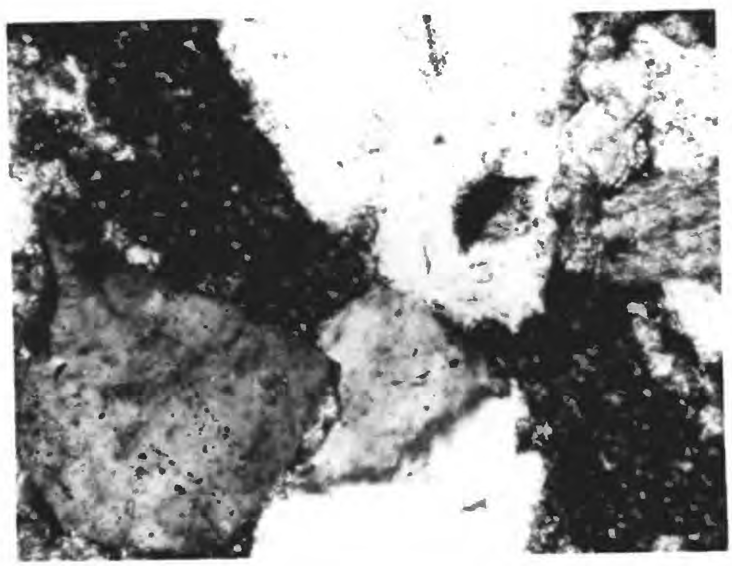


Figure 10. Photomicrograph showing dissolved quartz grains which have been replaced with kaolinite cement. Carbonate is the final alteration mineral in the sandstone. Sample 78ACh76, Kurupa anticline section, 160x magnification.

point or tangential contacts; and (5) floating grains that are not in contact with other framework constituents. Most samples exhibit more than one type of grain contact. Textural components of cement, matrix, pores, and framework grains were determined from the modal analysis of each thin section.

Histograms of these observations (fig. 11) show that the sandstones are typically composed of fine to very fine sand and are moderately to poorly sorted. Samples have grain contacts which reveal a history of compaction, dissolution, and cementation. Sutured, concave, and long grain boundaries typify samples from the Nanushuk; samples from the subsurface, which are finer grained, have higher percentages of grain boundaries which are tangent or floating. Quartz grains are typically strained and cracked (fig. 4), and many feldspar twins are offset or bent. Most mica grains are bent, and many have been altered to chlorite or "exploded" by calcite or silica cement.

Porosity and Reservoir Potential

Surface samples average 1 to 2 percent of visible porosity (measured petrographically), whereas those from the subsurface are more favorable from a reservoir standpoint, averaging 5 percent in the western belt and 6 percent in the central belt. The percentage of framework grains is highest in the outcrop samples (80 percent). The relation of visible (measured petrographically) to measured effective porosities (measured in the laboratory) is shown in table 3 (a large discrepancy exists between visible and effective porosities). This discrepancy may be due to the large amounts of platey or fine-grained matrix materials which provide submicroscopic pores too tiny to detect petrographically, but still of importance from a reservoir standpoint.

The potential value of the Nanushuk Group as a hydrocarbon reservoir from a petrographic standpoint is apparently least favorable in the Corwin Delta (western) outcrop belt, gaining slightly in potential in the Umiat Delta (central) outcrop belt, and most favorable to the north in the subsurface. In the Corwin Delta outcrop belt, average visible porosity totals 1.4 percent, average effective porosity totals 8.4 percent, and air permeability measurements average 14.0 millidarcys (table 3 and figure 11). Petrographically the Corwin Delta sandstones reveal high percentages of matrix and cement when compared to sandstones from the Umiat Delta outcrop belt. The Corwin samples are enriched in sedimentary lithic grains, which are conducive to alteration and pore-plugging during compaction, reducing permeability. Nevertheless, an occasional rare sandstone may have excellent porosity and permeability and reduced amounts of matrix and cement, resulting in a favorable reservoir rock (for example, Barabara syncline, sample 77ACh184). Pores typically are lined with a reddish-brown, probably iron-rich coating. The overall paucity of sand bodies and the lack of continuous stacked beds in the whole western system are negative factors for hydrocarbon potential in the Corwin Delta (Huffman, 1979).

As in the Corwin Delta, the Umiat Delta sandstones are lenticular, with extensive shale interbeds, and many of the sandstones are shaley or muddy. Samples from the central outcrop belt record nearly the same

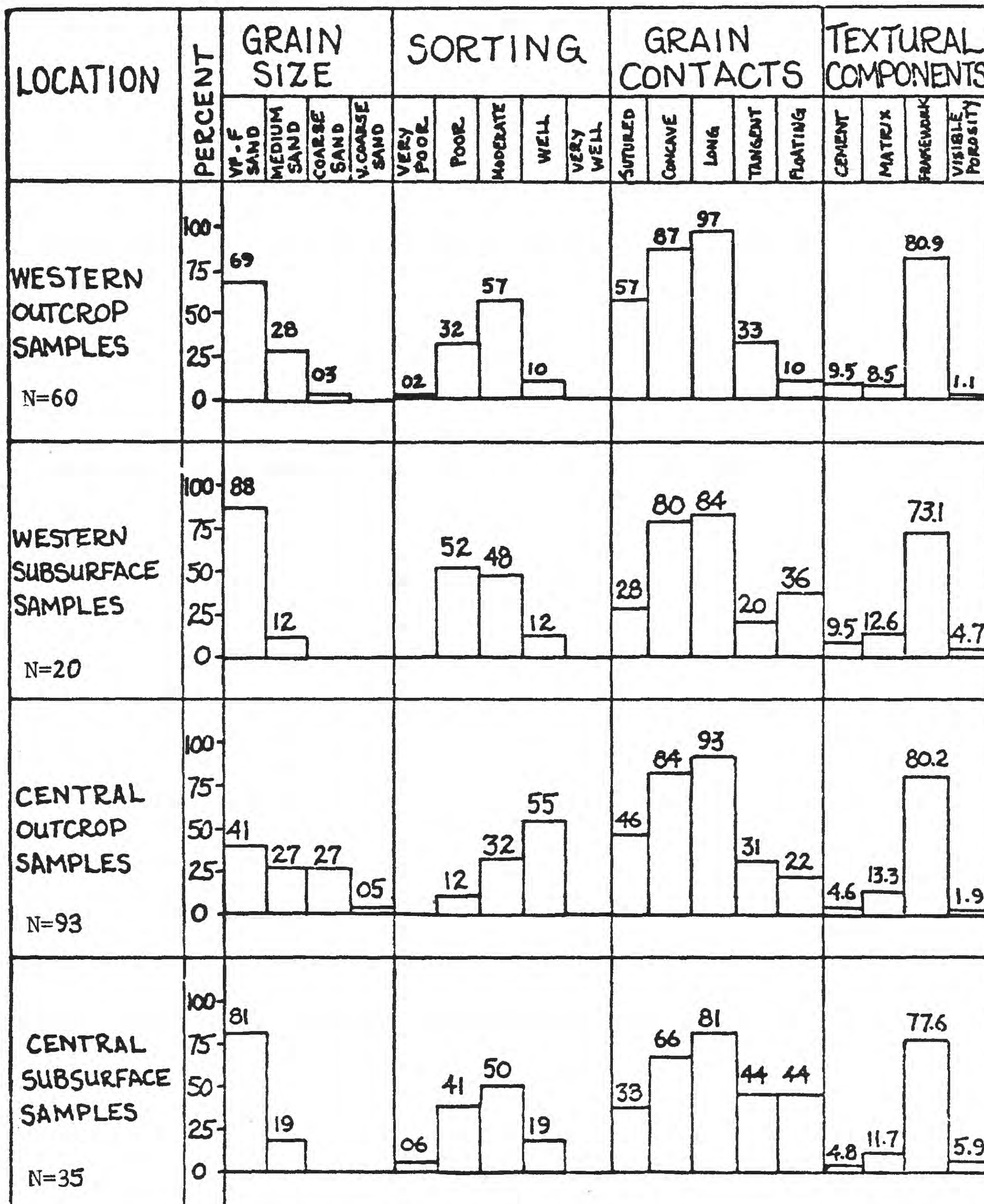


Figure 11. Histograms showing results of petrographic observations of textural properties in sandstones of the Nanushuk Group and Torok Formation. In general, the most favorable characteristics for increased porosity and permeability are shown to the right of each histogram. N=minimum number of samples in population.

values of porosity and permeability as those from the western belt. Visible porosity in the Umiat Delta samples averages 1.6 percent, effective porosity averages 6.6 percent, and air permeability measurements average 12.2 millidarcys (Table 3 and figure 11). However, as was the case in the Corwin Delta, sporadic occurrences of significant porosity and permeability measurements (Tuktu Bluff, sample 77AAh49-L) suggest that isolated sand bodies in the central Umiat Delta may have excellent reservoir potential. The sandstones, in general, are slightly coarser in the central outcrop belt (fig. 11), with slightly lesser amounts of matrix and cementing material and higher percentages of quartzose grains (fig. 2) which resist squeezing and compaction.

Secondary porosity

More encouraging values for effective porosity, air permeability, and visible porosity were recorded and observed in sandstones of the Nanushuk Group and Torok Formation in the subsurface (table 3). These values may be due to the lack of alteration by surface weathering, a function of the mode of transport of the sand during deposition (a higher energy environment of deposition); or an increase in dissolution of framework grains and(or) cement, combined with the lack of later stages of calcite cementation. Grains most often dissolved include the unstable types, such as lithic and feldspar grains, as well as quartzose grains and clays (figs. 12-16). Extensive interbedded shale sequences can provide large quantities of fluids, through compaction and expulsion of water, which are easily transported through the interbedded fine-grained sandstones.

Secondary porosity was recognized in these rocks by using the techniques and criteria described by Scholle (1979, p. 171). Such features as partial dissolution and corrosion of grains and cements, inhomogeneity of packing, oversized porespaces, floating grains, and fractured or cracked grains were observed. Secondary porosity may subsequently be totally or partially destroyed by recementation and(or) infilling of diagenetic clays, especially kaolinite. In at least one sample (suspected in others), kaolinite has been dissolved to create secondary porosity (fig. 13). A sandstone from the Inigok well has developed abundant secondary porosity because some of the potassium feldspars have been dissolved and others have not (fig. 14). In some sandstones, quartz grains have been dissolved (fig. 15). This evidence suggests that secondary porosity in these rocks may have been created in several stages and may have involved complex and diverse dissolving fluids resulting possibly from changing pressure and temperature conditions in the host rocks.

Very small quantities of dark-brown to black, slightly translucent material was often observed and suspected to be oil, though no hydrocarbon tests were employed. Fragments of coal are also present in these rocks; the microscopic distinction between the two organic components is often difficult.

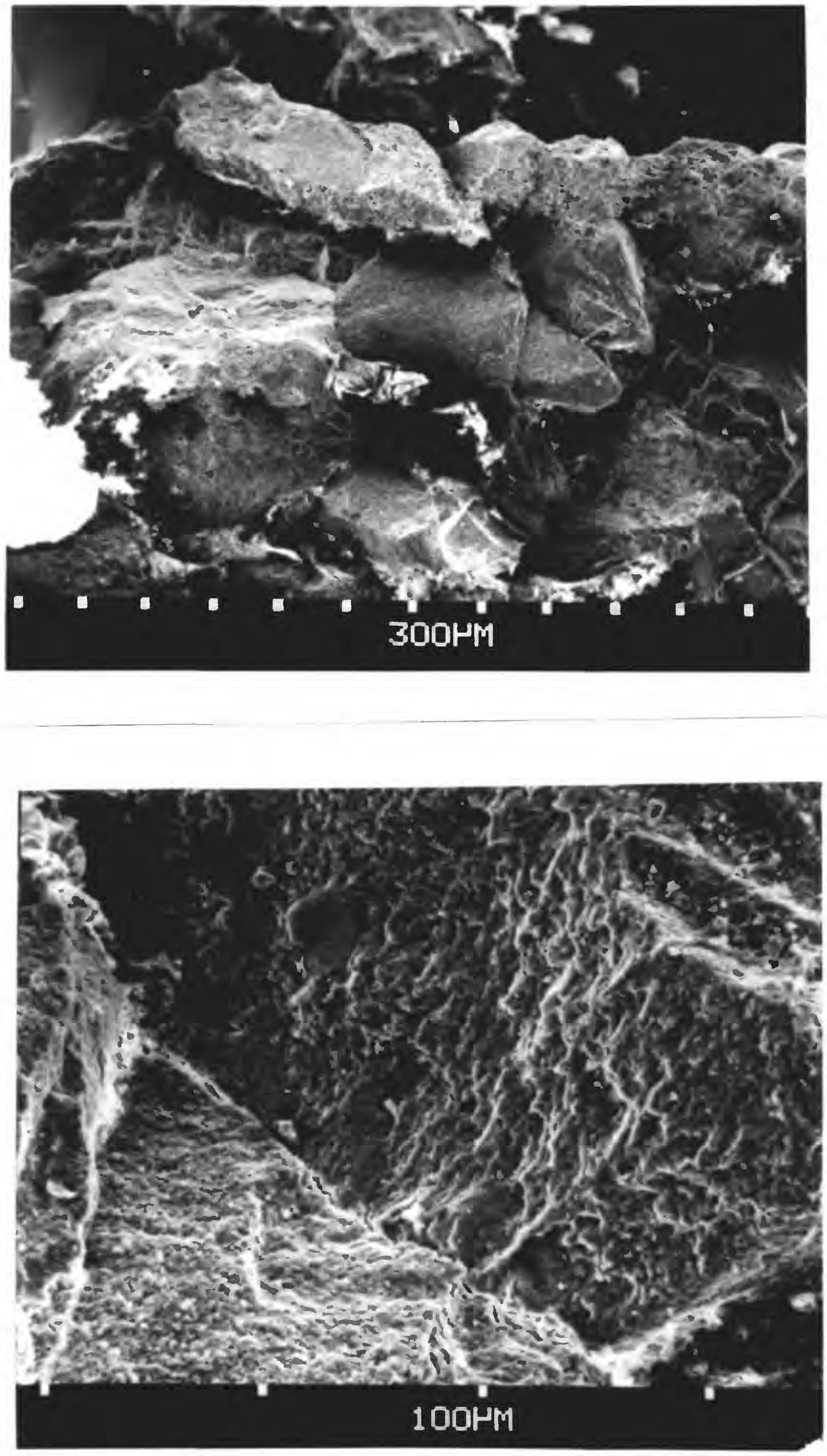


Figure 12. Scanning-electron-microscope photographs showing sandstone sample with good porosity, probably resulting from leaching and corrosion of detrital grains. Note development of quartz overgrowths (lower right corner, view A) and pitted surfaces (view B). Sample 78ACh41, Marmot syncline. (A) 32x magnification; distance between white ticks on bottom of photograph=300 microns; (B) 312x magnification; distance between white ticks on bottom of photograph=100 microns.

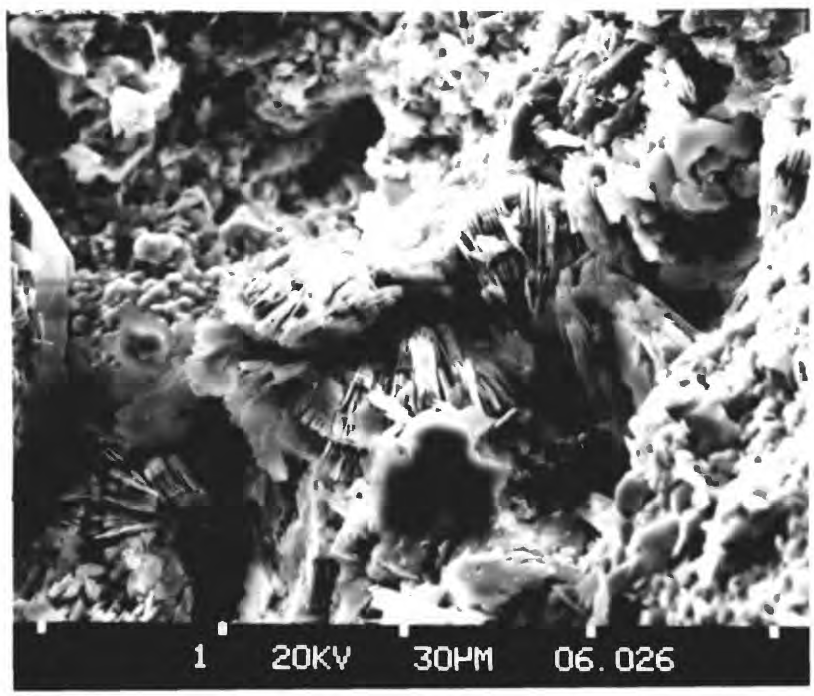


Figure 13. Scanning-electron-microscope photograph of vermicular clays (probably kaolinite) and quartz-overgrowth development (left edge of photograph) in a sandstone from the Torok Formation. This close-up view shows kaolinite(?) crystals that have lost their hexagonal shape and have ragged edges indicating that they may have been etched or dissolved by through-going fluids. Sample from the 1,906 to 1,916-foot depth, South Barrow No. 1 well; 8,900x magnification; distance between white ticks on bottom of photograph=30 microns.

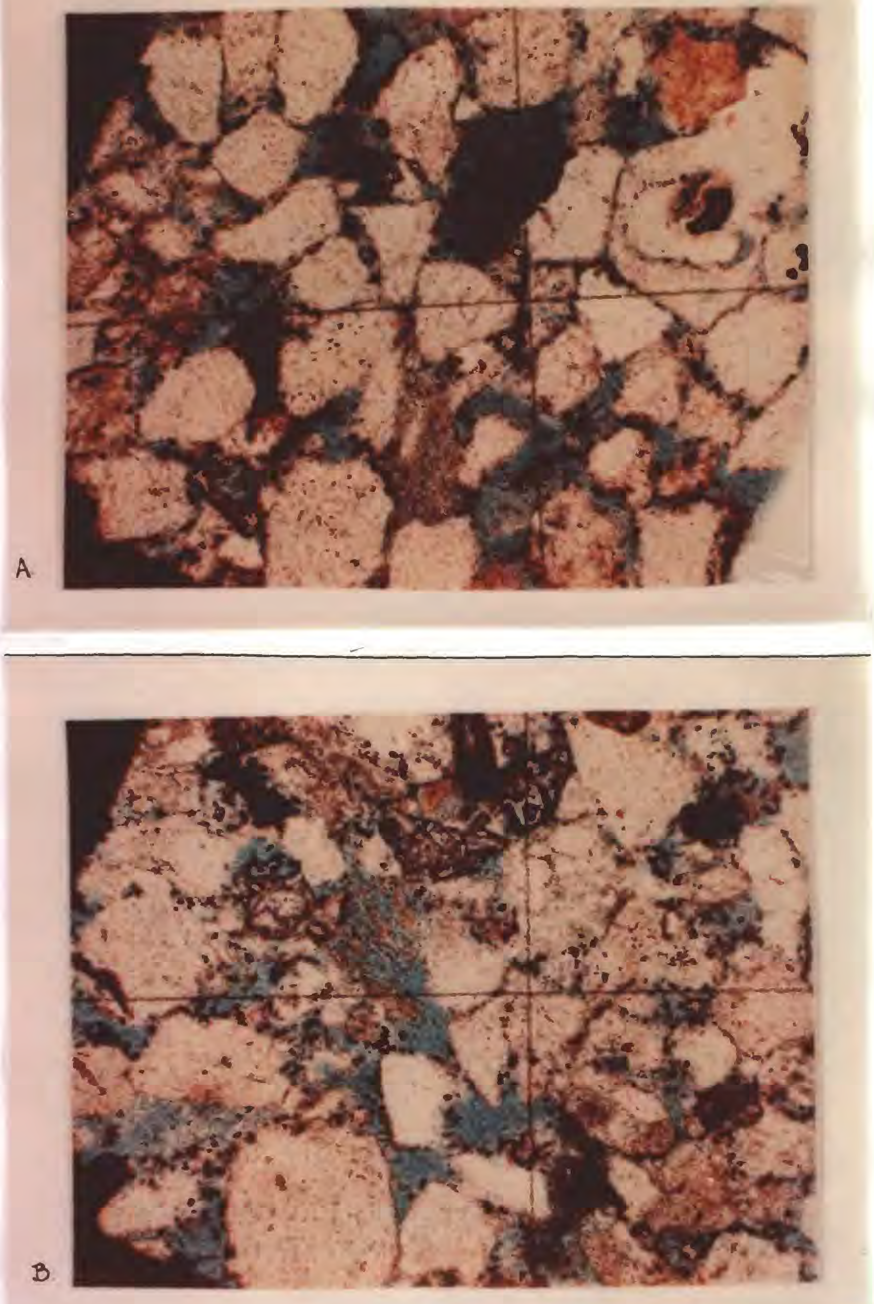


Figure 14. A sandstone sample of the Nanushuk Group from the 2,662-foot depth in the Inigok well. The sample, concentrated with heavy minerals (opaque), has abundant secondary porosity, shown by the blue plastic dye injected into the sandstone before grinding of the thin section. Original grain boundaries are visible as opaque heavy-mineral outlines, but the grains have been dissolved. Remnants of original texture show framework grains having tangential, long, and concave boundaries, indicating that the original sandstone has undergone considerable compaction. In view A, potassium feldspars (yellow) have not been dissolved, but in view B, potassium feldspars are almost completely gone. Only remnants of lithic grains remain in the sandstone.

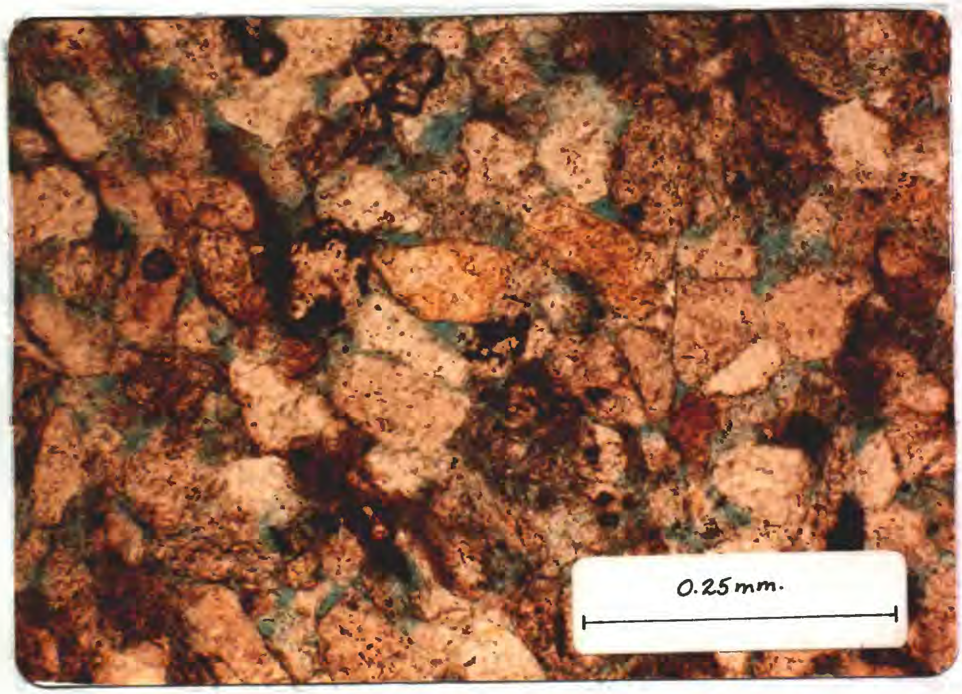


Figure 15. Abundant development of leached grain porosity in a Nanushuk Group sandstone from the 2,406-foot depth in the East Simpson well. Secondary porosity has been created by dissolution of lithic volcanic grains and embayment of monocrystalline quartz grains. Potassium feldspar, plagioclase, and calcite grains remain intact.

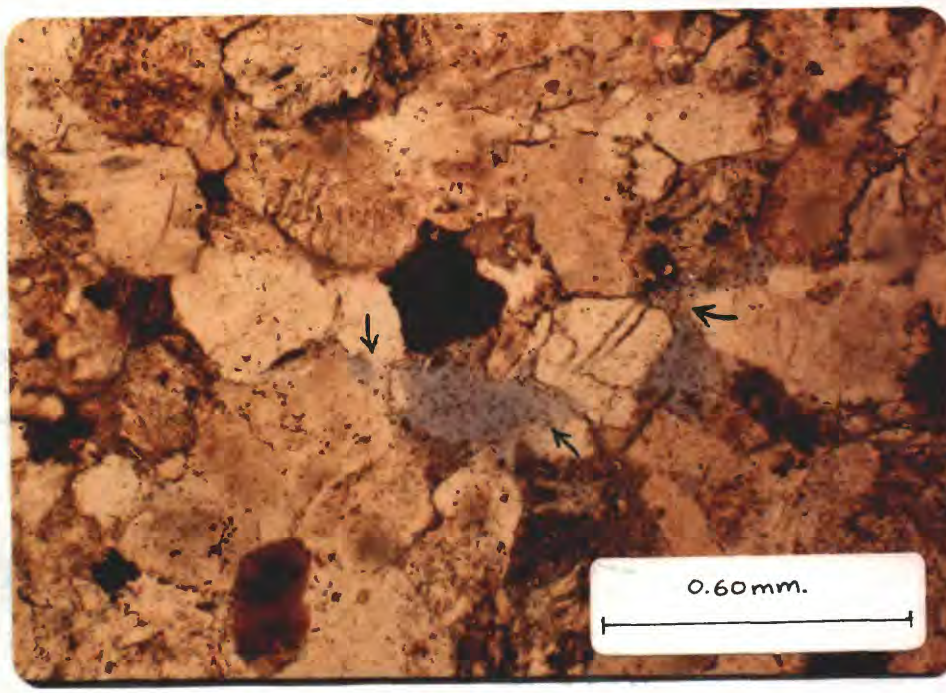


Figure 16. An oversized pore, diagnostic of leached grain porosity, in a sandstone from the Nanushuk Group located on the Colville River north of Siksikpuk Ridge. Note dissolution of grains adjacent to the pore (arrows). Sample F2075.

Summary

Matrix and cementing materials found in the interstices between detrital grains in most of the sandstones of the Nanushuk Group reduce their reservoir potential. The most promising sandstones in the Nanushuk Group are those in the northern and eastern subsurface sections, since it is in samples from these sections that preliminary tests of porosity and permeability show the highest values. Much of the porosity may be secondary, and thus may improve the reservoir potential of these sandstones. At least three factors may be responsible for the northeastward increase in porosity and permeability: (1) Complex and diverse fluids capable of distributing dissolving agents may, at least in part, be derived by compaction and fluid expulsion from interbedded and down-dip shale beds, which are more abundant to the north. (2) The detrital calcite grains which came from the Brooks Range to the south and west and which are the source for much of the calcite cement, may decrease in numbers northeastward. (3) The style of Nanushuk deposition changes from low- to moderate-energy deltaic environments in the south and west to higher energy barrier-coast-line environments in the subsurface to the north, resulting in a probable increase in the lateral extent and sorting coefficient of the sandstone bodies.

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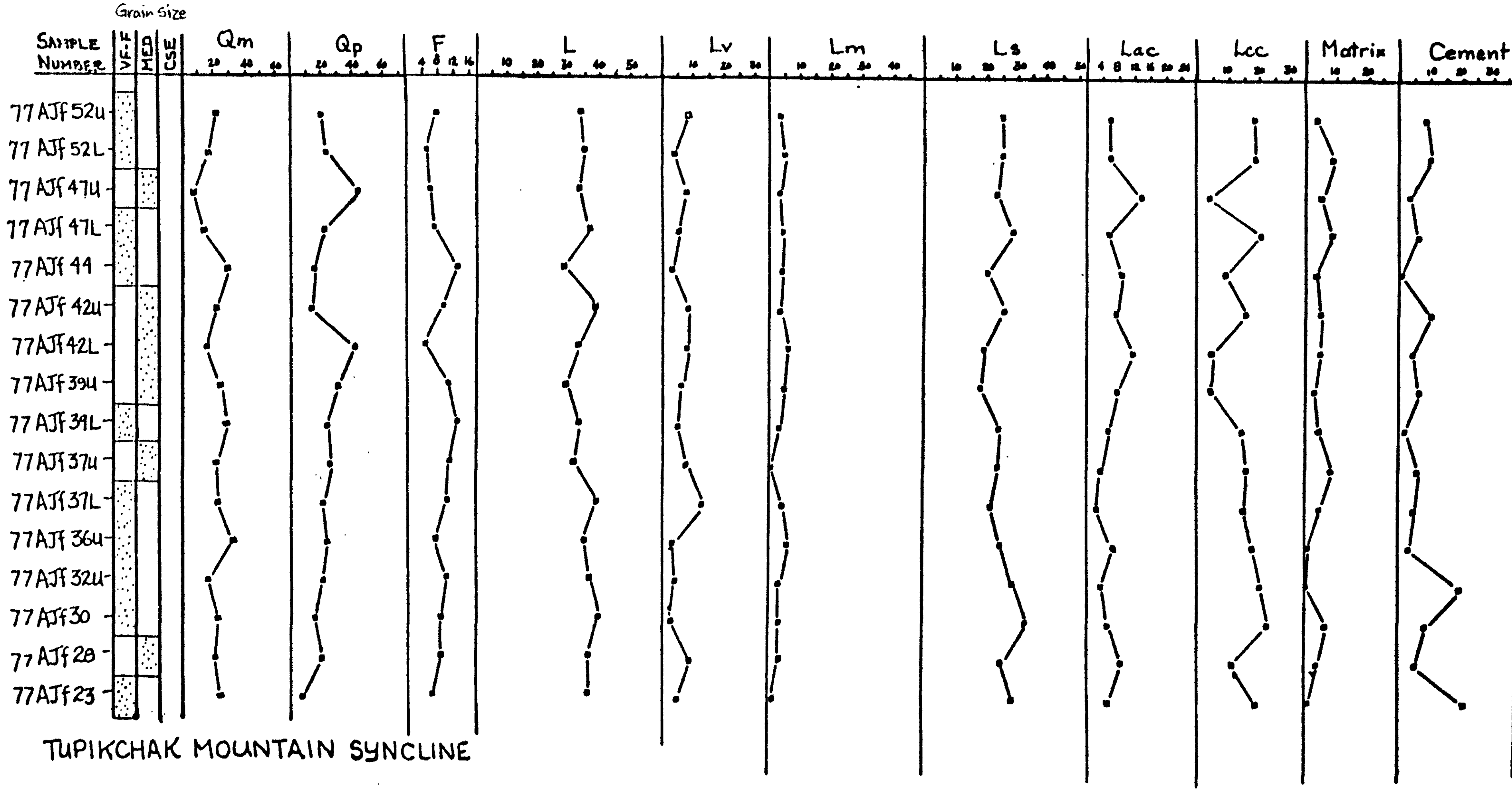
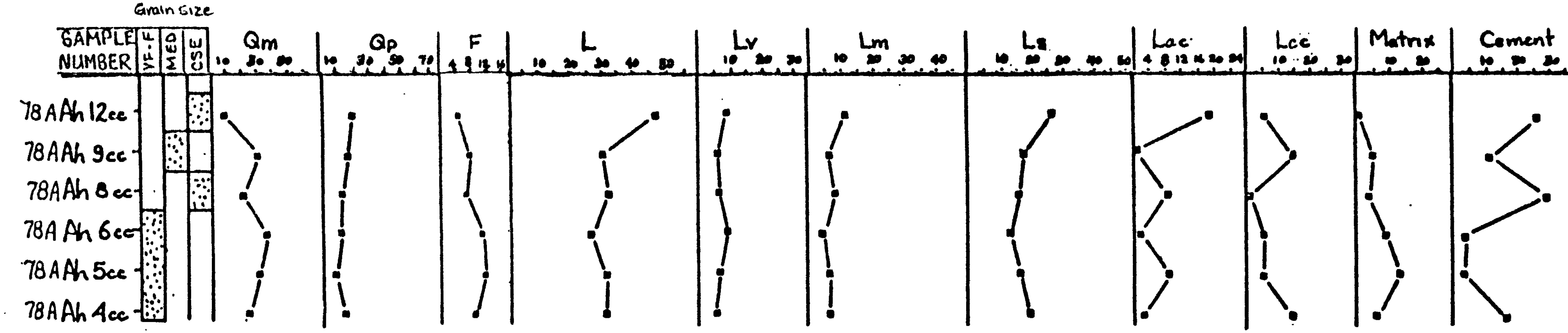
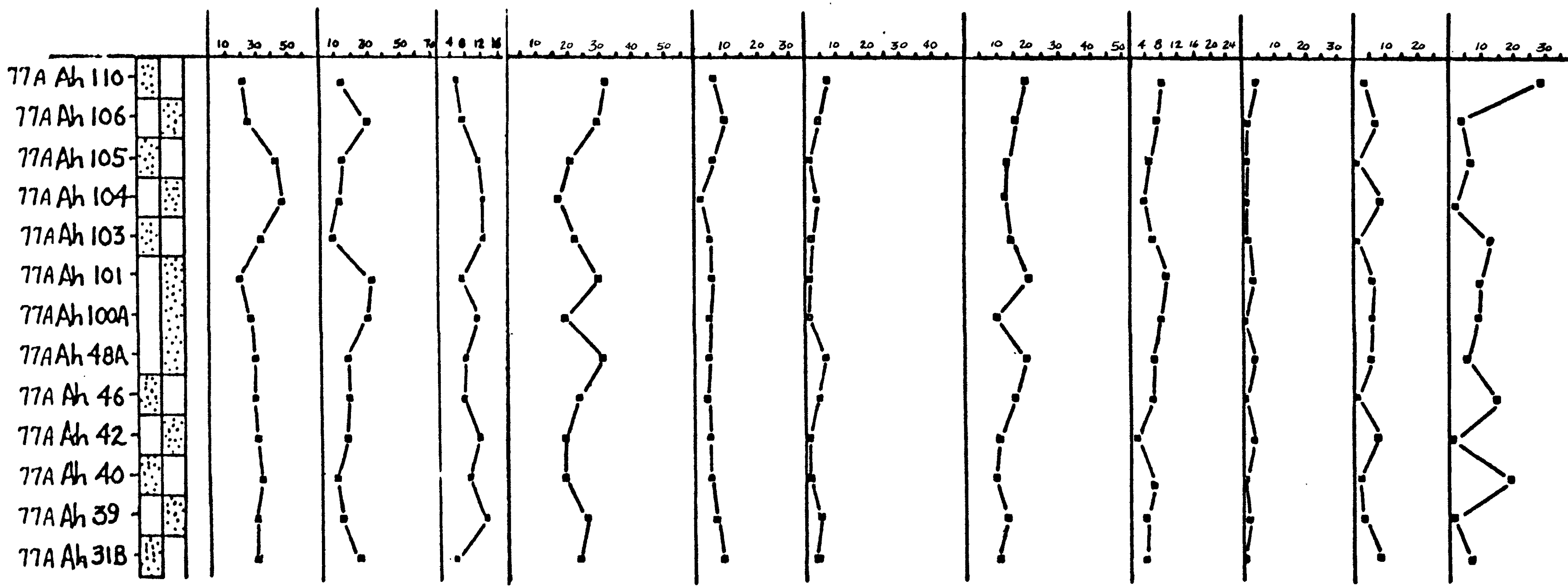


Table 1. Vertical variation in percentage compositions of sandstones from eight measured sections and subsurface samples. Location of sections and wells shown in figure 1. (Qm, monocrystalline quartz; Qp, polycrystalline quartz; L, total lithic grains; Lv, volcanic lithic grains; Lm, metamorphic lithic grains; Ls, sedimentary lithic grains; Ac, argillaceous and carbonaceous grains; Cc, calcareous grains).

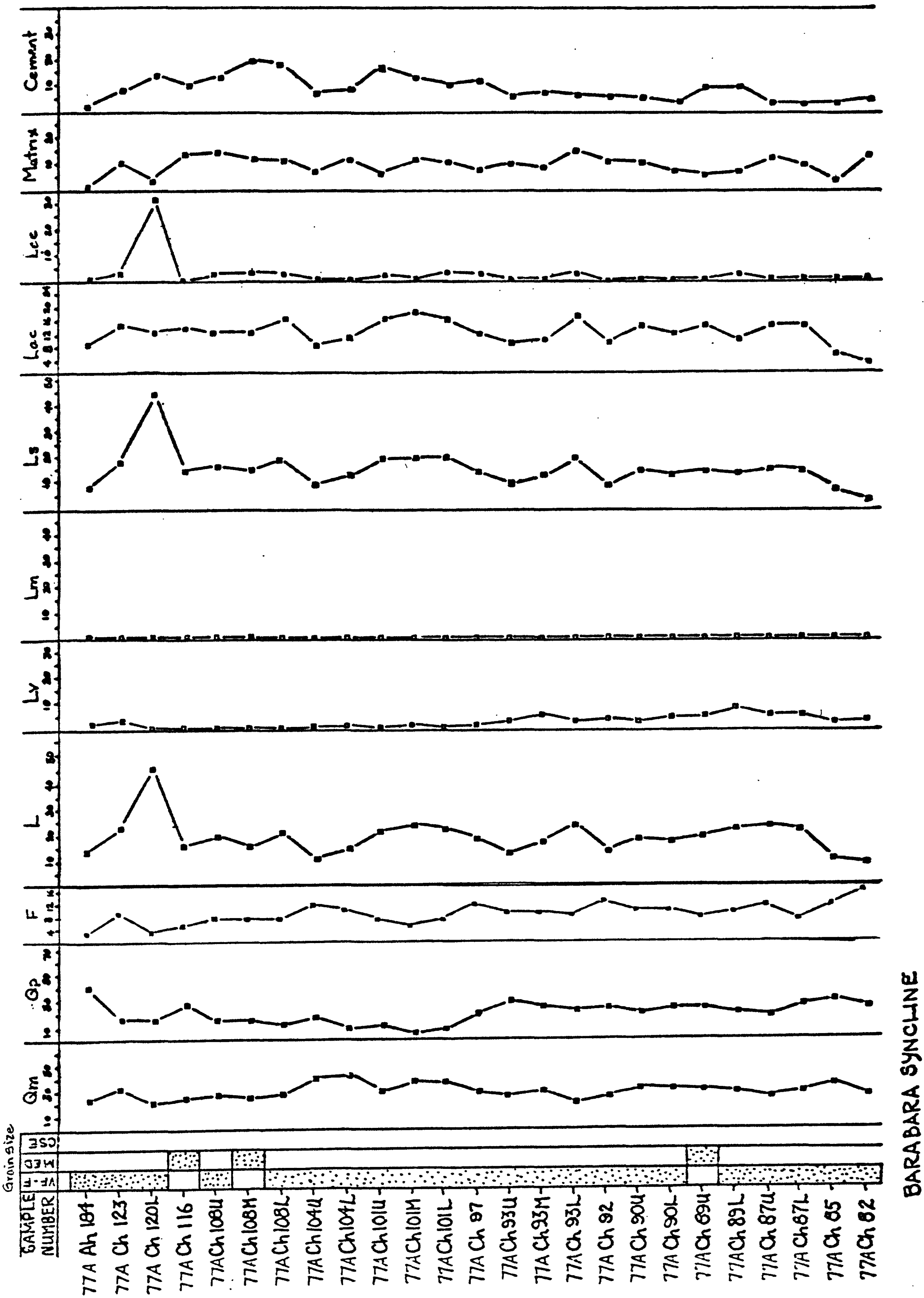


CARBON CREEK ANTICLINE



CORWIN BLUFF

Table 1 (continued)



Cement
Matrix
Lcc
Lac
Ls
Lm
Lv
L
F
Qp
Qm
Grain size
SAMPLE NUMBER
77A Ah 184
77A Ch 123
77A Ch 120L
77A Ch 116
77ACh108U
77ACh108M
77ACh108L
77ACh104U
77ACh104L
77ACh101U
77ACh101M
77ACh101L
77A Ch 97
77ACh93U
77ACh93M
77ACh93L
77A Ch 92
77A Ch 90U
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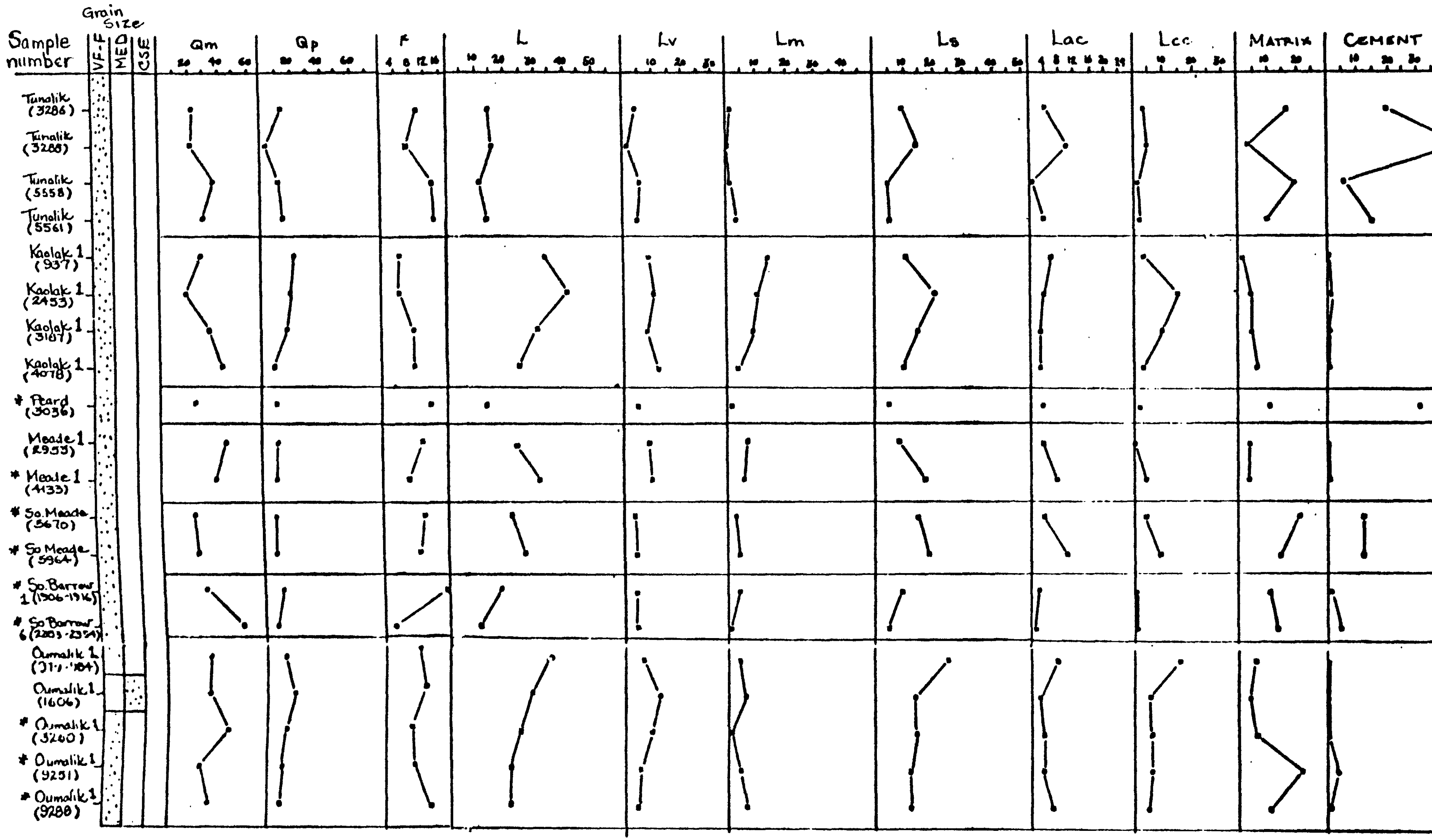
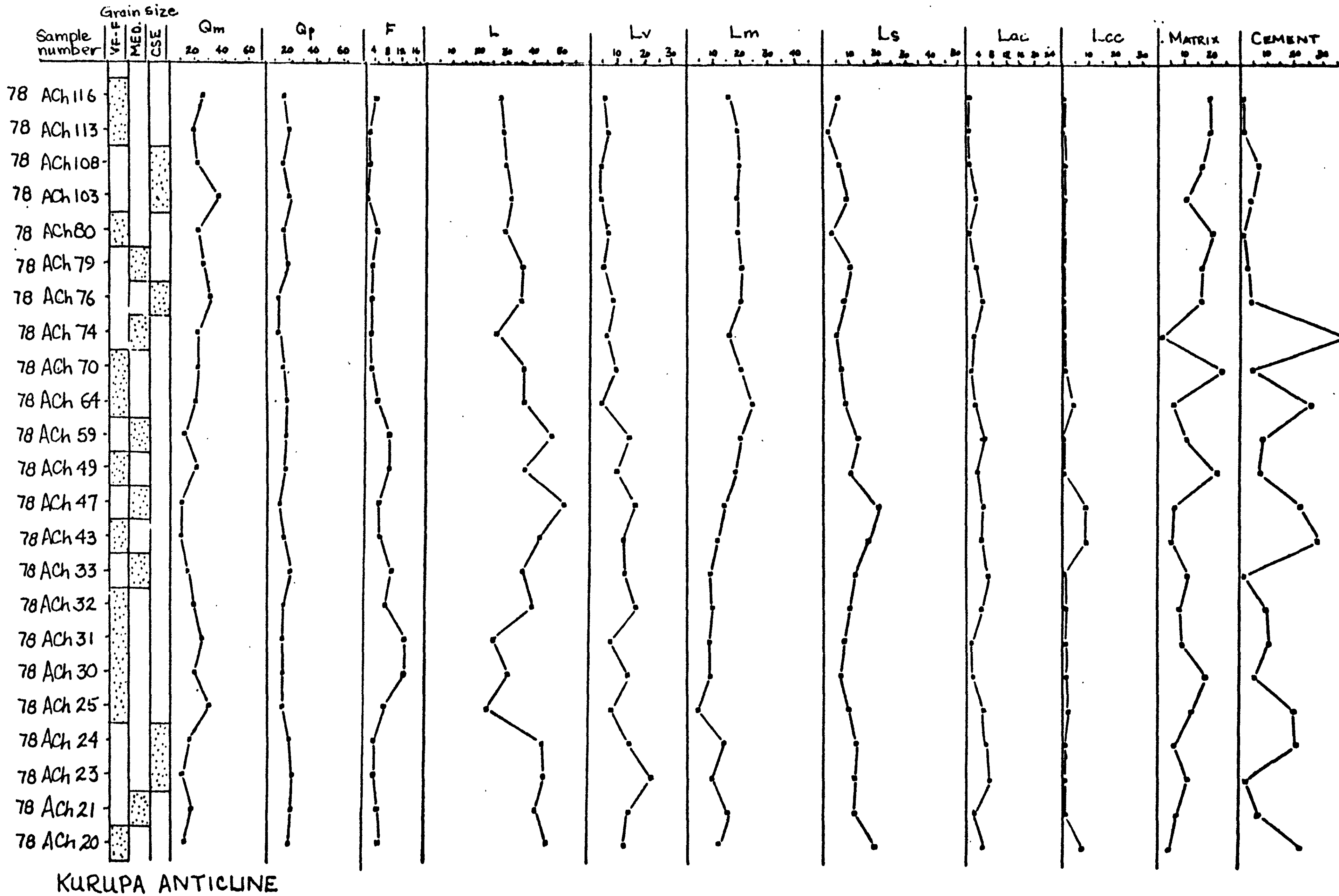
77ACh 82
BARABARA SYNCLINE



WESTERN SUBSURFACE

* Samples from Torok Formation

Table 1. (continued)



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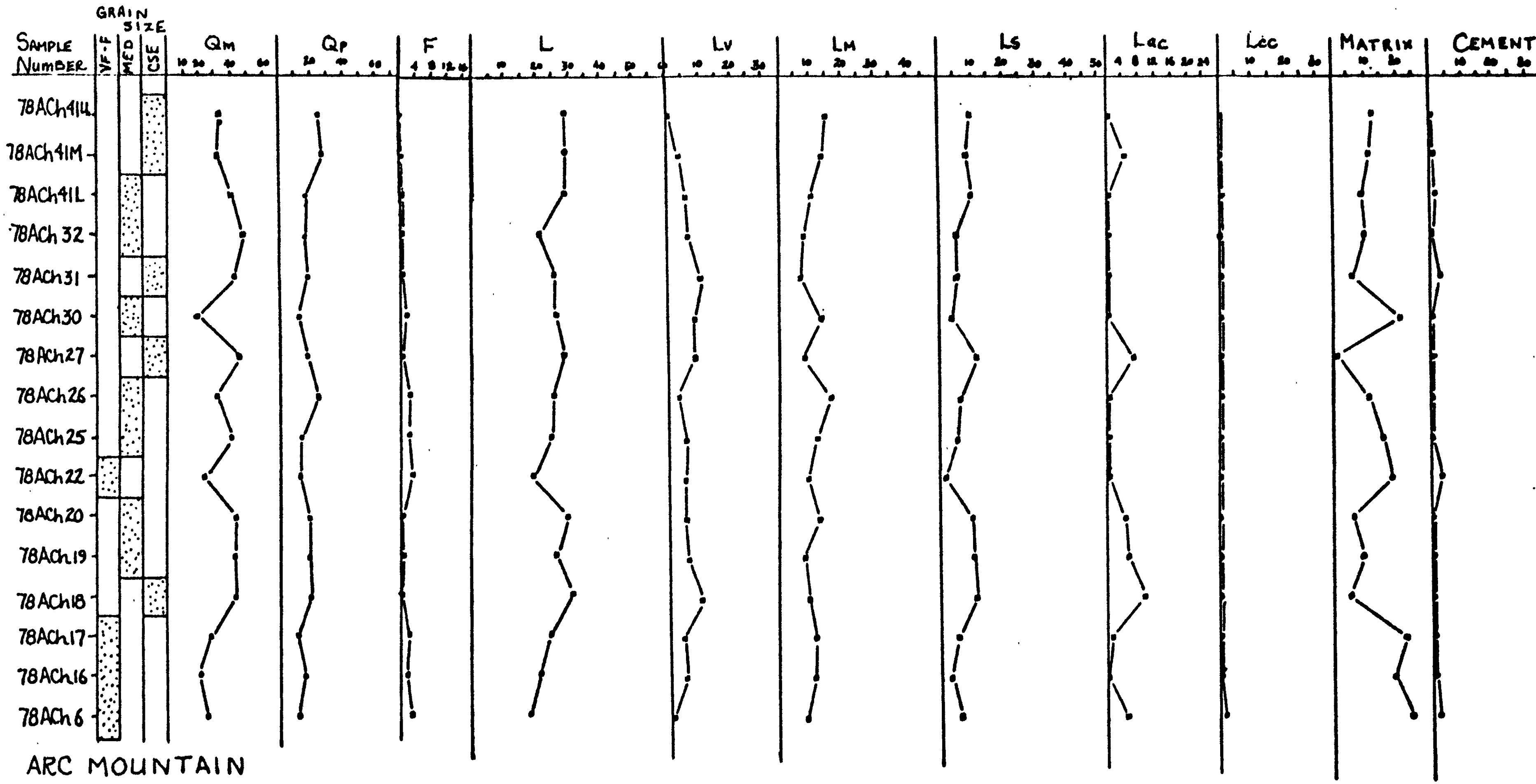

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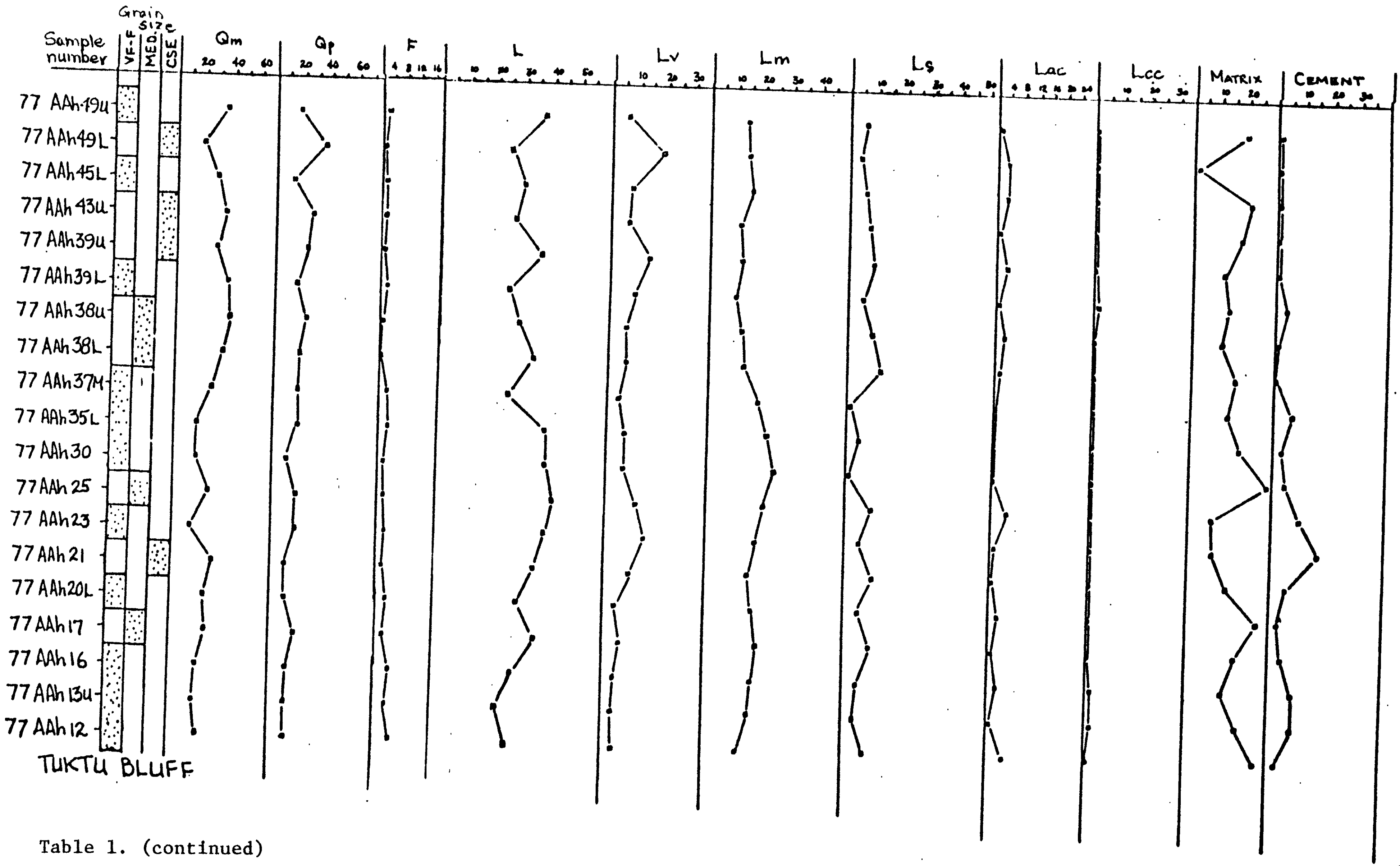

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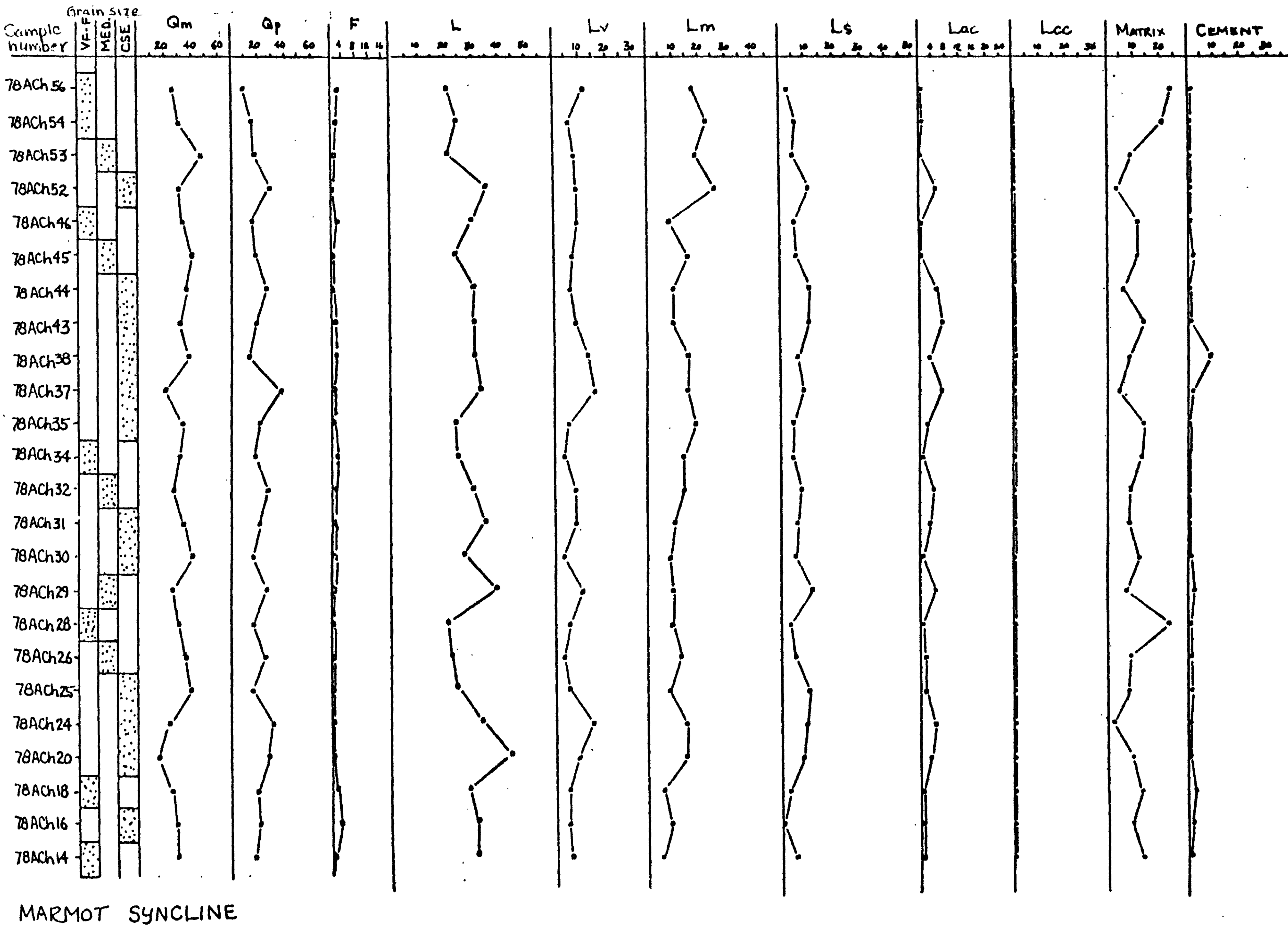

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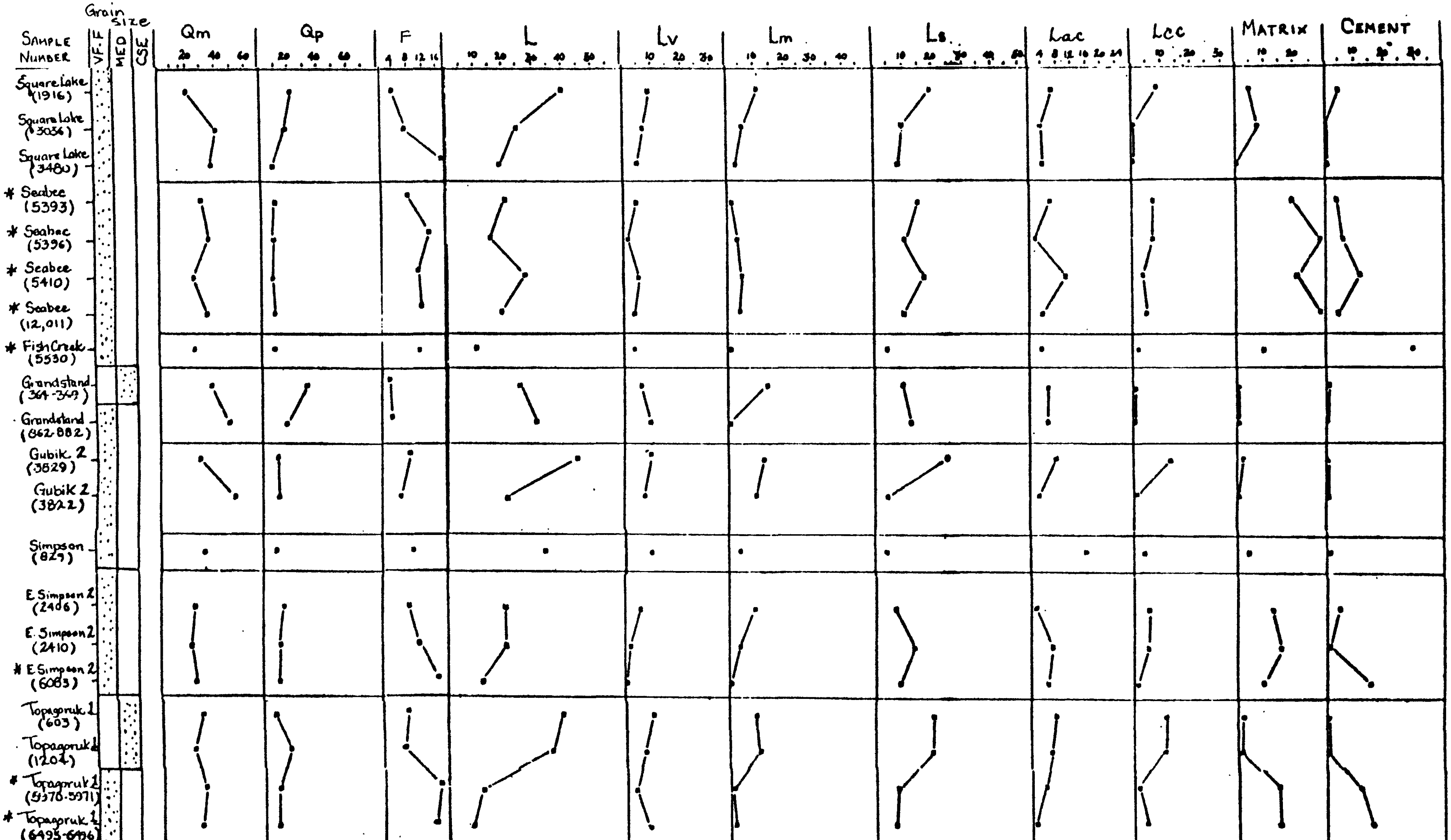
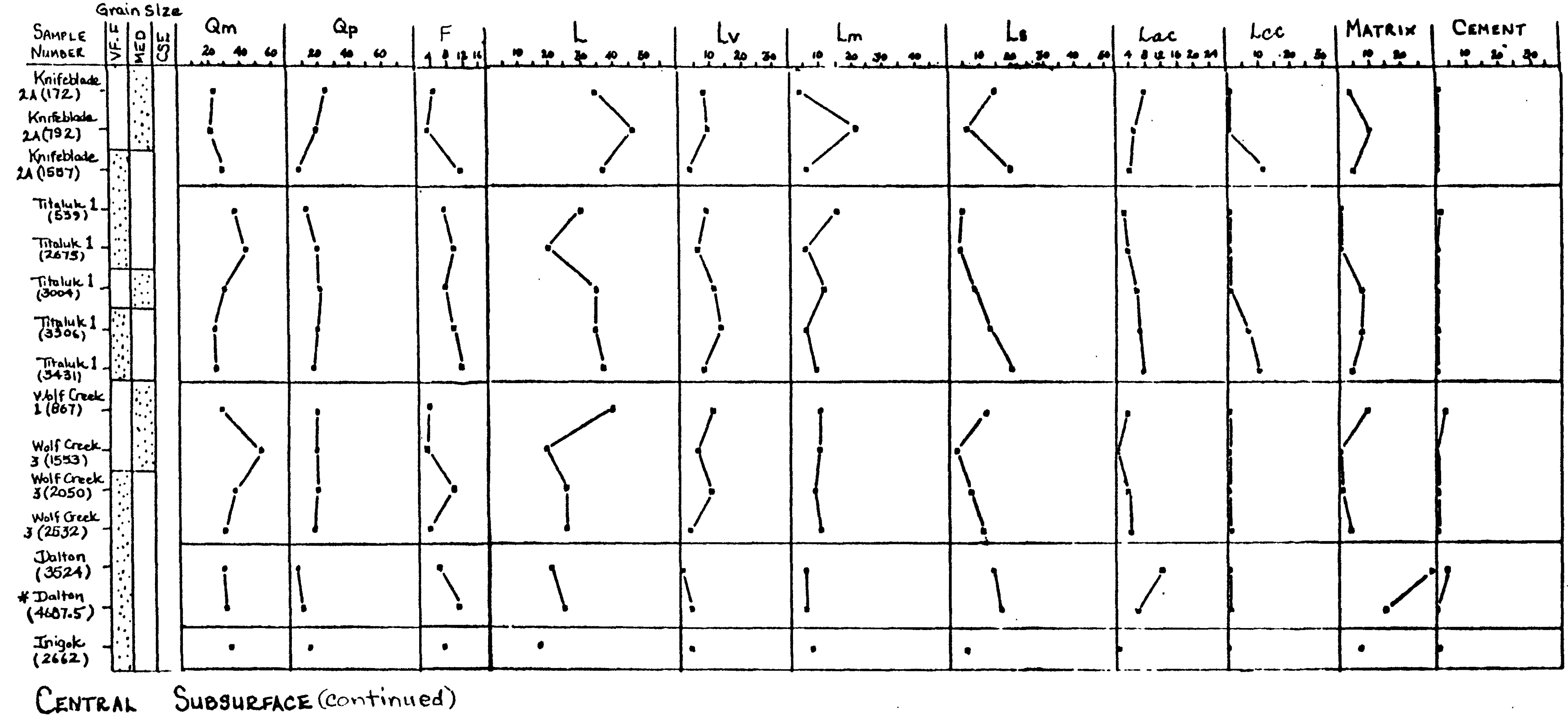


CENTRAL SUBSURFACE

* Samples from Torok Formation

Table 1. (continued)



* Samples from Torok Formation

Table 1. (continued)

TABLE 2.--Clay-mineral analyses by X-ray diffraction of the clay-fraction separates of samples from scattered outcrops and the subsurface. [Oriented mounts were made to aid in identification of the clay minerals; glycolation, potassium-acetate intersalation, and various heating techniques were incorporated. Estimated amounts of the minerals present in each sample were determined from the x-ray diffraction traces and are listed below as parts in ten; trace = less than 5%; less than 1 = 5-9 percent; (+) or (-) indicates that the actual amount is slightly higher or lower than the value reported. Leaders (--) indicate none present. Paul D. Blackmon and Harry C. Starkey, analysts]

Sample No.	Clay types								
	Illite	Illite-mica or mica	Illite montmorillonite, mixed	Montmorillonite	Chlorite-montmorillonite, mixed	Chlorite	Mica-Chlorite, mixed	Kaolinite	Serpentine
Surface									
1075	---	4	---	---	---	5	---	---	---
1175	---	4+	---	---	---	4+	---	---	---
1275	---	3+	---	---	---	2+	---	2+	---
1475	---	5	---	---	---	1	---	1	---
1575	---	5	---	---	---	2	---	1+	---
1875	---	3+	---	Trace	---	2+	---	2+	---
2075	---	2+	---	1	---	2+	---	2+	---
2175	---	3+	---	1-	---	2+	---	1+	---
2675	---	1+	---	---	---	1+	---	---	4+
3075	---	3+	---	---	2	2+	---	---	---
3275	---	2	---	---	---	2	---	---	3+
3375	---	1+	---	Trace	---	1+	1	1-	---
3675	---	1+	---	1-	---	1-	---	1+	---
3875	---	1+	---	Trace	---	1	---	---	3+
4275	---	1+	---	---	---	1-	---	5	---
4375	---	2	1	---	---	Trace	---	4+	---
4575	---	2+	---	---	---	1-	---	3+	---
4875	---	1	1-	---	---	Trace	---	5+	---
5175	---	1+	Trace	---	---	Trace	---	4	---
5375	---	1+	1+	---	---	Trace	---	3+	---
5475	---	1-	1-	---	---	Trace	---	5+	---
Subsurface									
Kaolak 1-937	-1	---	---	Trace	---	Trace	---	Trace	---
Kaolak 1-2453	1+	---	---	---	---	Trace	---	-1	---
Kaolak 1-3187	1	---	Trace	---	---	Trace	---	-1	---
Kaolak 1-4078	-1	---	Trace	---	---	Trace	---	1	---
Kaolak 1-6739	-1	---	Trace	---	---	Trace	---	Trace	---
Topagoruk 1-304p	-1	---	Trace	---	---	Trace	---	Trace	---
Topagoruk 1-603p	-1	---	Trace	---	---	Trace	---	Trace	---
Topagoruk 1-1204p	1	---	---	---	---	Trace	---	Trace	---
Topagoruk 1-1790p	---	-1	Trace	---	---	Trace	---	Trace	---
Topagoruk 1-5972	---	-1	---	---	---	Trace	---	Trace	---
Topagoruk 1-6498	1+	---	Trace	---	---	Trace	---	---	---
Simpson 454	---	1	Trace	---	---	-1	---	Trace	---
Simpson 829	---	1	Trace	---	---	-1	---	Trace	---
Simpson 979	---	1	---	---	---	-1	---	Trace	---
Meade 1-2953	-1	---	Trace	---	---	Trace	---	Trace	---
Meade 1-4133	-1	---	Trace	---	---	Trace	---	-1	---
Oumalik 1-979p	-1	---	---	---	---	Trace	---	Trace	---
Oumalik 1-1606p	-1	---	---	---	---	Trace	---	-1	---
Oumalik 1-3260p	-1	---	Trace	---	---	Trace	---	Trace	---
Oumalik 1-3752p	1	---	---	Trace	---	Trace	---	Trace	---
Titaluk 1-539p	---	1+	---	---	---	-1	---	-1	---
Titaluk 1-2675p	Trace	---	---	---	---	Trace	---	Trace	---
Titaluk 1-3004p	-1	---	---	---	---	Trace	---	-1	---
Titaluk 1-3306	-1	---	---	---	---	Trace	---	Trace	---
Titaluk 1-3431p	Trace	---	---	---	---	-1	---	---	---
Wolf Creek 1-867	---	1	---	---	---	Trace	---	-1	---
Wolf Creek 3-1553	Trace	---	---	---	---	Trace	---	Trace	---
Wolf Creek 3-2050	-1	---	---	---	---	Trace	---	Trace	---
Wolf Creek 3-2532	---	1+	---	---	---	1	---	---	---
Wolf Creek 3-3109	1	---	Trace	---	---	-1	---	Trace	---
Wolf Creek 3-3509	1	---	---	---	---	-1	---	---	---
Grandstand 364-69	---	-1	---	---	---	Trace	---	Trace	---
Grandstand 862-82	---	-1	---	---	---	Trace	---	Trace	---
Grandstand 2484	---	1	---	---	---	Trace	---	---	---
Knifeblade 2A-172p	Trace	---	---	---	---	Trace	---	-1	---
Knifeblade 2A-792p	-1	---	---	---	1	-1	---	---	---
Knifeblade 2A-1557n	-1	---	---	---	---	-1	---	---	---
Square Lake 1685	1+	---	---	Trace	---	Trace	---	Trace	---
Square Lake 1854	1	---	Trace	---	---	Trace	---	Trace	---
Square Lake 1916	1	---	---	---	---	Trace	---	Trace	---
Square Lake 3036	-1	---	---	---	---	Trace	---	Trace	---
Square Lake 3480	-1	---	---	---	---	Trace	---	Trace	---
Square Lake 3856	-1	---	---	---	---	Trace	---	Trace	---
Gubik 2-3112	---	1+	Trace	---	---	-1	---	---	---
Gubik 2-3529	1+	---	Trace	---	---	-1	---	---	---
Gubik 2-3645	1	---	Trace	---	---	Trace	---	Trace	---
Gubik 2-3822	-1	---	---	---	---	Trace	---	Trace	---
Gubik 2-4243	1+	---	---	---	---	Trace	---	Trace	---

Table 3. Modal grain size, percent visible porosity, effective porosity, and air permeability measurements of many of the sandstones of the Nanushuk Group and Torok Formation included in the petrographic study (continued). [n, number of samples; ---, no testing done; *, sample from Torok Formation. Averages take into account only those samples tested.]

Sample Number	Modal grain size (est.)	Visible porosity (%)	Effective porosity (Ø)	Air permeability (md)
Barabara syncline n=25				
77ACh82	.25	2.0	12.6	1.45
77ACh85	.20	0.6	11.7	1.65
77ACh87-1	.25	0.6	11.4	1.31
77ACh87-u	.15	1.0	11.0	0.27
77ACh89-1	.25	0.0	7.2	---
77ACh89-u	.30	0.3	9.5	0.61
77ACh90-1	.25	1.3	11.2	1.48
77ACh90-u	.25	0.6	11.7	1.25
77ACh92	.25	2.3	11.3	1.25
77ACh93-1	.15	0.0	10.3	1.47
77ACh93-m	.20	0.0	10.7	0.68
77ACh93-u	.15	0.0	10.5	0.47
77ACh97	.20	0.3	8.7	0.30
77ACh101-1	.20	2.0	12.0	1.13
77ACh101-m	.25	1.3	10.4	1.04
77ACh101-u	.25	0.0	6.4	---
77ACh104-1	.18	1.3	14.6	2.75
77ACh104-u	.18	1.3	13.6	1.74
77ACh108-1	.20	0.0	8.9	0.38
77ACh108-m	.30	0.0	8.1	0.19
77ACh108-u	.20	1.0	12.0	0.99
77ACh116	.30	0.0	8.2	33.37
77ACh120-1	.23	0.7	12.8	1.51
77ACh123	.15	0.6	9.6	1.40
77ACh184	.25	14.6	29.5	1,278.80
Range	.15-.30	0.0-14.6	7.2-29.5	0.190-1,278.8
Average	.22	1.27	11.4	53.42

Table 3. (continued) Modal grain size, percent visible porosity, effective porosity, and air permeability measurements of many of the sandstones of the Nanushuk Group and Torok Formation included in the petrographic study. [n, number of samples; ---, no testing done; *, sample from Torok Formation. Averages take into account only those samples tested.]

Sample Number	Modal grain size (est.)	Visible porosity (%)	Effective porosity (Ø)	Air permeability (md)
Tupikchak Mountain syncline n=16				
77AJF23	.15	0.3	7.3	---
77AJF28	.30	0.0	8.6	1.17
77AJF30	.18	0.3	8.0	0.16
77AJF32-u	.23	0.0	4.1	---
77AJF36-u	.23	0.0	4.6	---
77AJF37-1	.25	0.0	6.2	---
77AJF37-u	.30	0.0	7.3	---
77AJF39-1	.25	0.7	6.8	---
77AJF39-u	.30	0.7	5.6	---
77AJF42-1	.34	1.3	4.2	---
77AJF42-u	.30	0.0	6.1	---
77AJF44	.18	0.3	6.6	---
77AJF47-1	.18	0.0	5.2	---
77AJF47-u	.45	1.0	5.3	---
77AJF52-u	.25	0.0	6.4	---
77AJF52-1	.25	0.0	5.5	---
Range	.15-.45	0.0-1.3	4.1-8.6	0.0-1.17
Average	.26	.29	6.1	.67
Carbon Creek n=6				
77AAh4cc	.15	0.0	7.6	0.12
78AAh5cc	.23	4.3	12.6	0.43
78AAh6cc	.23	8.0	14.5	1.20
78AAh8cc	.50	0.0	4.5	0.15
78AAh9cc	.30	6.0	13.6	2.20
78AAh12cc	.60	0.0	4.3	0.07
Range	.15-.60	0.0-8.0	4.3-14.5	0.07-2.20
Average	.34	3.1	9.5	0.70
Corwin Bluff n=13				
77AAh31b	.23	3.7	8.3	0.45
77AAh39	.30	1.3	10.3	0.35
77AAh40	.23	0.0	---	---
77AAh42	.46	0.3	7.2	---
77AAh46	.18	0.0	1.4	---
77AAh48a	.30	0.0	4.8	---
77AAh100a	.30	3.3	10.1	3.9
77AAh101	.30	0.0	3.3	---
77AAh103	.23	0.0	3.9	---
77AAh104	.25	0.7	8.8	1.44
77AAh105	.18	1.0	5.4	---
77AAh106	.30	1.7	9.2	0.84
77AAh110	.18	0.3	3.4	---
Range	.18-.46	0.0-3.7	1.4-10.3	0.35-3.9
Average	.26	0.9	6.3	1.40

Table 3. (continued) Modal grain size, percent visible porosity, effective porosity, and air permeability measurements of many of the sandstones of the Nanushuk Group and Torok Formation included in the petrographic study (continued). [n, number of samples; ---, no testing done; *, sample from Torok Formation. Averages take into account only those samples tested.]

Sample Number	Modal grain size (est.)	Visible porosity (%)	Effective porosity (Ø)	Air permeability (md)
Kurupa anticline n=23				
78ACh20	.23	0.0	6.0	34.0
78ACh21	.30	3.3	11.7	0.26
78ACh23	.60	6.3	11.2	7.2
78ACh24	.50	2.0	6.8	39.0
78ACh25	.18	0.0	---	---
78ACh30	.18	3.3	11.1	0.21
78ACh31	.23	10.0	---	---
78ACh32	.23	6.7	11.7	1.1
78ACh33	.30	6.0	13.8	2.4
78ACh43	.23	0.0	---	---
78ACh47	.30	0.0	---	---
78ACh49	.18	0.0	9.4	0.33
78ACh59	.40	3.0	---	---
78ACh64	.23	0.3	5.1	0.05
78ACh70	.23	1.3	15.2	4.7
78ACh74	.30	0.0	4.9	0.47
78ACh76	.60	5.7	17.7	62.0
78ACh79	.30	0.7	9.8	0.97
78ACh80	.23	0.3	7.3	0.18
78ACh103	.50	0.3	6.6	0.15
78ACh108	.60	0.0	6.6	0.12
78ACh113	.23	0.0	---	---
78ACh116	.23	0.0	5.5	0.13
Range	.18-.60	0.0-10.0	4.9-17.7	.05-62.0
Average	.32	2.14	9.4	6.66

Table 3. (continued) Modal grain size, percent visible porosity, effective porosity, and air permeability measurements of many of the sandstones of the Nanushuk Group and Torok Formation included in the petrographic study (continued). [n, number of samples; ---, no testing done; *, sample from Torok Formation. Averages take into account only those samples tested.]

Sample Number	Modal grain size (est.)	Visible porosity (%)	Effective porosity (Ø)	Air permeability (md)
Tuktu Bluff n=19				
77AAh12	.18	0.0	6.5	---
77AAh13-u	.15	0.0	7.5	---
77AAh16	.23	0.3	7.8	---
77AAh17	.30	0.0	6.1	---
77AAh20-1	.18	0.0	5.3	---
77AAh21	.60	0.7	5.5	---
77AAh23	.23	3.7	---	---
77AAh25	.30	1.7	11.0	0.79
77AAh30	.18	0.0	3.8	---
77AAh35-1	.15	0.3	4.8	113.0(hairline fracture)
77AAh37-m	.23	0.6	6.2	0.25
77AAh38-1	.45	1.7	4.2	0.15
77AAh38-u	.40	3.8	7.7	0.41
77AAh39-1	.15	0.3	3.4	0.07
77AAh39-u	.70	1.6	7.9	6.2
77AAh43-u	.60	1.3	6.9	0.26
77AAh45-1	.23	0.7	8.1	0.33
77AAh49-u	.18	0.0	14.6	320.0
77AAh49-1	.55	16.0	11.2	6.6
Range	.15-.70	0.0-16.0	3.4-14.6	0.07-320.0
Average	.32	1.7	7.1	40.7
Arc Mountain syncline n=16				
78AAh6	.15	0.0	4.2	0.06
78AAh16	.20	0.0	3.4	0.06
78AAh17	.18	0.0	5.2	0.59
78AAh18	1.20	2.3	5.7	1.0
78AAh19	.40	1.3	6.6	0.28
78AAh20	.40	1.3	7.1	0.38
78AAh22	.15	0.3	---	---
78AAh25	.25	0.3	5.2	0.22
78AAh26	.30	0.0	4.3	0.12
78AAh27	.60	5.3	8.4	3.90
78AAh30	.30	0.0	---	---
78AAh31	.60	3.0	5.1	0.17
78AAh32	.30	4.0	7.4	0.31
78AAh41-1	.40	1.7	2.7	0.12
78AAh41-m	.60	2.7	6.0	0.26
78AAh41-u	.60	0.0	3.7	0.07
Range	.15-1.20	0.0-5.3	2.7-8.4	0.06-3.90
Average	0.42	1.4	5.4	0.54

Table 3. (continued) Modal grain size, percent visible porosity, effective porosity, and air permeability measurements of many of the sandstones of the Nanushuk Group and Torok Formation included in the petrographic study (continued). [n, number of samples; ---, no testing done; *, sample from Torok Formation. Averages take into account only those samples tested.]

Sample Number	Modal grain size (est.)	Visible porosity (%)	Effective porosity (Ø)	Air permeability (md)
Marmot syncline n=24				
78ACh14	.23	0.0	3.1	0.31
78ACh16	.77	3.3	3.8	0.10
78ACh18	.13	0.3	4.7	0.08
78ACh20	.60	0.3	2.5	0.11
78ACh24	1.20	8.3	2.3	0.06
78ACh25	.60	0.7	5.0	0.17
78ACh26	.48	1.7	3.7	0.12
78ACh28	.23	3.0	4.1	0.06
78ACh29	.40	0.7	---	---
78ACh30	.60	0.0	3.2	0.13
78ACh31	1.20	2.0	4.4	0.10
78ACh32	.30	0.0	---	---
78ACh34	.12	1.0	3.1	0.05
78ACh35	.60	0.3	2.9	0.08
78ACh37	.60	2.7	5.5	0.19
78ACh38	.65	1.3	7.6	13.0
78ACh43	.60	0.0	4.8	0.15
78ACh44	.60	0.0	5.0	0.65
78ACh45	.40	0.3	6.5	0.20
78ACh46	.20	1.0	4.7	0.25
78ACh52	1.20	3.0	6.9	0.56
78ACh53	.38	1.3	5.6	0.10
78ACh54	.23	0.0	3.4	0.06
78ACh56	.20	0.0	5.5	0.17
Range	.12-1.20	0.0-8.3	2.3-7.6	0.05-13.0
Average	0.52	1.3	4.5	0.80

Table 3. (continued) Modal grain size, percent visible porosity, effective porosity, and air permeability measurements of many of the sandstones of the Nanushuk Group and Torok Formation included in the petrographic study (continued). [n, number of samples; ---, no testing done; *, sample from Torok Formation. Averages take into account only those samples tested.]

Sample Number	Modal grain size (est.)	Visible porosity (%)	Effective porosity (Ø)	Air permeability (md)
Subsurface Samples n=31				
Western: n=9				
Kaolak 1(937)	.23	6.3	11.55	imperm.
Kaolak 1(2453	.23	2.0	11.90	imperm.
Kaolak 1(3187)	.18	1.0	10.04	imperm.
Kaolak 1(4078)	.15	5.3	11.28	imperm.
Meade 1(2953)	.23	7.7	19.2	13.48
*Meade 1(4133)	.23	3.7	9.35	imperm.
Oumalik 1(979-984)	.23	3.3	15.2	34.0
Oumalik 1(1606)	.26	1.7	10.9	8.8
*Oumalik 1(3260)	.18	2.0	9.2	less than 4
Range	.15-.26	1.0-7.7	9.2-19.2	
Average	.21	3.7	12.1	
Central: n=22				
Knifeblade 2A(172)	.30	9.3	16.0	41.0
Knifeblade 2A(792)	.40	3.3	14.2	1.3
Knifeblade 2A(552)	.15	4.7	11.6	less than 1
Titaluk 1(539)	.15	4.7	12.0	imperm.
Titaluk 1(2675	.15	7.3	12.5	17.0
Titaluk 1(3004)	.27	1.7	8.3	imperm.
Titaluk 1(3306)	.23	2.7	9.0	imperm.
Titaluk 1(3431)	.17	1.7	10.5	imperm.
Wolf Creek 1(867)	.30	0.0	5.3	imperm.
Wolf Creek 3(1553)	.30	10.3	18.9	305.0
Wolf Creek 3(2050)	.17	2.0	10.6	less than 1
Wolf Creek 3(2532)	.20	0.0	4.7	imperm.
Sq. Lake (1916)	.17	5.3	17.5	----
Sq. Lake (3036)	.23	6.3	13.3	17.6
Sq. Lake (3480)	.14	8.7	12.7	imperm.
Grandstand (364-69)	.46	2.3	10.6	----
Grandstand (862-82)	.17	2.3	11.2	less than 1
Gubik 2(3529)	.17	3.7	13.5	2.3
Gubik 2(3822)	.18	8.0	14.1	22.0
Simpson (829)	.13	12.3	28.8	----
Topagoruk 1(603)	.15	13.0	27.2	316.2
Topagoruk 1(1204)	.23	11.4	26.0	200.4
Range	.13-.46	0.0-13.0	4.7-28.8	
Average	.22	5.5	14.0	

TABLE 4. Tabulated modal compositions and textural data from petrographic examination of sandstones from the Nanushuk Group and Torok Formation. Locations of scattered outcrop samples, measured sections, and wells are shown in figure 1. [n=number of samples; * indicates sandstones from the Torok Formation; --- not analyzed; Q, monocrystalline and polycrystalline quartz, quartzite, and chert; Qm, monocrystalline quartz; F, feldspar; L, lithic grains; Lv, volcanic lithic grains; Lm, metamorphic lithic grains, Ls, sedimentary lithic grains; Lac, argillaceous and carbonaceous grains; Lcc, calcareous grains; W=well sorted, M=moderately sorted, P=poorly sorted; VP=very poorly sorted; grain contacts: S=sutured, C=concavo-convex, L=long, straight, P=point, tangent, F=floating.]

Textural Data

Suite	Sample Number	Maximum grain size (mm)	Modal grain size (mm)	Sorting	Grain contact type	Percent Matrix	Percent Cement
Scattered	1075	.15	.07	VP	L, P, F	37.0	1.7
outcrop	1175	.45	.20	VP	L, P, F	25.9	6.7
samples	1275	.45	.20	P	C, L	21.6	6.6
	1475	.70	.30	M	L, P	3.7	0.9
n=21	1575	.70	.40	P	L, P	10.8	13.8
	1875	.17	.11	W	C, L	18.1	1.7
	2075	.77	.38	M	----	13.3	5.9
	2175	.56	.18	W	C, L	9.1	2.6
	2675	.45	.12	P	C, L, P, F	13.8	15.3
	3075	.12	.18	VP	F	23.7	16.6
	3275	.35	.18	P	S, C, L	15.0	15.3
	3375	.76	.46	M	S, C, L	8.3	20.8
	3675	.36	.18	P	C, L	15.3	16.5
	3875	.38	.18	P	S, C, L	6.4	23.2
	4275	.39	.23	M	P, F	26.0	25.7
	4375	.92	.38	P	C, L	13.0	12.3
	4575	.18	.15	P	F	3.6	57.4
	4875	.46	.24	M	C, L	27.3	5.2
	5175	.45	.30	W	F	5.3	40.7
	5375	.38	.16	VP	C, L, F	10.4	32.0
	5475	.90	.58	M	C, L, P	11.7	8.8
Range		.12-.92	.07-.58	VP-W	----	3.6-37.0	0.9-57.4
Average		.48	.25	M-P	----	15.2	15.7
Tupikchak	77AJF23	----	.15	M	S, C, L	1.6	22.4
Mountain	" 28	----	.30	M	C, L	4.3	6.1
Syncline	" 30	----	.18	W	S, C, L	6.6	9.0
measured	" 32-u	----	.23	M	C, L, P, F	1.3	20.0
section	" 36-u	----	.23	W	S, C, L	2.3	3.4
	" 37-1	----	.25	M	S, C, L	5.0	5.0
n=16	" 37-u	----	.30	P	S, C, L	7.7	6.4
	" 39-1	----	.25	M	C, L	4.6	2.0
	" 39-u	----	.30	M	S, C, L	3.3	7.3
	" 42-1	----	.34	P	S, C, L	5.3	4.7
	" 42-u	----	.30	P	S, C, L	5.4	11.0
	" 44	----	.18	M	S, C, L	13.3	0.3
	" 47-1	----	.18	M	S, C, L, P	8.0	7.0
	" 47-u	----	.45	M	C, L	5.3	3.3
	" 52-1	----	.25	M	S, C, L	8.3	10.0
	" 52-u	----	.25	P	S, C, L	4.3	8.3
Range			.15-.34	W-P	----	1.3-13.3	0.3-22.4
Average			.26	M	----	5.4	7.9

Table 4 (continued)

Compositional Data (percent of total composition)

Suite	Sample #	Q	Qm	Qp	F	L	Lv	Lm	Ls	Lac	Lcc
Scattered	1075	32.3	19.7	12.6	2.7	27.2	4.4	16.4	6.4	6.3	0.1
outcrop	1175	29.7	12.3	17.4	2.0	31.2	8.0	21.5	1.7	1.7	0.0
samples	1275	38.1	11.0	27.1	2.7	26.4	7.6	16.8	2.0	2.0	0.0
	1475	52.7	24.8	27.9	2.0	21.3	9.9	8.6	2.8	2.8	0.0
n=21	1575	42.0	16.7	25.3	3.7	28.1	3.1	23.9	1.1	0.8	0.3
	1875	57.2	34.3	22.9	2.6	17.9	5.5	8.5	3.9	3.9	0.0
	2075	56.5	15.7	40.8	2.7	19.5	9.7	6.5	3.3	3.3	0.0
	2175	42.8	21.3	21.5	2.0	28.0	12.2	13.0	2.8	2.5	0.3
	2675	47.6	29.3	18.3	9.6	10.4	4.0	5.3	1.1	1.1	0.0
	3075	31.7	12.3	19.4	2.0	25.6	9.9	14.4	1.3	1.3	0.0
	3275	37.5	21.0	16.5	8.0	21.2	6.5	2.2	12.2	2.2	10.0
	3375	40.2	8.3	31.9	2.3	26.3	8.4	2.1	15.8	8.1	7.7
	3675	36.9	23.6	13.3	6.3	24.4	4.7	1.5	18.2	0.9	17.3
	3875	40.9	11.3	29.6	2.7	26.4	9.7	3.0	13.7	4.0	9.7
	4275	15.2	11.3	3.9	1.0	31.7	1.0	0.0	30.7	0.7	30.0
	4375	49.6	22.3	27.3	6.0	18.3	6.3	8.0	4.0	2.3	1.7
	4575	25.8	11.4	14.4	3.6	9.3	1.0	7.0	1.3	1.0	0.3
	4875	36.0	13.3	22.7	2.3	32.5	3.6	2.6	26.3	0.3	26.0
	5175	30.4	12.7	17.7	6.0	16.9	3.9	6.7	6.3	4.0	2.3
	5375	32.3	17.7	14.6	8.6	15.8	5.0	1.4	9.4	0.7	8.7
	5475	43.9	8.0	35.9	1.7	26.2	18.5	4.3	3.4	3.4	0.0
Range		15.0-57.2	8.0-34.3	3.9-40.8	1.0-8.6	9.3-32.5	1.0-18.5	0.0-23.9	1.1-26.3	0.3-8.1	0.0-30.0
Average		39.0	17.1	22.0	3.8	23.1	6.8	8.3	8.0	2.5	5.4
Tupikchak	77AJF23	33.0	24.7	8.3	6.7	35.6	6.4	1.6	27.6	6.3	20.0
Mountain	" 28	44.3	23.3	21.0	9.3	37.3	9.3	3.4	24.6	9.0	12.3
Syncline	" 30	37.3	24.3	13.0	9.0	38.8	3.0	2.7	33.1	5.7	26.7
measured	" 32-u	32.7	16.7	16.0	10.3	36.4	5.3	2.7	28.4	3.7	24.0
section	" 36-u	52.0	31.7	20.3	8.0	35.2	4.3	5.6	25.3	6.7	18.3
	" 37-1	39.7	22.0	17.7	10.7	39.3	13.7	3.7	21.9	3.3	16.3
n=16	" 37-u	42.0	21.3	20.7	11.7	32.4	8.0	1.4	23.0	3.7	17.0
	" 39-1	49.0	29.0	20.0	13.3	33.0	6.0	3.3	23.7	6.3	14.7
	" 39-u	51.0	25.3	25.7	11.0	29.3	7.0	5.0	17.3	8.3	4.7
	" 42-1	53.0	16.0	37.0	4.7	33.0	8.0	6.3	18.7	12.0	4.7
	" 42-u	37.7	22.3	15.4	9.7	38.0	9.0	2.7	26.3	8.3	16.7
	" 44	45.4	29.7	15.7	12.7	28.4	3.7	4.4	20.3	9.3	8.3
	" 47-1	36.4	14.7	21.7	7.3	37.4	6.0	3.7	27.7	5.7	20.7
	" 47-u	52.6	7.3	45.3	6.0	34.0	8.3	2.6	23.1	13.7	2.7
	" 52-1	41.3	17.3	24.0	5.3	34.4	4.0	5.4	25.0	6.0	17.7
	" 52-u	44.3	23.0	21.3	8.0	35.1	7.7	2.7	24.7	6.3	17.7
Range		32.7-52.6	7.3-31.7	8.3-45.3	4.7-13.3	28.4-39.3	3.0-13.7	1.4-6.3	17.3-28.4	3.3-13.7	4.7-26.7
Average		43.2	21.8	21.4	9.0	34.9	6.9	3.6	24.4	7.1	15.2

TABLE 4. (Continued)

Textural Data

Suite	Sample Number	Maximum grain size (mm)	Modal grain size (mm)	Sorting	Grain contact type	Percent Matrix	Percent Cement
Carbon	77AAh4cc	----	.15	P	C, L, P	6.7	16.7
Creek	" 5cc	----	.23	P	C, L	13.0	4.0
measured	" 6cc	----	.23	M	L	9.3	3.6
section	" 8cc	----	.50	M	L, P, F	4.0	28.9
	" 9cc	----	.30	M	C, L	4.7	12.3
n=6	" 12cc	----	.60	P	L, P, F	1.0	27.4
Range			.15-.60	M-P	----	1.0-13.0	4.0-28.9
Average			.34	M-P	----	6.5	15.5
Corwin	77AAh31b	----	.23	----	----	8.7	6.6
Bluff	" 39	----	.30	M	S, C, L, P	14.3	2.0
measured	" 40	----	.23	M	C, L, P	11.6	18.7
section	" 42	----	.46	P	L, P	17.7	2.0
	" 46	----	.18	M	S, C, L	9.7	15.4
n=13	" 48a	----	.30	VP	C, L, P	15.0	6.3
	" 100a	----	.30	W	S, C, L	6.0	8.0
	" 101	----	.30	M	C, L	6.0	8.0
	" 103	----	.23	P	C, L, P	11.7	12.0
	" 104	----	.25	M	S, C, L	8.3	1.3
	" 105	----	.18	P	S, C, L	11.0	5.6
	" 106	----	.30	P	C, L	7.0	2.7
	" 110	----	.18	P	L, P	2.7	27.7
Range			.18-.46	W-VP	----	2.7-17.7	1.3-27.7
Average			.27	M	----	10.0	8.9
Barabara	77ACh82	----	.25	M	C, L	14.7	5.6
Syncline	" 85	----	.20	P	S, C, L, P	4.6	4.7
measured	" 87-1	----	.25	M	S, C, L	10.3	3.3
section	" 87-u	----	.15	P	S, C, L	13.3	4.0
	" 89-1	----	.25	M	S, C, L	8.7	10.3
n=25	" 89-u	----	.30	P	C, L, P	7.6	9.4
	" 90-1	----	.25	M	S, C, L	8.3	4.3
	" 90-u	----	.25	W	S, C, L	10.6	6.0
	" 92	----	.25	M	S, C, L, P	12.0	6.6
	" 93-1	----	.15	P	L, P, F	16.0	7.0
	" 93-m	----	.20	M	L, P, F	9.9	7.7
	" 93-u	----	.15	P	S, C, L	10.9	6.7
	" 97	----	.20	M	S, C, L	8.0	12.6
	" 101-1	----	.20	M	S, C	9.6	11.0
	" 101-m	----	.25	M	C, L	12.3	14.0
	" 101-u	----	.25	M	C, L, P	8.6	17.6
	" 104-1	----	.18	W	S, C, P	12.7	9.9
	" 104-u	----	.18	W	S, C, L	7.3	8.0
	" 108-1	----	.20	M	S, C, L	12.6	17.0
	" 108-m	----	.30	M	C, L, P, F	12.6	20.0
	" 108-u	----	.20	M	S, C, L	16.9	13.7
	" 116	----	.30	P	S, C, L	15.6	11.0
	" 120-1	----	.23	P	S, C, L	4.0	13.6
	" 123	----	.15	M	C, L, P	11.7	8.3
	" 184	----	.25	M	L	2.2	3.7
Range			.15-.30	W-P	----	2.2-16.9	3.3-20.0
Average			.22	M	----	10.4	9.4

Table 4 (continued)

Compositional Data (percent of total composition)

Suite	Sample #	Q	Qm	Qp	F	L	Lv	Lm	Ls	Lac	Lcc
Western	Tunalik (3286)	36.0	24.0	12.0	10.3	15.3	3.7	2.0	9.6	4.3	3.3
subsurface	" (3288)	27.4	23.4	4.0	7.4	16.3	2.0	0.3	14.0	10.0	3.7
	" (5558)	46.3	35.7	10.6	14.0	11.6	5.6	1.0	5.0	1.0	0.7
n=20	" (5561)	41.7	29.7	12.0	14.6	14.2	5.4	2.7	6.1	3.7	1.7
	Kaolak 1 (937)	44.3	23.0	21.3	5.3	34.0	8.7	14.0	11.3	6.3	3.0
Nanushuk=	" (2453)	31.3	13.7	17.6	4.7	42.4	10.0	11.3	21.1	3.7	14.7
11	" (3187)	43.7	27.7	16.0	8.7	31.0	8.3	9.0	13.7	2.7	8.7
Torok=9	" (4078)	42.6	36.0	6.6	9.0	25.2	12.0	3.6	9.6	3.0	3.3
	*Peard (3036)	30.7	21.7	9.0	13.7	12.8	5.0	2.4	5.4	3.7	1.7
	Meade 1 (2953)	49.9	40.3	9.6	11.7	22.9	8.0	6.6	8.3	4.3	0.3
	* " (4133)	42.7	33.7	9.0	7.7	32.1	8.7	6.0	17.4	6.7	3.7
	*So. Meade (5670)	30.7	21.7	9.0	12.3	22.0	3.7	3.0	15.3	10.3	3.0
	* " " (5964)	31.3	23.3	9.0	11.3	26.8	4.7	3.7	18.4	8.0	7.7
	*So. Barrow 1 (1906-1916)	39.9	28.8	11.1	18.3	18.4	5.3	4.2	8.9	2.3	1.3
	*So. Barrow 6 (2353-2354)	58.1	51.7	6.4	3.3	11.3	4.6	1.7	5.0	2.0	0.7
	Oumalik 1 (979-984)	36.0	24.7	11.3	10.0	35.3	6.3	4.0	25.0	7.3	15.0
	" (1606)	41.3	24.0	17.3	12.0	28.3	11.0	4.7	12.6	3.0	6.3
	* " (3260)	47.0	35.7	11.3	8.3	25.0	9.4	2.3	13.3	4.3	6.3
	* " (9251)	33.0	23.7	9.3	9.0	21.6	5.7	4.0	11.9	4.3	6.3
	* " (9288)	33.3	27.3	6.0	13.0	22.0	4.7	5.6	11.7	6.0	5.0
Range		27.4-58.1	13.7-51.7	4.0-21.3	3.3-18.3	11.3-35.3	2.0-12.0	0.3-14.0	5.0-25.0	1.0-10.3	0.3-15.0
Average		38.9	28.5	10.9	10.2	23.4	6.6	4.6	12.2	4.9	4.8
Nanushuk Average		40.1	27.5	12.6	9.8	25.1	7.4	5.4	12.4	4.5	5.5
Torok Average		37.5	29.7	8.9	10.8	21.3	5.8	3.7	11.9	5.3	4.0

Table 4 (continued)

Compositional Data (percent of total composition)

Suite	Sample #	Q	Qm	Qp	F	L	Lv	Lm	Ls	Lac	Lcc
Carbon	77AAh4cc	34.0	20.7	13.3	9.3	31.0	5.7	6.6	18.7	3.0	15.0
Creek	" 5cc	35.0	27.0	8.0	12.3	31.0	7.1	6.6	17.3	8.7	6.3
measured	" 6cc	42.7	33.0	9.7	11.6	26.1	7.7	5.4	13.0	3.3	6.0
section	" 8cc	29.7	19.0	10.7	7.3	31.7	6.7	7.7	17.3	9.0	3.3
	" 9cc	42.3	27.0	15.3	8.0	31.0	6.0	6.7	18.3	1.0	15.3
n=6	" 12cc	23.6	6.3	17.3	5.7	47.3	8.0	12.3	27.0	19.0	6.0
Range		23.6-42.7	6.3-33.0	8.0-17.3	5.7-12.3	26.1-47.3	6.0-8.0	5.4-12.3	13.0-27.0	1.0-19.0	3.3-15.3
Average		34.6	22.2	12.4	9.0	33.0	6.9	7.6	18.6	7.3	8.7
Corwin	77AAh31b	51.9	29.0	22.9	6.0	24.0	8.7	4.0	11.3	3.7	0.3
Bluff	" 39	43.0	29.0	14.0	14.3	25.0	7.3	4.7	13.0	4.3	1.7
measured	" 40	43.0	33.0	10.0	9.0	18.1	5.4	2.4	10.3	6.3	0.0
section	" 42	46.6	30.3	16.3	12.0	17.7	5.0	2.0	10.7	2.0	2.7
	" 46	44.7	28.0	16.7	8.3	22.7	2.7	3.7	16.3	6.0	0.0
n=13	" 48a	42.0	25.7	16.3	8.0	30.9	4.3	7.3	19.3	6.3	2.7
	" 100a	54.0	25.0	29.0	11.3	18.3	5.0	2.0	11.3	8.0	0.0
	" 101	51.4	18.7	32.7	7.3	28.6	5.7	2.3	20.6	9.3	3.0
	" 103	40.3	33.0	7.3	12.7	21.6	5.3	1.7	14.6	6.3	2.0
	" 104	57.0	46.3	10.7	12.7	17.4	2.0	2.7	12.7	3.7	0.3
	" 105	49.0	36.0	13.0	11.3	21.0	6.0	2.0	13.0	4.7	0.3
	" 106	53.0	23.0	30.0	6.3	28.7	8.7	4.0	16.0	7.0	0.7
	" 110	32.6	20.3	12.3	5.7	32.3	5.7	7.3	19.3	8.0	4.0
Range		32.6-57.0	18.7-46.3	7.3-32.7	5.7-14.3	17.4-32.3	2.0-8.7	1.7-7.3	10.3-20.6	2.0-9.3	0.0-4.0
Average		46.8	29.0	17.8	9.6	23.6	5.5	3.6	14.5	5.8	1.4
Barabara	77ACh82	51.3	26.0	25.3	16.9	9.0	4.0	0.3	4.7	4.0	0.7
Syncline	" 85	63.3	34.3	29.0	12.0	10.3	3.0	0.0	7.3	6.7	0.6
measured	" 87-1	54.7	28.0	26.7	7.6	22.2	6.6	0.0	15.6	15.6	0.0
section	" 87-u	44.6	25.3	19.3	11.6	23.6	6.6	0.0	17.0	15.7	1.3
	" 89-1	49.0	28.3	20.7	9.3	22.0	8.0	0.0	14.0	11.0	3.0
n=25	" 89-u	54.6	30.1	24.5	7.9	19.9	5.2	0.0	14.7	14.7	0.0
	" 90-1	55.7	31.0	24.7	10.6	17.6	5.0	0.0	12.6	12.3	0.0
	" 90-u	52.6	32.3	20.3	10.0	19.3	3.3	0.3	15.7	15.7	0.0
	" 92	51.0	26.3	24.7	12.5	14.9	4.0	0.3	10.0	10.0	0.0
	" 93-1	42.9	20.6	22.3	8.6	24.0	3.0	0.0	21.0	18.0	3.0
	" 93-m	53.6	29.0	24.6	9.3	17.6	5.3	0.0	12.3	10.7	1.6
	" 93-u	58.3	26.7	31.6	8.6	13.3	3.0	0.0	10.3	9.7	0.6
	" 97	48.0	29.0	19.0	12.0	18.0	2.0	0.0	16.0	12.3	3.7
	" 101-1	45.0	36.3	8.7	7.3	22.6	1.3	0.0	21.3	17.3	4.0
	" 101-m	42.3	37.3	5.0	5.7	23.3	2.3	0.0	21.0	19.0	2.0
	" 101-u	42.6	31.6	11.0	7.6	22.0	1.6	0.0	20.4	17.7	2.7
	" 104-1	50.0	42.0	8.0	10.3	15.0	2.0	0.0	13.0	11.7	1.3
	" 104-u	56.6	39.3	17.3	12.0	11.3	1.0	0.0	10.3	8.6	1.7
	" 108-1	38.6	27.3	11.3	7.6	21.3	0.6	0.0	20.7	17.3	3.4
	" 108-m	40.6	25.3	15.3	7.3	16.3	0.0	0.0	16.3	13.0	3.3
	" 108-u	40.6	26.6	14.0	6.6	19.0	1.3	0.0	17.7	13.6	4.1
	" 116	48.9	22.6	26.3	4.3	16.6	0.3	1.3	15.0	14.0	1.0
	" 120-1	34.6	20.0	14.6	3.3	46.3	0.3	1.0	45.0	13.0	32.0
	" 123	47.3	32.3	15.0	8.6	22.5	3.6	0.6	18.3	15.3	3.0
	" 184	63.3	22.3	41.0	2.6	13.9	2.7	1.3	9.9	9.6	0.0
Range		34.6-63.3	20.0-39.3	5.0-41.0	2.6-16.9	9.0-46.3	0.0-8.0	0.0-1.3	4.7-45.0	4.0-19.0	0.0-32.0
Average		47.2	29.2	20.0	8.8	19.3	3.0	0.2	16.0	13.1	2.9

TABLE 4. (Continued)

Textural Data

Suite	Sample Number	Maximum grain size (mm)	Modal grain size (mm)	Sorting	Grain contact type	Percent Matrix	Percent Cement
Western	Tunalik (3286)	.23	.12	M-P	S, C, L	16.7	19.9
subsurface	" (3288)	.30	.08	M	F	3.3	45.0
	" (5558)	.46	.18	M	S, C, L	18.7	6.0
n=20	" (5561)	---	.15	W	S, C, L	10.3	14.7
	Kaolak 1 (937)	.58	.23	M-P	C, L, F	12.7	1.7
Nanushuk=	" (2453)	.60	.23	M	C, L, F	9.0	4.0
11	" (3187)	.30	.18	P	C, L, F	12.0	5.2
Torok=9	" (4078)	.30	.15	P	S, C, L, F	10.7	7.4
	*Peard (3036)	.23	.08	M-P	L, P, F	11.3	31.0
	Meade 1 (2953)	.38	.23	W	C, L	3.0	3.6
	* " (4133)	.45	.23	P	S, C, L	10.7	3.6
	*So. Meade (5670)	.45	.23	M	S, C, L	21.3	12.3
	* " " (5964)	.60	.15	P	S, C	15.0	12.0
	*So. Barrow 1 (1906-1916)	.46	.17	M	C, L	10.5	1.7
	*So. Barrow 6 (2353-2354)	.23	.09	W	C, L	12.7	5.4
	Oumalik 1 (979-984)	.30	.23	P	C, F	10.0	5.6
	" (1606)	.43	.26	P	C, L	10.7	5.0
	* " (3260)	.45	.18	P	C, L, P, F	10.7	6.1
	* " (9251)	.23	.08	P	C, L	23.0	11.3
	* " (9288)	.30	.12	M-P	S, C, L	22.0	3.6
Range		.23-.60	.08-.26	W-P	---	3.0-23.0	1.7-45.0
Average		.38	.17	M	---	12.7	10.3
Nanushuk Average		.39	.19	M	---	10.7	10.7
Torok Average		.38	.15	M	---	15.2	9.7

TABLE 4. (Continued)

Textural Data

Suite	Sample Number	Maximum grain size (mm)	Modal grain size (mm)	Sorting	Grain contact type	Percent Matrix	Percent Cement
Kurupa	78ACh20	.60	.23	M	L, P, F	4.7	25.6
Anticline	" 21	.70	.30	M	C, L	7.0	7.3
measured	" 23	2.30	.60	W	C, L, P	11.6	3.7
section	" 24	1.20	.50	P	C, L, P, F	6.3	20.3
	" 25	.60	.18	M	C, L, P, F	12.1	20.0
n=23	" 30	.45	.18	W	L, P, F	17.0	6.7
	" 31	.60	.23	---	---	9.7	11.3
	" 32	.60	.23	M	C, L	8.0	9.9
	" 33	.60	.30	P	P, F	11.0	2.0
	" 43	.50	.23	M	L, P	6.0	28.3
	" 47	.60	.30	M	S, C, L, P, F	6.6	22.7
	" 49	.40	.18	M	C, L	21.9	7.2
	" 59	.70	.40	M	C, L, P	11.0	8.7
	" 64	.50	.23	W	C, L, P	5.7	25.7
	" 70	1.20	.23	M	C, L	24.3	4.9
	" 74	.70	.30	M	L, P, F	1.7	39.7
	" 76	.70	.60	M	C, L	16.0	4.7
	" 79	.70	.30	M	C, L, P, F	17.0	3.7
	" 80	.70	.23	W	S, C, L	19.3	0.7
	" 103	.70	.50	W	S, C, L	11.3	4.3
	" 108	.70	.60	W	S, C, L	16.0	7.0
	" 113	.60	.23	W	S, C, L	18.7	1.6
	" 116	.60	.23	W	S, C, L	18.3	1.6
Range						1.7-24.3	0.7-39.7
Average						12.2	11.6
Tuktu	77AAh12	.70	.18	M	C, L, P, F	26.0	3.0
Bluff	" 13-u	.23	.15	W	L, P, F	19.7	8.3
measured	" 16	.60	.23	W	L, P, F	14.6	9.0
section	" 17	.70	.30	M	C, L	18.4	5.0
	" 20-1	.50	.18	M	C, L, P, F	25.7	3.0
n=19	" 21	.70	.60	M	C, L	14.3	6.4
	" 23	.40	.23	M	C, L	9.7	15.7
	" 25	.70	.30	W	L	9.3	10.0
	" 30	.75	.18	W	C, L	28.0	5.0
	" 35-1	.40	.15	W	C, L	17.1	3.0
	" 37-m	.60	.23	M	S, C, L	14.4	7.1
	" 38-1	.70	.45	M	---	15.9	0.6
	" 38-u	.60	.40	W	C, L	11.0	1.1
	" 39-1	.60	.15	P	C, L, P, F	13.6	4.3
	" 39-u	1.70	.70	W	S, C, L	12.7	2.0
	" 43-u	1.00	.60	W	C, L	17.4	0.0
	" 45-1	.60	.23	W	S, C, L	21.0	1.0
	" 49-u	.38	.18	W	S, C, L	19.0	1.0
	" 49-1	.70	.55	W	C, L	2.3	1.3
Range		.23-1.70	.15-.70	W-P	---	2.3-28.0	0.0-15.7
Average		.56	.32	W-M	---	16.3	4.6

Table 4 (continued)

Compositional Data (percent of total composition)

Suite	Sample #	Q	Qm	Qp	F	L	Lv	Lm	Ls	Lac	Lcc
Kurupa	78ACh20	22.3	9.3	13.0	3.7	45.0	14.7	12.3	18.0	5.0	7.0
Anticline	" 21	34.3	15.3	19.0	3.7	42.0	15.7	15.0	11.3	2.7	0.3
measured	" 23	29.0	9.0	20.0	3.0	44.7	24.0	9.0	11.7	7.0	0.7
section	" 24	29.0	12.0	17.0	2.7	43.3	16.6	14.4	12.3	7.3	0.3
	" 25	38.8	27.4	11.4	6.0	22.9	9.0	4.0	9.9	6.6	2.0
n=23	" 30	31.6	18.3	13.3	11.7	30.6	15.7	8.6	6.3	3.3	1.0
	" 31	34.0	21.7	12.3	12.0	24.9	9.6	8.0	7.3	2.3	1.7
	" 32	28.7	16.0	12.7	6.3	39.3	18.4	10.0	10.9	5.3	1.3
	" 33	31.3	13.3	18.0	8.0	35.8	14.7	9.7	11.4	7.7	0.0
	" 43	21.0	7.7	13.3	4.3	48.4	14.7	12.0	16.7	4.7	7.7
	" 47	18.9	8.3	10.6	3.7	51.4	18.0	13.3	20.1	5.7	8.7
	" 49	32.2	17.9	14.3	5.0	36.4	9.3	17.9	9.2	4.3	1.3
	" 59	23.4	8.7	14.7	6.7	47.0	14.4	20.0	12.6	6.0	0.3
	" 64	32.3	17.3	15.0	3.7	36.0	4.3	24.0	7.7	3.3	3.7
	" 70	32.0	20.0	12.0	2.3	36.4	9.4	20.3	6.7	2.7	1.7
	" 74	29.6	19.3	10.3	2.3	27.0	6.7	15.6	4.7	3.7	0.0
	" 76	38.0	28.7	9.3	2.3	35.0	7.3	20.0	7.7	5.0	0.0
	" 79	39.6	23.3	16.3	2.3	35.4	4.7	20.7	10.0	3.3	0.7
	" 80	31.3	19.0	12.3	3.7	28.4	6.7	18.7	3.0	1.0	0.3
	" 103	50.6	34.3	16.3	0.0	31.6	4.0	18.0	9.6	3.0	1.3
	" 108	31.7	19.0	12.7	1.7	29.7	4.3	19.7	5.7	0.7	1.7
	" 113	33.3	16.3	17.0	1.7	28.7	7.3	18.7	2.7	1.0	0.0
	" 116	38.3	23.0	15.3	3.3	27.7	6.7	15.7	5.3	1.3	0.3
Range		18.9-50.6	7.7-34.3	9.3-20.0	0.0-12.0	22.9-51.4	4.0-24.0	4.0-24.0	2.7-20.1	0.7-7.7	0.0-8.7
Average		31.8	17.6	14.2	4.4	35.8	11.1	15.0	9.6	4.0	1.8
Tuktu	77AAh12	31.3	19.0	12.3	5.3	26.9	3.7	14.6	8.6	5.3	0.3
Bluff	" 13-u	29.0	16.0	13.0	2.7	25.0	3.0	17.4	4.6	0.3	2.0
measured	" 16	30.0	18.0	12.0	4.3	29.2	4.0	18.6	6.6	3.3	2.0
section	" 17	42.0	23.0	19.0	2.7	36.6	6.0	20.0	10.6	1.3	0.0
	" 20-1	34.1	22.7	11.4	6.0	29.7	4.6	18.4	6.7	2.7	0.0
n=19	" 21	39.0	27.3	11.7	1.7	35.6	9.0	16.3	10.3	1.0	0.0
	" 23	30.0	12.7	17.3	2.7	38.0	13.0	19.3	5.7	1.7	1.7
	" 25	41.0	24.0	17.0	2.0	41.7	10.3	21.7	9.7	4.7	0.0
	" 30	26.0	15.0	11.0	1.3	33.4	6.0	25.4	2.0	0.7	0.3
	" 35-1	34.6	15.8	18.8	2.6	33.1	5.3	22.8	5.0	0.7	0.3
	" 37-m	43.9	25.3	18.6	3.2	24.9	4.8	17.9	2.2	0.3	0.0
	" 38-1	51.5	33.1	18.4	0.3	33.7	6.8	13.3	13.6	2.0	0.0
	" 38-u	58.7	36.7	22.0	1.3	27.6	5.7	12.2	9.7	2.8	0.0
	" 39-1	57.3	35.2	16.1	3.2	24.3	8.1	10.6	5.6	1.0	2.3
	" 39-u	51.2	28.7	22.5	0.7	35.4	13.3	12.4	9.7	2.9	0.0
	" 43-u	59.0	33.0	26.0	1.0	26.0	6.6	12.0	7.4	1.7	0.0
	" 45-1	42.1	28.7	13.4	1.0	28.0	7.6	14.7	5.7	2.7	0.0
	" 49-u	50.3	34.3	16.0	2.7	24.6	5.6	13.0	6.0	1.3	0.0
	" 49-1	53.6	17.3	36.3	0.3	36.7	18.3	14.0	4.4	2.7	0.0
Range		26.0-59.0	12.7-36.7	11.0-36.3	0.3-6.0	24.3-41.7	3.0-18.3	10.6-25.4	2.0-13.6	0.3-5.3	0.0-2.3
Average		42.0	24.5	17.5	2.4	31.1	7.5	16.6	7.1	2.1	0.5

TABLE 4. (Continued)

Textural Data

Suite	Sample Number	Maximum grain size (mm)	Modal grain size (mm)	Sorting	Grain contact type	Percent Matrix	Percent Cement
Arc	78AAh6	.40	.15	M	S, C, L	25.3	3.3
Mountain	" 16	.30	.20	W	S, C, L	19.7	2.2
Syncline	" 17	.80	.18	W	S, C, L	23.0	1.6
measured	" 18	2.30	1.20	W	S, C, L	5.3	1.0
section	" 19	1.20	.40	M	S, C, L	10.0	1.6
	" 20	.60	.40	W	S, C, L	7.3	0.6
n=16	" 22	.40	.15	M	S, C, L	18.7	4.7
	" 25	.60	.25	W	S, C, L	16.4	0.6
	" 26	.80	.30	W	S, C, L	12.0	0.3
	" 27	1.20	.60	W	S, C, L	2.7	2.0
	" 30	.45	.30	M	C, L	22.0	0.7
	" 31	1.20	.60	W	S, C, L	6.3	4.4
	" 32	.80	.30	W	S, C, L	10.7	0.6
	" 41-l	1.08	.40	W	S, C	9.0	1.0
	" 41-m	1.20	.60	W	S, C, L	12.3	1.6
	" 41-u	1.20	.60	W	S, C, L	12.7	0.3
Range				M-W		2.7-25.3	0.3-4.7
Average				W		13.3	1.7
Marmot	78ACh14	.45	.23	W	S, C, L	13.6	2.3
Syncline	" 16	3.50	.77	W	S, C, L	10.0	2.7
measured	" 18	.24	.13	W	S, C, L	13.0	3.0
section	" 20	4.00	.60	W	S, C, L	10.3	0.3
	" 24	1.72	1.20	W	S, C, L	2.7	1.4
n=24	" 25	1.72	.60	W	---	8.3	2.1
	" 26	.77	.48	W	S, C, L	9.4	2.0
	" 28	2.30	.23	M-P	C, L	23.7	2.3
	" 29	2.30	.40	---	---	7.4	2.9
	" 30	1.30	.60	M	C, L, P, F	12.3	1.0
	" 31	4.60	1.20	W	S, C, L	8.4	0.3
	" 32	.90	.30	W	C, L	9.0	0.2
	" 34	.60	.12	P	C, L, P	13.4	0.3
	" 35	.90	.60	W	C, L	14.0	0.3
	" 37	1.60	.60	W	L	5.0	2.6
	" 38	1.20	.65	M	C, L	8.7	8.3
	" 43	2.00	.60	W	S, C, L	14.9	1.8
	" 44	2.30	.60	W	C, L	6.6	0.3
	" 45	1.20	.40	W	C, L	11.3	2.3
	" 46	1.54	.20	M-P	S, C	11.0	0.6
	" 52	1.20	1.20	P	L	3.6	0.3
	" 53	1.00	.38	W	S, C, L	9.0	0.6
	" 54	.60	.23	M	C, L	21.0	1.7
	" 56	.40	.20	W	S, C, L	24.4	2.3
Range						2.7-24.4	0.2-8.3
Average						11.3	1.7

Table 4 (continued)

Suite	Sample #	Q	Qm	Qp	F	L	Lv	Lm	Ls	Lac	Lcc
		Compositional Data (percent of total composition)									
Arc	78AAh6	38.7	25.7	13.0	3.0	17.4	2.0	8.4	7.0	4.7	0.3
Mountain	" 16	36.9	21.0	15.9	1.9	21.3	6.1	11.1	4.1	0.0	0.0
Syncline	" 17	39.4	26.0	13.4	2.3	23.3	5.0	12.0	6.3	1.7	0.3
measured	" 18	62.9	42.7	20.2	0.0	31.5	10.9	9.3	11.3	9.6	0.0
section	" 19	62.6	42.3	20.3	1.0	26.0	7.0	8.6	10.4	5.7	0.0
	" 20	63.0	43.3	20.0	0.3	29.3	6.3	12.7	10.3	5.0	0.0
n=16	" 22	38.3	23.3	15.0	3.7	18.7	6.0	10.0	2.7	1.7	0.0
	" 25	55.1	40.7	14.4	2.3	24.8	6.7	12.4	5.7	1.7	0.0
	" 26	56.3	31.3	25.0	2.3	26.6	3.6	16.0	7.0	1.0	0.0
	" 27	62.3	45.0	17.3	0.7	28.7	8.7	8.0	12.0	7.3	0.0
	" 30	34.3	19.7	14.6	2.0	26.7	8.0	14.0	4.7	0.7	0.0
	" 31	61.6	42.3	19.3	0.7	25.2	11.3	7.6	6.3	1.3	0.0
	" 32	64.7	47.3	17.4	0.7	21.1	6.7	8.4	6.0	1.3	0.0
	" 41-l	59.9	41.2	18.7	1.0	28.6	6.6	11.7	10.3	1.7	0.0
	" 41-m	58.7	32.3	26.4	0.3	28.4	4.3	14.7	9.4	4.7	0.0
	" 41-u	58.6	33.0	25.6	0.3	29.3	3.3	16.0	10.0	1.3	0.7
Range		34.3-64.7	19.7-47.3	13.0-26.4	0.0-3.7	17.4-29.3	2.0-11.3	7.6-16.0	2.7-12.0	0.0-9.6	0.0-0.7
Average		53.4	34.8	18.5	1.4	25.4	6.4	11.3	7.7	3.1	0.1
Marmot	78ACh14	51.4	31.0	20.4	1.7	31.3	7.3	17.4	6.6	1.3	0.0
Syncline	" 16	52.9	30.3	22.6	3.3	32.0	6.0	23.0	3.0	1.0	0.0
measured	" 18	48.0	26.7	21.3	2.0	29.3	6.3	18.7	4.3	1.3	0.0
section	" 20	52.3	23.3	29.3	0.0	45.4	9.0	26.7	9.7	3.7	0.0
	" 24	59.3	25.3	34.0	0.0	33.3	15.0	8.0	10.3	5.3	0.0
n=24	" 25	58.3	41.0	17.3	0.0	24.4	6.4	16.3	11.7	2.0	0.0
	" 26	62.7	37.0	25.7	0.0	22.1	4.4	11.0	6.7	2.0	0.0
	" 28	49.0	31.0	18.0	0.7	21.7	6.4	10.3	5.0	0.7	0.0
	" 29	54.7	27.0	27.7	0.0	39.7	12.0	15.4	12.3	5.3	0.0
	" 30	59.3	41.0	18.3	0.3	27.0	4.7	15.3	7.0	1.0	0.0
	" 31	59.0	25.3	23.7	0.7	34.4	8.3	18.7	7.4	3.7	0.0
	" 32	55.6	27.3	28.3	1.0	30.6	8.0	14.3	8.3	4.3	0.0
	" 34	52.4	32.7	19.7	1.7	24.8	5.0	14.4	5.4	1.7	0.0
	" 35	58.0	35.7	22.3	0.0	24.3	7.0	11.0	6.3	2.3	0.0
	" 37	60.9	21.3	39.6	0.3	33.3	15.7	9.3	8.3	7.0	0.0
	" 38	53.3	39.0	14.3	1.3	31.0	13.4	10.3	7.3	3.7	1.3
	" 43	54.0	33.2	20.8	1.5	31.1	8.8	10.4	11.0	7.0	0.0
	" 44	63.0	37.0	26.0	0.0	31.4	7.0	12.7	11.7	5.7	0.0
	" 45	62.0	41.7	20.3	0.3	23.3	7.4	9.3	6.6	0.3	0.0
	" 46	53.3	35.7	17.6	2.3	30.0	9.7	15.0	5.3	1.0	0.0
	" 52	62.7	32.7	30.0	0.0	35.0	9.7	15.0	10.3	5.0	0.0
	" 53	67.7	49.7	18.0	1.3	21.0	8.3	6.3	6.4	0.7	0.0
	" 54	47.3	31.3	16.0	2.3	23.3	7.0	9.0	7.3	1.3	0.0
	" 56	40.4	28.7	11.7	2.7	21.0	12.3	5.7	3.0	0.3	0.0
Range		40.4-67.7	21.3-49.7	11.7-39.6	0.0-3.3	21.0-45.4	4.4-15.7	5.7-26.7	3.0-12.3	0.3-7.0	0.0-1.3
Average		55.7	33.1	22.6	1.0	29.6	8.5	13.5	7.6	2.8	0.1

TABLE 4. (Continued)

Textural Data

Suite	Sample Number	Maximum grain size (mm)	Modal grain size (mm)	Sorting	Grain contact type	Percent Matrix	Percent Cement
Central	Knifeblade 2A (172)	.45	.30	M	C, L	3.0	3.0
Subsurface	" (792)	.77	.40	P	P, F	5.3	8.7
	" (1557)	.38	.15	W	C, L	7.0	4.7
n=35	Titaluk 1 (539)	.23	.15	M	C, L, P	11.0	1.3
	" (2675)	.30	.15	M	S, C, L	4.7	0.0
Nanushuk=	" (3004)	.34	.27	P	L, P	6.6	6.7
27	" (3306)	.36	.23	P	C, L, F	9.4	6.6
Torok=8	" (3431)	.23	.17	M	P, F	11.7	3.6
	Wolf Creek 1 (867)	.58	.30	VP	S, C, F	7.0	8.6
	Wolf Creek 3 (1553)	.58	.30	W	C, L	0.3	0.6
	" " (2050)	.45	.17	P	S, C, F	10.0	2.0
	" " (2532)	.46	.20	P	S, C, F	12.0	3.7
	Dalton (3524)	.30	.08	W-M	L, P, F	33.7	2.7
	* " (4687.5)	.60	.09	M-P	C, L	14.7	1.3
	Inigak (2662)	.77	.18	W-M	S, C, L	6.6	0.3
	Square Lake (1916)	.48	.17	P	L, P, F	4.0	4.7
	" " (3036)	.45	.23	M	S, C, L, P	2.7	7.3
	" " (3480)	.18	.14	P	L, P, F	13.3	1.0
	*Seabee (5393)	.23	.12	M	C, L	19.3	3.6
	* " (5396)	.17	.08	M-P	S, C, L	33.0	6.0
	* " (5410)	.27	.15	M	S, C, L, P	21.3	12.0
	* " (12,011)	.45	.15	M-P	L, P, F	29.0	4.6
	Fish Creek (5530)	.30	.11	M	L, P, F	9.0	30.0
	Grandstand (364-369)	.90	.46	W	S, C, L	8.7	1.3
	" (862-882)	.38	.17	VP	S, C, L	8.0	0.7
	Gubik 2 (3529)	.45	.17	P	L, P, F	11.4	1.6
	" (3822)	.38	.18	W	S, C, L	8.0	0.3
	Simpson (829)	.23	.13	P	C, L, P, F	8.3	3.3
	E. Simpson (2406)	.18	.06	M	C, L	11.7	4.0
	" " (2410)	.29	.06	P	C, L	15.3	1.0
	*" " (6083)	.16	.08	M	S, C, L	19.3	14.0
	Topagoruk 1 (603)	.38	.15	M	L, P	14.3	2.0
	" (1204)	.77	.23	M	L, P	8.4	1.8
	* " (5970-5971)	.33	.15	M-P	C, L	14.0	11.7
	* " (6495-6496)	.40	.11	P	C, L	15.3	15.7
Range		.16-.90	.06-.46	W-VP	---	0.3-33.7	0.0-30.0
Average		.41	.18	M	---	11.9	6.7
Nanushuk Average		.43	.20	M	---	9.3	4.1
Torok Average		.33	.12	M	---	20.7	8.6

Table 4 (continued)

Compositional Data (percent of total composition)

Suite	Sample #	Q	Qm	Qp	F	L	Lv	Lm	Ls	Lac	Lcc
Central	Knifeblade 2A (172)	48.7	28.7	25.0	4.3	34.7	12.7	7.3	14.7	6.7	1.3
Subsurface	" (792)	38.4	21.7	16.7	2.7	46.2	15.3	23.0	7.9	5.3	0.3
	" (1557)	38.2	29.3	8.9	10.7	36.7	9.4	8.6	18.7	3.7	12.3
n=35	Titaluk 1 (539)	47.3	36.0	11.3	7.0	28.7	8.7	15.0	5.0	2.3	0.0
	" (2675)	59.4	42.0	17.4	9.3	18.6	6.6	7.0	5.0	3.0	0.0
Nanushuk=	" (3004)	49.0	29.0	20.0	6.7	32.6	12.0	12.3	8.3	5.3	1.3
27	" (3306)	40.0	22.3	17.7	9.0	34.2	14.4	6.4	13.4	5.7	6.0
Torok=8	" (3431)	37.1	23.7	13.4	11.3	35.7	7.7	7.7	20.3	7.0	7.3
	Wolf Creek 1 (867)	43.7	26.0	17.7	3.7	32.8	10.7	10.4	11.7	2.7	1.0
	Wolf Creek 3 (1553)	69.0	52.0	17.0	3.0	19.2	6.6	9.6	3.0	1.3	0.0
	" " (2050)	52.3	35.0	17.3	9.0	25.2	10.0	8.6	6.6	3.0	1.3
	" " (2532)	43.0	26.7	16.3	3.0	24.7	3.7	10.3	10.7	4.0	2.0
	Dalton (3524)	32.4	27.7	4.7	5.7	20.3	1.3	5.0	14.0	11.3	0.7
	* " (4687.5)	37.0	29.7	7.3	10.0	24.3	3.3	4.7	16.3	6.3	2.0
	Inigak (2662)	43.3	30.7	12.6	6.3	16.3	3.3	6.7	6.3	1.0	0.3
	Square Lake (1916)	39.4	18.7	20.7	4.3	39.7	9.0	10.7	20.0	6.7	8.0
	" " (3036)	54.3	39.0	15.3	7.0	23.7	7.4	6.3	10.0	3.7	0.3
	" " (3480)	41.3	33.0	8.3	16.4	17.6	5.0	4.0	8.6	4.3	0.0
	*Seabee (5393)	34.4	25.7	8.7	7.6	20.3	4.3	2.0	14.0	4.7	7.3
	* " (5396)	39.9	32.3	7.6	13.3	15.3	1.6	3.0	10.7	1.7	7.0
	* " (5410)	27.4	21.7	5.7	10.3	26.9	4.9	5.0	17.0	9.7	3.3
	* " (12,011)	36.7	30.0	6.7	11.3	16.3	3.3	2.7	10.3	4.0	5.0
	Fish Creek (5530)	32.4	24.7	7.7	10.7	10.6	3.6	2.0	5.0	3.0	2.0
	Grandstand (364-369)	58.3	30.0	28.3	2.0	28.0	6.4	12.6	9.0	4.7	0.0
	" (862-882)	54.3	39.3	15.0	3.3	31.6	9.3	10.3	12.0	5.0	0.0
	Gubik 2 (3529)	33.3	21.3	12.0	7.6	43.3	8.0	12.7	22.6	7.3	12.0
	" (3822)	58.1	44.7	13.4	5.3	21.4	6.7	9.7	5.0	3.3	0.0
	Simpson (829)	34.3	25.3	9.0	8.3	33.3	9.3	4.3	19.7	15.3	2.7
	E. Simpson (2406)	35.6	23.6	12.0	7.0	19.6	4.9	8.0	6.7	1.8	4.6
	" " (2410)	31.4	20.7	10.7	10.0	19.5	2.4	3.7	13.4	5.7	5.0
	*" " (6083)	33.7	22.7	11.0	14.7	11.6	1.0	2.0	8.6	5.3	2.0
	Topagoruk 1 (603)	29.0	21.3	7.7	7.0	37.9	9.3	9.0	19.6	7.0	11.3
	" (1204)	33.9	15.6	18.3	6.0	35.4	7.2	9.6	18.6	6.0	10.5
	* " (5970-5971)	35.0	25.7	9.3	16.0	10.9	2.6	1.3	7.0	3.7	2.3
	* " (6495-6496)	34.3	25.0	9.3	14.3	17.8	8.4	3.7	5.7	1.3	3.7
Range		27.4-59.4	15.6-52.0	4.7-28.3	2.0-16.4	10.6-46.2	1.0-15.3	1.3-15.3	3.0-22.6	1.0-15.3	0.0-12.3
Average		41.6	28.5	13.1	8.1	26.0	6.9	7.6	11.6	4.9	3.6
Nanushuk Average		43.6	29.0	14.6	6.9	28.4	7.8	8.9	11.7	5.0	3.4
Torok Average		34.8	26.6	8.2	12.2	17.9	3.7	3.1	11.2	4.6	4.1