Petrographic analysis of 50 sandstone samples from the North Slope of the Brooks Range, Alaska, 1974

Enlows, H.E., and Amoco Oil Co.

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PETROGRAPHIC ANALYSIS OF 50 SANDSTONE SAMPLES FROM THE NORTH SLOPE OF THE BROOKS RANGE, ALASKA

BY

HAROLD E. ENLOWS

JANUARY, 1974

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Petrographic Analysis of 50
Sandstone Samples from the North Slope of
The Brooks Range, Alaska

For

Union Oil Company of California

Harold E. Enlows

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CONTENTS

Petrographic Analysis of 50 Sandstone Samples from the North Slope of The Brooks Range, Alaska

SUMMARY

I Cretaceous Rocks

Introduction. Despite a wide geographic spread, from the Canning River to the Delong Mountains, and despite differences in age from Early to Late Cretaceous, all the Cretaceous sandstones examined exhibited remarkable similarities. Differences were largely differences in degree of similar characteristics rather than fundamental differences. The similarity of the provenance is apparent in that the clasts exhibit a remarkable constancy in type but vary in their proportions.

The sandstones are generally fine to very fine grained, moderately well sorted and usually contain over 10% matrix resulting in classification as wackes. The matrix has been somewhat altered by diagenesis and the presence of authigenic chlorite is almost universal, which aids materially in the lithification of the rocks. The cement is commonly a combination of quartz and carbonate. Due to both abundant matrix and cement the porosity is usually very low.

Clasts.

Quartz: Both metamorphic and igneous quartz are usually present. Much of the metamorphic quartz may be first cycle but it is thought probable that the igneous quartz is second cycle, derived probably from Paleozoic and Lower Mesozoic sandstones.

Chert: The chert may be in part second cycle but the Paleozoic of the Brooks Range is so rich in chert that it may well be first cycle.

Feldspar: Various types of feldspar are noted. Most commonly it is plagioclase, largely andesine, and may be from a volcanic source. Microcline and untwinned feldspar may be second cycle, perhaps from the sandstones furnishing the igneous quartz, but in some instances it is found with granitic fragments and may come from limited granitic outcrops.

Low Rank Metamorphics: Phyllite or very fine grained schist and argillite are common. Usually classed as phyllite in individual reports, one has to look no farther than the Pre-Devonian Neruokpuk Formation or its equivilents for the source of the material. Muscovite and biotite also commonly found, but seldom in large quantities, are probably from the same source.

Mudstone: A variety of dark cryptocrystalline to opaque grains, some organic rich and some thought to be phosphatic, are classified merely as "mudstone". In some specimens aggregate polarization dictates they be termed "argillite". Some grains appear to be silicified thus accounting for their resistance to wear. Carbonaceous and phosphatic shales and mudstones, such as those of the Shublik or Lisburne, readily account for this material.

Volcanics: Fine grained mafic volcanics of an andesitic nature are most common but glass shards and bubble walls, some still vitreous, and devitrified silicic glass is also found in some samples. Generally volcanics are most abundant in Neocomian rocks, but they are also abundant in the Late Cretaceous Schrader Bluff.

Carbonate Grains: The very common carbonate grains are usually thought of as shell material, perhaps Inoceramus prisms in the case of marine rocks. These grains are commonly single crystals but some are polycrystalline and a very few are micritic. Very often they are surrounded by a red rim of iron oxide. A nearby limestone source may be barely possible for some of the micritic or polycrystalline grains.

Miscellaneous Grains: Glauconite, perhaps from the Sadlerochit Sandstone, coarse chlorite, tourmaline, zircon, garnet and granitic fragments are occasionally encountered.

Matrix.

Rather coarse chlorite was ubiquitous, noted both by optical and X-ray techniques. Mica was often observed as was kaolinite. In a few samples vermiculite and smectite were identified, especially in rocks containing volcanic debris. Silt sized quartz grains were also ubiquitous, as was organic matter.

Cement.

Quartz overgrowths and pore fillings and carbonate impregnations are the common cements. Very coarse albite was found in the Fortress Mountain Formation and asphalt? in the Kemik Sandstone. In a few samples authigenic chlorite was so coarse and pure, especially in interstitial openings, that it was considered a cement.

Illustrations.

It was thought that various summations of composition, classification and texture for the various Cretaceous Formations, grouping them according to age and locality, might be useful and informative. Such illustrations follow. Some are diagrams and some are tables with discussions.

In the summary tables the sorting is said to be "good" if only two sand classes are involved, "fair" if three classes are found and "poor" if there are four or more. The figures on quartz-chert, feldspar and unstable lithics are calculated to 100%. The figure following quartz-chert (ie 82/18) represents the quartz to chert ratio with the number on the left representing quartz. Unstable lithics are broken into the common volcanic, low-rank metamorphic and mudstone classes and are given a percentage of the total unstable lithic value.

Neocomian of Western Alaska

	Okpikruak	Turbidite	Kemik Equi.	Kukpowruk Type	Kukpowruk Misc.	Corwin Misc.	Corwin point bar
Median grain size	VF	F	VF	VF	VF	F	VF
Sorting	Good	Poor	Good	Moderate	Moderate	Moderate	Moderate
Quartz - Chert	70% 82/18	27 44/56	98 96/4	58 75/25	69 52/48	76 57/53	77 39/61
Feldspar	24%	12	1.1	22	15	11	11
Unstable Lithics	6%	61	0.9	20	16	13	12
Metamorphics	47%	29	38	75	50	28	18
Volcanics	17%	29	0	4	3	1	1
Mudstone	36%	42	62	21	47	71	81
Classification	Feldspathic Wacke	Volcanic Wacke	Quartz Wacke	Feldspathic Wacke	Lithic Arenite	Lithic Arenite	Lithic Arenite

The turbidite is something of an exception. The rest are relatively high in quartz - chert and feldspar is equal to or higher than the amount of unstable lithics. Most of the formations are rich in both low rank metamorphics and mudstones and all but one contain volcanic debris.

Neocomian of the Umiat Area and the Canning River

	Ft.Mtn.	Kemik Ss
Median Grain size	M	VF
Sorting	Very poor	Good
Quartz - Chert	43% 4/96	92% 91/9
Feldspar	5	Less than 1
Unstable Lithics	52	8
Metamorphics	1	100
Volcanics	45	0
Mudstone	54	0
Classification	Lithic Wacke	Quartz Wacke

In both samples unstable lithics are much more abundant than feldspar. The Umiat area unstables differ drastically from those of the Canning River, as does the texture, sorting and quartz/chert ratio.

Albian (only the Umiat area is represented by true Albian rocks but the Ninuluk is termed "Middle Cretaceous" so is listed here)

	Grandstand	Killik	Ninuluk
Median grain size	VF	Vf	VF
Sorting	Moderate	Moderate	Good
Quartz - Chert	80% 87/13	70% 76/24	66% 85/15
Feldspar	2	Less than 1	4
Unstable Lithics	18	30	30
Metamorphics	59	55	85
Volcanics	0	0	0
Mudstone	41	45	15
Classification	Subfeld-spathic Lithic Wacke	Subfeld-spathic Lithic Wacke	Subfeld-spathic Lithic Wacke

The very strong similarity of all these rocks is well shown by the table and no discussion seems necessary.

Turonian (only one sample is available, the Seabee of the Umiat area)

	Seabee
Median grain size	VF
Sorting	Moderate
Quartz - Chert	68% 74/26
Feldspar	22
Unstable Lithics	10
Metamorphics	90
Volcanics	Tr.
Mudstone	10
Classification	Feldspathic Wacke

The pattern displayed here is very different from that of the underlying Neocomian and Albian of the Umiat area. Note that the feldspar content is more than twice that of the unstable lithics. However, the texture and quartz/chert ratio are about the same, metamorphics are abundant and only a trace of volcanics is apparent.

Late Cretaceous

	Sagwon	Schrader Bluff
Median grain size	VF	VF
Sorting	Good	Poor
Quartz - Chert	68% 85/15	51% 84/16
Feldspar	10	14
Unstable Lithics	22	35
Metamorphics	77	23
Volcanics	Tr.	68
Mudstone	23	9
Classification	Lithic Wacke	Lithic Wacke

The similarities are apparent. An interesting point is the dramatic change in the type of unstable lithics.

TEXTURAL SUMMARY

(Averages if more than one sample available)

	Kemik Ss	Late K Sagwon	Ft. Mtn.	Grand-stand	Killik	Ninuluk	Seabee	Schra-der Bluff	Okpik-ruak	Neo. Turb-idite	Kemik Equi.	Kukpow-ruk Type.	Corwin point bar	Corwin	Kukpow-ruk Misc.	Paleo-cene
Very Fine	87.5%	91.4%	15.6%	58.3%	51.0%	74.3%	77.0%	83.0%	85.0%	41.0%	96.0%	65.2%	58.0%	42.7%	63.4%	37.7
Fine	12.5	8.0	24.7	40.3	42.5	25.7	22.0	15.0	15.0	38.0	4.0	34.2	31.0	47.0	34.1	31.0
Medium	Tr	0.6	34.7	1.4	6.5		1.0	1.5		19.0		0.6	10.7	10.3	2.5	30.3
Coarse			25.0					0.5		2.0			0.3			1.0
No. of samples	2	5	4	3	2	3	1	2	1	1	2	6	3	4	8	3

FRAMEWORK SUMMARY

(Recalculated to 100%. Averages if more than one sample available)

	Kemik Ss	Late K Sagwon	Ft. Mtn.	Grand-stand	Killik	Ninuluk	Seabee	Schra-der Bluff	Okpik-ruak	Neo. Turb-idite	Kemik Equi.	Kukpow-ruk Type.	Corwin point bar	Corwin	Kukpow-ruk Misc.	Paleo-cene
Quartz and Chert	92.0%	68.4%	43.1%	80.1%	69.7%	66.0%	68.0%	51.4%	70.2%	26.6%	98.0%	58.4%	77.4%	76.6%	69.7%	83.5%
Feldspar	0.3	10.0	4.9	2.0	0.7	4.5	21.5	13.8	23.6	12.0	1.1	21.6	10.7	10.5	14.7	0.3
Unstable * Lithics	7.7	21.6	52.0	17.9	29.6	29.5	10.5	34.8	6.2	61.4	0.9	20.0	11.9	12.8	15.6	16.2

* Carbonate grains are excluded.

COMPOSITION SUMMARY

(Average composition if more than one sample available)

	Kemik Ss	Late K Sagwon	Ft. Mtn.	Grand-stand	Killik	Nimuluk	Seabee	Schra-der Bluff	Okpik-ruak	Neo. Turb-idite	Kemik Equi.	Kukpow-ruk Type.	Corwin point bar	Corwin	Kukpow-ruk Misc.	Paleo-cene
Framework	71.5%	61.1%	74.4%	69.3%	69.0%	66.6%	51.3%	63.7%	68.7%	48.8%	66.7%	58.2%	62.5%	66.1%	60.3%	64.9%
Quartz	61.3	34.4	1.3	49.0	36.2	35.2	25.8	24.1	39.2	5.4	62.0	24.8	17.5	23.2	19.1	29.6
Chert	5.8	6.5	29.2	7.1	11.1	7.5	9.1	4.5	8.4	6.8	2.4	8.3	27.2	25.7	17.4	24.4
Feld.	0.2	6.0	3.5	1.4	0.5	2.9	11.0	7.7	16.0	5.5	0.7	12.2	6.2	6.7	7.7	0.2
Phyllite Mica	5.6	10.3	0.2	7.7	11.1	16.3	4.9	5.7	2.1	9.0	0.3	8.4	2.1	3.1	4.5	3.7
Mudstone	-	2.6	16.1	4.8	9.0	2.8	0.5	1.6	1.1	10.0	0.3	2.5	4.8	5.1	3.5	6.8
Carbonate	Tr	2.5	-	Tr	0.7	1.3	Tr	8.1	-	-	0.6	0.6	4.6	2.1	7.7	-
Volcanic	-	Tr	20.5	-	-	-	Tr	12.1	0.5	6.8	-	0.4	Tr	Tr	0.2	-
Other	5.9	0.2	2.3	-	-	0.2	-	0.2	0.3	2.2	0.3	-	-	-	-	Tr
Matrix	10.5	25.6	18.3	16.8	16.2	13.9	20.0	29.2	14.9	14.9	16.9	15.8	7.7	9.6	7.5	19.8
Cement	16.4	10.1	9.6	5.8	12.6	15.7	26.9	5.6	15.2	36.2	14.1	24.1	28.1	17.8	27.5	2.1
Quartz	85.7*	28.9*	69.6*	100.0*	62.7*	39.8*	6.4*	5.0*	26.5*	- *	41.5*	44.4*	30.7*	57.4*	23.1*	95.0*
Carb.	-	61.1	7.3	-	13.1	55.2	93.6	59.5	73.5	99.0	-	40.9	61.4	42.6	70.0	-
Chlorite	-	7.0	13.4	-	24.2	5.0	-	35.5	-	-	55.5	14.7	2.3	-	6.9	5.0
Other	14.3*	3.0	9.7	-	-	-	-	-	-	1.0	-	-	4.2	-	-	-
Porosity	1.6	3.2	3.0	7.3	1.8	3.8	1.9	1.7	1.2	0.2	1.6	2.6	1.6	6.4	4.6	13.2
Classification	Quartz Wacke	Lithic Wacke	Lithic Wacke	Subfeldspathic Lithic Wacke	Subfeldspathic Lithic Wacke	Subfeldspathic Lithic Wacke	Feld-spathic Wacke	Lithic Wacke	Feld-spathic Wacke	Volcan-ic Wacke	Quartz Wacke	Feld-spathic Wacke	Lithic Arenite	Lithic Arenite	Lithic Arenite	Subfeldspathic Lithic Wacke

* Figures are percentage of total cement

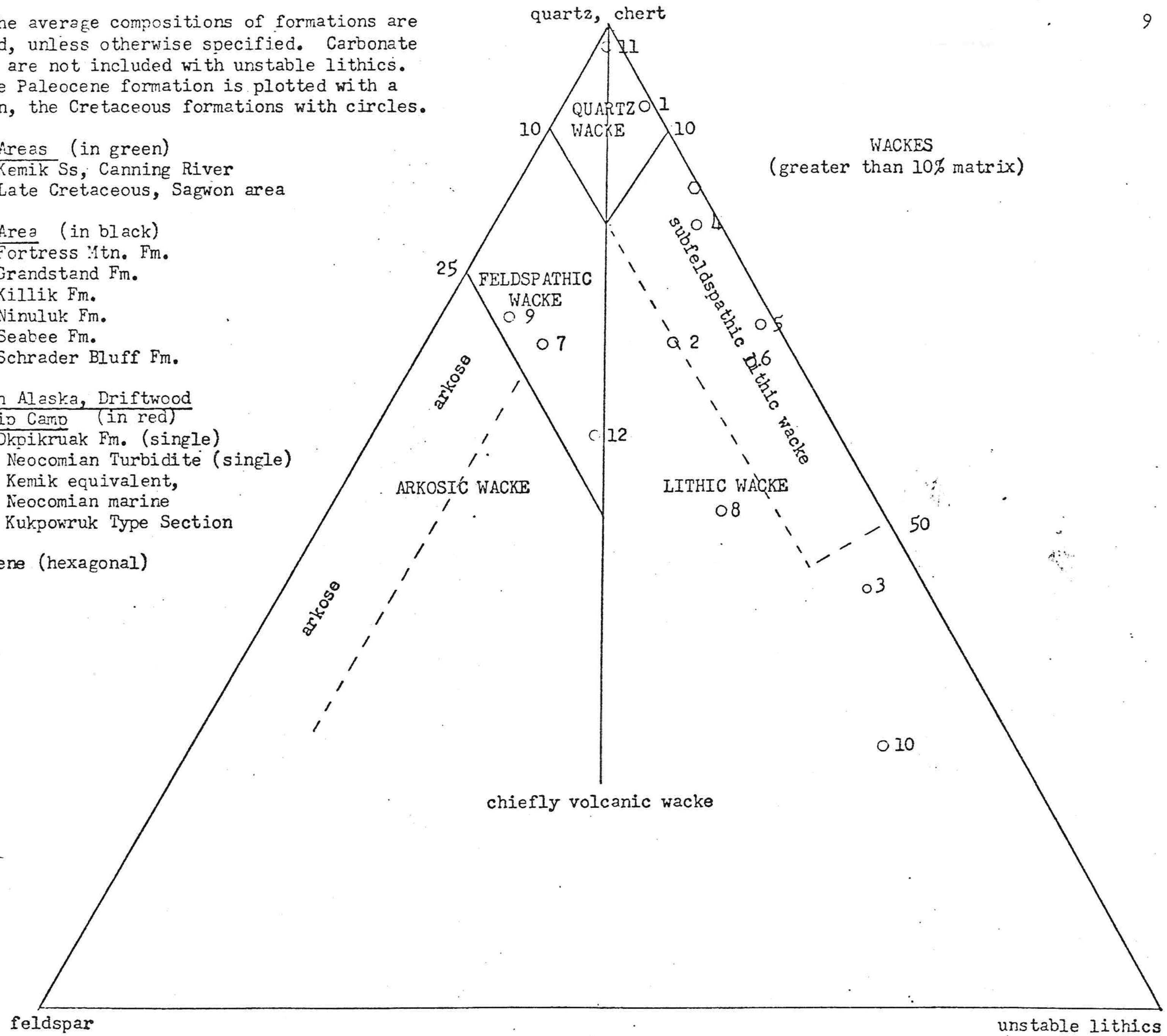
The average compositions of formations are plotted, unless otherwise specified. Carbonate grains are not included with unstable lithics. The one Paleocene formation is plotted with a hexagon, the Cretaceous formations with circles.

Misc. Areas (in green)
(1) Kemik Ss, Canning River
(2) Late Cretaceous, Sagwon area

Umiat Area (in black)
(3) Fortress Mtn. Fm.
(4) Grandstand Fm.
(5) Killik Fm.
(6) Ninuluk Fm.
(7) Seabee Fm.
(8) Schrader Bluff Fm.

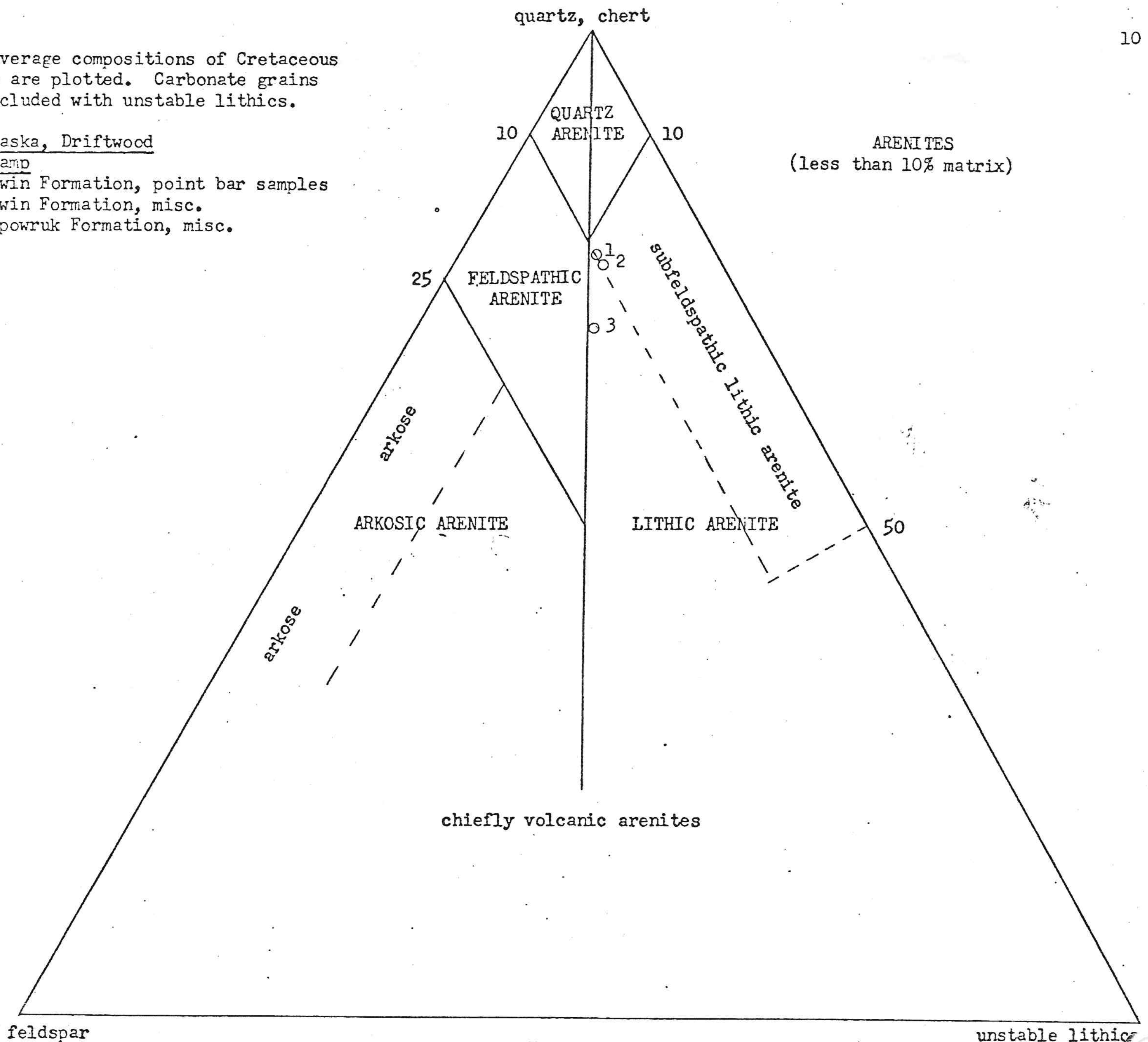
Western Alaska, Driftwood Airstrip Camp (in red)
(9) Okpikruak Fm. (single)
(10) Neocomian Turbidite (single)
(11) Kemik equivalent, Neocomian marine
(12) Kukpowruk Type Section

Paleocene (hexagonal)



The average compositions of Cretaceous formations are plotted. Carbonate grains are not included with unstable lithics.

Western Alaska, Driftwood Airstrip Camp
(1) Corwin Formation, point bar samples
(2) Corwin Formation, misc.
(3) Kukpowruk Formation, misc.



Diagenesis

Authigenic Minerals

Albite: In the Fortress Mountain Formation small tabular crystals of albite are found intergworn with authigenic quartz. They sometimes form terminated crystals extending into pores. In one other instance (Late Cretaceous Rocks) albite was noted as an overgrowth on detrital plagioclase grains.

Carbonate: All occurrances of carbonate were thought to be calcite. It is found as a cement filling interstices or impregnating the matrix.

Chlorite: A pale green matrix mineral was commonly noted in nearly all thin sections and identified as chlorite. The X-ray analyses of matrix minerals confirmed this identification. A 14 A peak unaffected by glycolation and heat treatment was taken as chlorite.

Pyrite: This mineral was not uncommon and was seen as irregular masses in the matrix.

Quartz: Quartz was ubiquitous in the Cretaceous sandstones most commonly as overgrowths on detrital grains but also as a mosaic of fine anhedral grains in the matrix or as a pore filling where it occasionally formed terminated crystals extending into the pores.

Smectite: It was identified by X-ray analyses but tied to a pale green mineral noted in thin section, apparently nontronite. It was usually found only where volcanic debris was noted and is taken as an alteration of volcanic glass or mafic lithic fragments.

Vermiculite: A mineral with a strong 14 A peak which did not expand upon glycolation and collapsed to 12 A upon heat treatment was taken as vermiculite. In thin section in both the matrix and in weathered portions of mafic igneous clasts a green phylosillicate whose birefringence ranged up to first order blue was identified as the vermiculite. It is thought to be an alteration product of the abundant volcanic debris always found in the sandstones containing this mineral.

Mica: The X-ray analysis of the matrix in many instances yielded a strong 10 A peak indicating mica. Whether that mica was detrital or authigenic was not always clear. Commonly all Cretaceous sandstones contained some metamorphic clasts and commonly the X-ray analysis indicated a 10 A peak in the matrix. The only samples exhibiting no 10 A peak were the Fortress Mountain and the Kemik Sandstone Equivilent and both of those are comparatively low in metamorphic clasts. It is thought probably that mica in the matrix is detrital.

Diagenesis

Diagenetic Environment

The formation of authigenic minerals in a sedimentary rock is related to the composition of the host, environmental pH and Eh, cation concentration, pressure and temperature. As a result of the heterogeneous nature of many sedimentary accumulations the Eh, pH and cation concentrations vary widely in local regions within the sediments. As a result of the relatively low temperature and pressure slow reaction rates are to be expected. Thus, metastable phases tend to be common and metastable mineral assemblages are common.

It is assumed that diagenesis took place during and after deposition in the depositional environment. Retention of the common organic matter in these Cretaceous sandstones indicates a reducing environment, the presence of pyrite suggests an Eh as low as -0.2. Estimation of the pH is more difficult since quartz and calcite are both precipitated as cement and both apparently owe their origin to solution of material within the environment. If abrasion pH can be said to be descriptive of the environment in which the mineral is formed then wide variations are present in the sediment since quartz has an abrasion pH of 6.5 and calcite 8.4. An overall pH near the limestone fence (7.8) with variations within the sediment sufficient to bring about either solution or precipitation of SiO_2 and $CaCO_3$ seems logical.

The intimate relationship of quartz and albite in the Fortress Mountain is both interesting and puzzleing since albite has an abrasion pH of 9 to 10, far higher than the 6.5 of quartz.

II Paleocene Rocks.

These non-marine samples vary widely both in texture and mineralogy. Rather than quoting an average, the three samples are treated seperately to illustrate their differences. (See longer discussion of Paleocene rocks for additional information)

	RRR 451 b	RRR 600	RRR 605
Median grain size	M	F	VF
Sorting	Poor	Moderate	Good
Quartz - Chert	99% 20/80	95% 58/42	81% 91/9
Feldspar	0	0	1
Unstable Lithics	1	5	18
Metamorphics	0	43	58
Volcanics	0	0	0
Mudstone	100	57	42
Classification	Quartz Arenite	Quartz Wacke	Subfeldspathic Lithic Wacke

PETROGRAPHIC METHODS

Clasts.

Measurements of grain sizes to determine sorting and rounding was accomplished by projection. Each slide was projected onto a white sheet of paper at a known magnification. The minimum diameter of 300 grains was measured, thus approximating what might have happened if the grains had been sieved. Remember that diameters measured from a thin section will be 24% smaller on the average than the diameters measured on the actual grains. If the range of grain sizes obtained varied over four Wentworth size classes the material was considered poorly sorted; over three sizes the sorting was considered fair and over two or less well sorted. When reporting sorting in this fashion the matrix is neglected, only the size variations in the framework are considered.

Measurement of roundness was most unsatisfactory. The shape of the quartz and chert grains in these sandstones is almost universally altered by overgrowths and in addition grains of the very fine class, and these rocks are rich in such grains, are commonly rather poorly rounded due to their small size.

A minimum of 600 points were counted on each thin section using a mechanical point counter and adjusting the grid to suit the grain size of the sample. The usual grids used were 0.2 or 0.3 by 0.5 mm.

Porosity determinations are not accurate on many of the slides due to plucking during grinding. In all cases the error is in the direction of too high a value.

Mineral identification for the clasts is reasonably straightforward but the rocks present more difficulties. Fine grained quartz may be either a schist or a chert with the former chosen if notably elongate grains are noted. Most of these rocks were so fine grained that the term quartzite was not used. So many conflicting opinions have been stated concerning the utility of the various methods used to determine the origin of quartz grains that it is thought necessary to set down some criteria.

Shape.

This was used with caution. Polycrystalline grains were not labeled metamorphic unless:

(1) The multiple grains were markedly elongate and parallel.

(2) The grains contained two distinctly different sizes of crystals.

Inclusions.

(1) Euhedral chlorite, muscovite, biotite, apatite, garnet or magnetite indicate metamorphic origin.

(2) Irregular inclusions and globules with liquid, especially if the liquid contains vapor bubbles exhibiting Brownian movement, indicate an igneous or gneissic origin, probably igneous.

(3) Acicular inclusions, perhaps rutile or tourmaline, indicate igneous origin.

Mudstone and argillite are similar, the latter term is used if the cryptocrystalline rock exhibits aggregate polarization. Very dark, sometimes opaque, mudstones may be organic or phosphatic. Examination by reflected light is usually necessary.

Matrix.

X-ray analyses were made on selected specimens to aid in the identification of the minerals in the matrix. These analyses proceeded as follows.

(1) Gentle grinding of the original rock to produce several grams of sample.

(2) The disaggregated material was placed in a test tube filled with distilled water and the sand sized particles allowed to settle out. Work proceeded with the suspended material.

(3) If the rock contained appreciable $CaCO_3$, or organic matter or iron oxide steps were taken for removal.

Removal of $CaCO_3$ Treat with 0.1 N HCl until all effervescence ceases. Decant leachate (commonly centrifuging is necessary) and treat with 0.1 N HCl again followed by two rinses with distilled water.

Removal of organic matter. Treat sample with 30% H_2O_2. Leave overnight, then boil 15 minutes to remove excess peroxide and rinse with distilled water at least twice.

Removal of iron oxide. Most samples did not require this treatment. Treat sample with 80 ml sodium citrate, add 10 ml 1 M $NaHCO_3$ solution, bring to 80°C, add 2 g solid $Na_2S_2O_4$ and leave on steam bath for 15 minutes. Centrifuge and discard supernatants.

(4) Pour concentrated clay suspension on slide and allow to dry. Run on X-ray.

Solvation with ethylene glycol and heat treating were used if necessary. The solvation involved placing the slide in a closed container with ethylene glycol, hold at 65°C for one hour then let sit overnight and run slide in the morning. The heat treatment involved heating to 550°C for at least one half hour before running.

Results are reported for each sample under the discussion of the matrix.

Cement.

Petrographic analysis in combination with the X-ray analyses were used in reporting upon the authigenic cement observed in each slide.

QUESTIONS

Several specific questions were asked the investigator as follows.

(1) How does RRR 951 (Okpikurak ?) differ from RRR 918 and 922 (Kemik Ss Equivilent).

	RRR 951 (Okpikruak ?)	RRR 918 - 922 (Kemik Ss Equi.)
Median Grain Size	VF	VF
Sorting	Good	Good
Framework	69%	66%
Matrix	14.9%	16.9%
Cement	15.0% Chiefly carbonate, minor pyrite	14.0% Quartz and matrix chlorite, no carbonate
Quartz - Chert	70% 82/18	98% 96/4
Feldspar	24%	1%
Unstable Lithics	6%	1%
Metamorphics	47%	38%
Volcanics	17%	0%
Mudstone	36%	62%
Classification	Feldspathic Wacke	Quartz Wacke

In each formation the quartz is of both igneous and metamorphic quartz with no difference in ratio noted.

The obvious differences are well seen in the table above.

(2) Is RRR 905 similar mineralogically to RRR 931 or 1168?

	RRR 905 (Corwin Fm.	RRR 931 (Kukpowruk)	RRR 1168 (Kukpowruk)
Framework	74%	60%	67%
Matrix	11	11	13
Cement	5	16	15
Quartz	82%	13%	39%
Carbonate	18%	74%	52%
Matrix chlorite	minor	13%	9%
Quartz - Chert	86% 24/76	83% 64/36	64% 50/50
Feldspar	2%	12%	19%
Unstable Lithics	12%	5%	17%
Metamorphics	18%	75%	54%
Volcanics	3%	0%	8%
Mudstone	79%	25%	38%
Carbonate grains (% of total rock)	1%	34%	0%
Classification	Subfeldspathic Lithic Wacke	Very fine Calcarenite	Feldspathic Wacke

RRR 1168 is a reasonably representative Kukpowruk sample. The unusually high carbonate in RRR 931, both as cement and as carbonate grains, dictates a classification as a limestone. The high chert and low feldspar in RRR 905 contrasts with a more balanced quartz/chert ratio and high feldspar in the Kukpowruk.

(3 and 4) Comment on the similarities or differences between Grandstand, Ninuluk, and Killik.

The similarities are very strong, as is well shown in the summary chart of the Albian shown on page 5. This similarity extends even to the matrix; all containing quartz, kaolinite, chlorite and mica. All are strongly cemented by quartz with carbonate varying with individual samples.

NEOCOMIAN OF WESTERN ALASKA

NEOCOMIAN - SOUTHERN SOURCE

Thin Sections

RRR 951 and 956.

Age and Field Relations (Rose')

These rocks are of Neocomian age and come from a southern source. They were collected in western Alaska while camped at the Driftwood Airstrip. RRR 951 is possibly from the Okpikruak Formation, RRR 956 is possibly a turbidite.

Texture

Both rocks are composed chiefly of fine to very fine grains but RRR 956 is much more poorly sorted than its companion, containing medium and coarse grains. Grains are angular to rounded but quartz overgrowths have obscured the shape of many of the quartz grains. Matrix forms about 15% of both rocks. Porosity is less than 2% in these samples due not only to matrix but to extensive cementation.

Mineralogy

Clasts: Quartz varies widely from 39% of RRR 951, the finer grained of the two, to only 5.4% in RRR 956. Chert is rather low forming 7 to 8% in each rock. Feldspar is relatively high comprising 5.5% of RRR 956 and 16% of RRR 951. Dark mudstone or argillite and dark rocks that may be phosphorite are common in the coarse grained RRR 956. Occasional grains of mica, chlorite or vermiculite and glauconite are found along with a fair amount of shell fragments.

Matrix: An X-ray analysis of RRR 956 made on the clay to silt sized fraction revealed, chlorite, mica, serpentine and vermiculite along with the ubiquitous quartz and organic material.

Cement: Carbonate is abundant, especially in RRR 956, there is minor pyrite and very minor quartz overgrowths. The authigenic clay minerals play a major part in lithifaction of the rocks.

Distinguishing Characteristics

The two Neocomian rock samples differ rather markedly. RRR 956 has several characteristics which might set it apart, such as: poor sorting, the presence of vermiculite and serpentine in the clay grade sample, the high proportion and great variety of the unstable lithics and the unusually large amount of carbonate cement present.

RRR 951, on the other hand, is about average for Cretaceous sandstones except it is, perhaps, a bit richer in feldspar than most.

Provenance

Low rank metamorphic clasts, mica and metamorphic derived quartz might well be gained from an outcrop of the Neruokpuk or an equivilent. Organic or phosphatic mudstones and cherty sediments are also required as is some source of second cycle quartz grains. Lisburne, Shublik and Siksiskpuk equivilents would be suitable. Limited amounts of mafic volcanics must also be available.

Climate and Relief

The presence of fragile rock clasts and abundant feldspar suggests a nearby source and moderate to high relief to supply swift moving currents. A reasonably severe climate would also be of assistance.

Transportation and Deposition

Swift stream transport followed by deposition in a low energy organic rich marine environment. The reducing environment necessary to produce the pyrite suggests stagnation and perhaps a lagoonal or barred basin environment.

Diagenetic History

The presence of vermiculite is interesting and suggests diagenetic alteration of mafic volcanic material. However, some specimens are very coarse and might be detrital. Some samples even suggest alteration of biotite. Glauconite is present but, as in other samples of Cretaceous rocks, is thought to be second cycle and hence detrital. Authigenic chlorite is common, sometimes in coarse cementing masses, and so is pyrite. The usual quartz and carbonate cement are thought due to solution and reprecipitation of quartz grains and shell debris.

Classification

The finer grained rock, RRR 951, is classified as a Feldspathic Wacke. Its coarser grained companion, RRR 956, is much richer in unstable rock fragments and relatively poor in quartz and feldspar hence is classified as a Volcanic Wacke.

Sample Number RRR 951

Formation Possible Okpikruak

Locality Western Alaska, near Driftwood Airstrip

Number of points counted 658

Slide quality good

Texture

Wentworth Size Classes

Very Fine	85%
Fine	15

Framework: 68.7% of rock

Porosity - 1.2%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to rounded but the true nature is hidden by overgrowths.

Matrix: 14.9%

Cement: 15.0%

Carbonate	41.4%
Quartz	45.5
Chlorite	12.1
Pyrite	1.0

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 39.2%

Types - (1) Euhedral inclusions of chlorite or muscovite
(2) Liquid-gas inclusions
Both the above are common, perhaps equal amounts of igneous and metamorphic quartz

Feldspar - 16.0%

Types - Plagioclase (andesine?) most common, some microcline

Mica - 0.7% Muscovite and vermiculite or altered biotite

Carbonate grains - 0.3%

Rock Fragments:

Chert - 8.4%

Volcanic - 0.5%

Schist or phyllite - 1.4%

Mudstone - 0.3%

Wacke (feldspathic) - 0.8%

Marble? (calcite and quartz) - 0.3%

Compositional Maturity: Immature

Diagenesis

Vermiculite may be either detrital or authigenic. Quartz overgrowths, carbonate and pyrite cement are authigenic. Coarse chloritic masses in interstices rather than in the matrix is termed authigenic cement.

Matrix Minerals

Quartz silt, iron-stained clay, organic matter and much chlorite probably formed from original clay matrix.

Cement Minerals

Quartz, carbonate, minor pyrite and coarse interstitial chlorite.

INFERENCES AND CONCLUSIONS

Provenance

Rock types - Low rank metamorphics, mafic volcanics and sedimentary rocks probably organic rich cherty mudstones and sandstone.

Climate and Relief - Moderate to high relief and temperate to severe climate.

Depositional Environment and Transport Mechanism - Carried by streams into an organic rich low energy marine environment.

Gilbert Classification

Percent matrix - 14.9% of rock

Quartz, quartzite and chert - 70.2% of framework

Feldspars and granitic rock fragments - 23.6%

Rock Name - Feldspathic Wacke

Sample Number RRR 956

Formation "Turbidite"

Locality Western Alaska, near Driftwood Airstrip

Number of points counted 632

Slide quality good

Texture

Wentworth Size Classes

Very Fine	41%
Fine	38
Medium	19
Coarse	2

Framework: 48.8% of rock

Porosity - 0.2%

Median grain size - Fine

Sorting - Poor

Roundness - Angular to well rounded, depending largely upon grain size and type of material. Quartz unaltered by overgrowths.

Matrix: 14.9%

Cement: 36.2%

Carbonate	98.3%
Pyrite	1.7

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz 5.4%

Types - (1) Euhedral inclusions, some obvious chlorite or muscovite. Very common
(2) Liquid-gas bubbles. Uncommon
Both igneous and metamorphic quartz but metamorphic predominates.

Feldspar - 5.5%

Types - Plagioclase and untwinned. Some plagioclase with inclusions of epidote.

Pyroxene - Tr. Clinopyroxene

Framework Minerals: (cont)

Chlorite or vermiculite - 2.8%

Glauconite - 0.6%

Remarks. Vermiculite coarsely crystalline, chlorite medium, glauconite cryptocrystalline.

Rock Fragments:

Chert - 6.8%

Volcanic - 6.8%

Schist or phyllite - 6.2%

Mudstone, somewhat argillitic - 6.8%

Mudstone rich in pyrite and organic or phosphatic material - 3.2%

Serpentinite? - 2.2%

See remarks at end of description concerning clasts of rock.

Compositional Maturity: Immature

Diagenesis

Large quantities of carbonate, probably from shell fragments, obscure details. X-ray analysis reveal chlorite and vermiculite probably authigenic with carbonate and pyrite cement. Serpentine may be either detrital or authigenic.

Matrix Minerals

An X-ray analysis of the matrix gave somewhat complicated results. An original 14 A peak moved to 15.27 on glycolation and collapsed to 14 A upon heating to 550° for one half hour. A 10 A and a 7 A peak both remained strong throughout glycolation and heating. There was also a good 3.53 A peak. Vermiculite, chlorite and mica seem certain and serpentine seems likely. The usual quartz peaks were obtained. Organic matter is also present.

Cement Minerals

Carbonate and minor pyrite are present. It is possible, even probable, that quartz is present but is hidden by the enveloping carbonate. The authigenic chlorite and vermiculite aid with lithifaction.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Low rank metamorphics, mafic volcanics and a sedimentary sequence containing cherty organic rich or phosphatic mudstones and probably some sandstones.

Remarks This slide contains such a variety of interesting rocks that it is probably worthwhile to list some.

(1) Fine grained mafic volcanic. Some with ophitic texture some with pilotaxitic, some bearing plagioclase in a devitrified glassy groundmass. The ferromagnesian minerals and some of the glass are

altered to green alteration products. Some mafic fragments are merely a mixture of glass and iron ore.

(2) Fine grained feldspathic wacke.
(3) Dark mudstone, some changing to argillite.
(4) Almost opaque mudstone containing pyrite and organic or phosphatic material
(5) Phyllitic to schistose rock rich in chlorite.
(6) Muscovite phyllite.
(7) Serpentinite? Polycrystalline masses of serpentine or chlorite.
(8) Verde antique. Coarse carbonate and serpentine or chlorite.
(9)Micrite.
(10) Carbonate grains (Inoceramus prisms?)

Climate and Relief - Moderate to high relief and nearby source, probably a temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a low energy organic rich marine environment, perhaps somewhat stagnant.

Gilbert Classification

Percent Matrix - 14.9% of rock

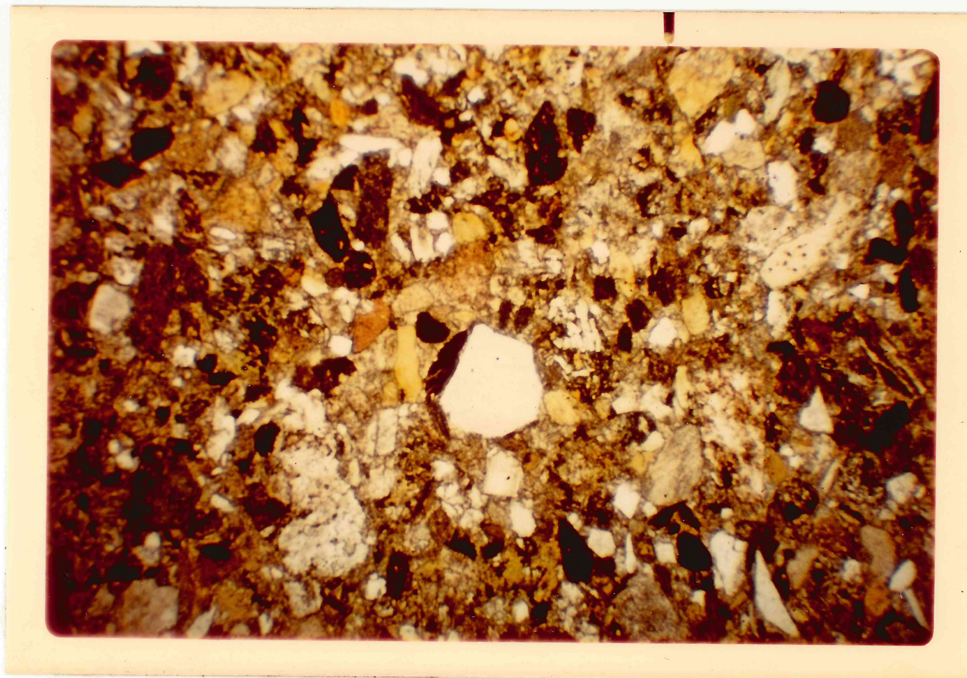
Quartz, quartzite and chert - 26.6% of framework

Feldspars and granitic rock fragments - 12.0%

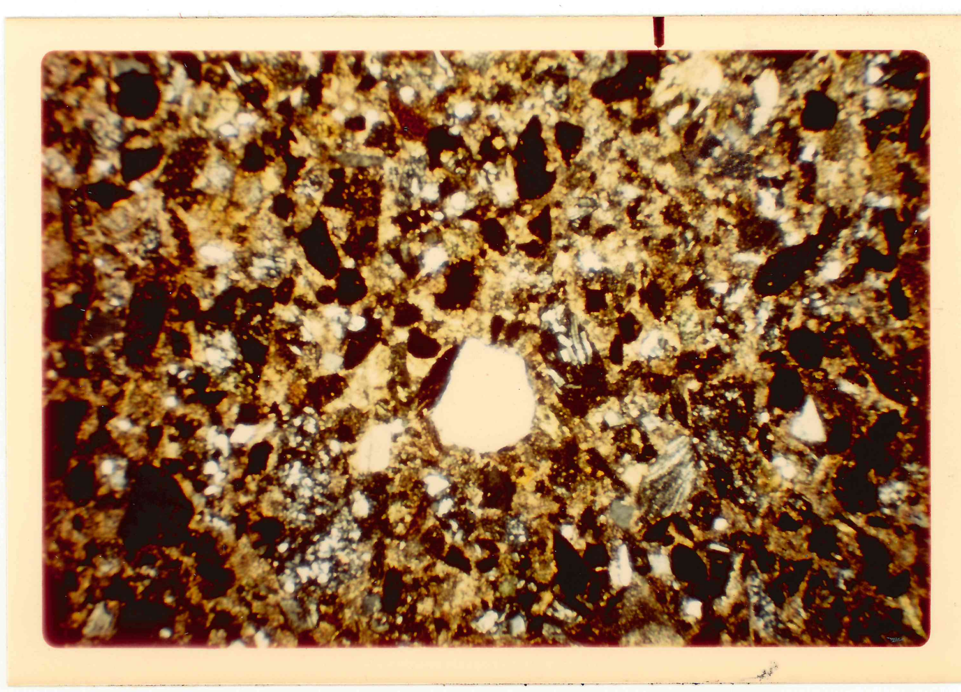
Unstable Lithics - 61.4%

Rock Name - Volcanic Wacke

Figure 1

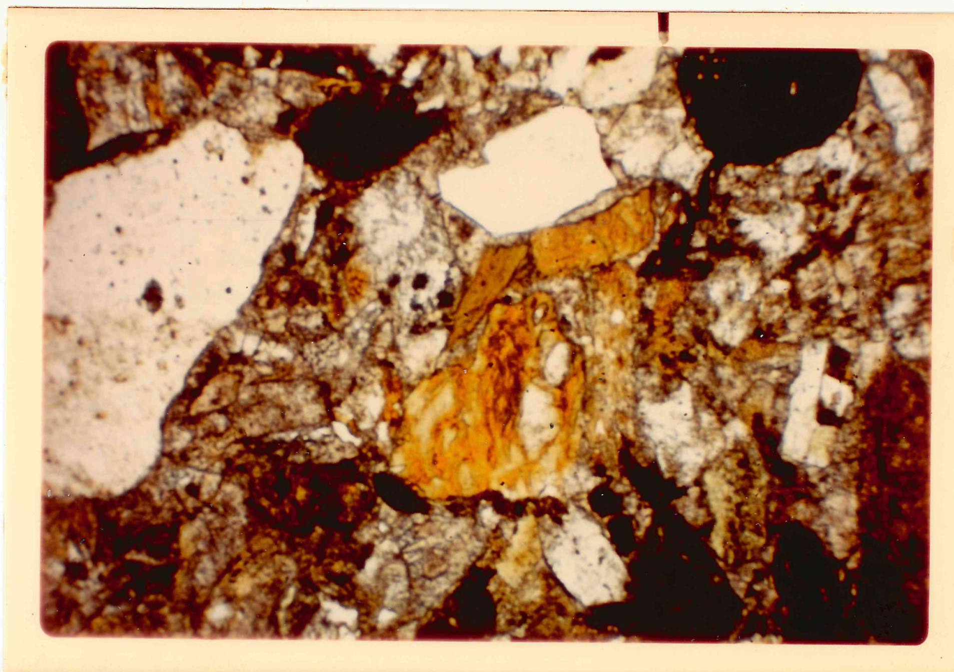


"Turbidite", western Alaska near Driftwood Airstrip. RRR 956, field 3.5 mm wide, parallel nicols. Clasts of quartz, volcanic debris, phyllite, chlorite or vermiculite, feldspar and mudstone. Matrix of quartz silt, mica and chlorite. Carbonate cement forms some 35% of the rock.

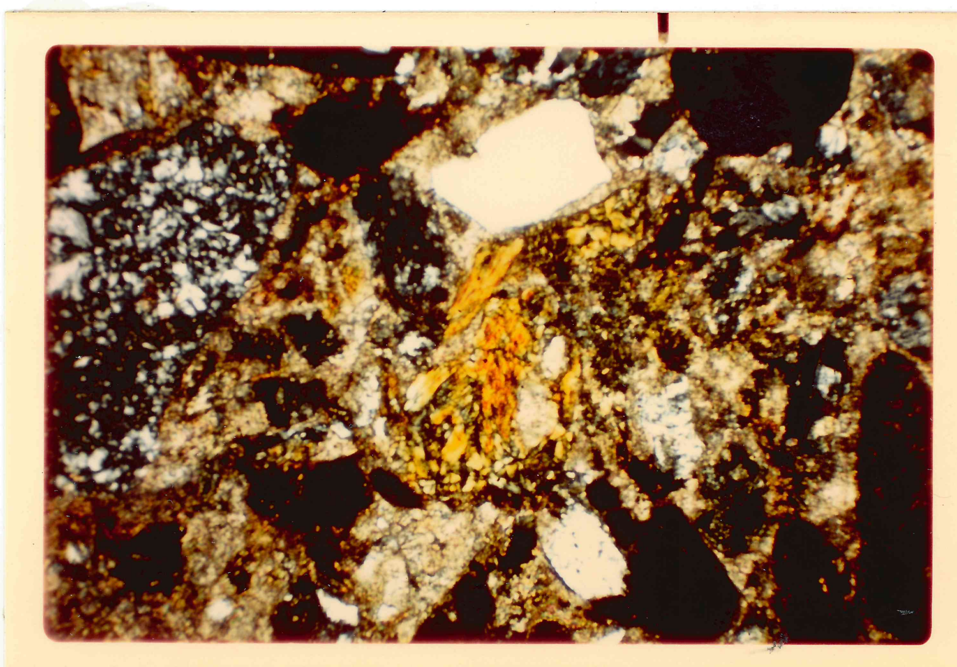


Same as above, crossed nicols.

Figure 2



"Turbidite", western Alaska near Driftwood Airstrip. RRR 956, field 1 mm wide, parallel nicols. Clasts of vermiculite?, chert, quartz, pyritic rich organic mudstone, wacke, feldspar and greenstone?. Matrix of quartz silt and chlorite. Carbonate cement forms some 35% of the rock.



Same as above, crossed nicols.

KEMIK SANDSTONE EQUIVALENT

Thin Sections

RRR 918 and 922

Age and Field Relations (Rose')

The samples are marine Neocomian, equivilent to the Kemik Sandstone. They were collected from western Alaska while camped at the Driftwood airstrip. The direction of the source is assumed to be to the north.

Texture.

The two samples are very similar. Both consist chiefly of very fine grained quartz sand. Some grains are well rounded but presently are extensively modified by quartz overgrowths. They were probably at least subrounded originally. There was originally enough clay matrix to classify the rocka as wackes but the clay has been almost entirely altered to chlorite. Extensive cementation by quartz, in addition to the matrix, has reduced the porosity to less than 3%.

Mineralogy

Clasts: Quartz grains form over 92% of the framework with chert forming about 3%. Carbonate grains, feldspar, glauconite, tourmaline, muscovite and organic rich mudstone make up the remainder.

Matrix: X-ray analysis of the clay sized constituents revealed only quartz and chlorite (RRR 922). Organic matter is also present and the quartz peak probably represents both quartz cement and silt sized grains.

Cement: Quartz as overgrowths and as pore filling joins with authigenic chlorite in cementing the rock firmly. It is difficult to determine what is matrix chlorite and what is chlorite that might have been deposited in pores.

Distinctive Characteristics.

These samples are amazingly similar to RRR 450 and 502 the Kemik Sandstone from the Canning River. The same good sorting of the sand with only very fine and fine grains present, the preponderance of quartz with an igneous origin in the framework and the pervasive cementation by quartz. Although glauconite, phyllite and muscovite are present they are much less common than in the Kemik of the Canning River and collophane appears to be completely missing. The Kemik and the Kemik Equivilent were the only Quartz Wackes and Quartz Arenites in this entire group of Cretaceous sandstones.

Provenance

The fine quartz sand grains with comparatively little else suggests weathering of pre-existing quartz rich sandstones containing much igneous derived quartz. Perhaps this, as in the case of the Kemik, might come from weathering of the Sadlerochit Formation. Muscovite and phyllite grains suggest a minor outcrop of low rank metamorphic rock but the carbonate grains are thought due to organic activity.

Relief and Climate

If the glauconite is detrital, as it is thought to be, it with the minor phyllite probably did not come far and moved with some rapidity. This suggests a nearby source and at least modest relief. Such a quartz rich rock might indicate some mineralogical maturity but it is more easily explained by a quartz rich sandstone source, hence as second cycle quartz.

Transportation and Deposition.

Modest stream currents with rapid deposition in a low energy marine or paralic environment, such as a lagoon, with little chance of winnowing is suggested.

Diagenetic History.

These samples are more thoroughly altered by diagenesis than the Kemik samples from the Canning River. The matrix appears to consist of little but chlorite, quartz and a little pyrite. Original pores are totally filled either by quartz cement or authigenic chlorite.

Classification.

Counting the chlorite cement as former matrix, both samples are classified as Quartz Wacke.

Sample Number RRR 918

Formation Kemik Sandstone Equivilent

Locality Northwest Alaska

Number of points counted 643

Slide quality good

Texture

Wentworth Size Classes

Very Fine 97%
Fine 3

Framework: 65.5%

Porosity - 2.9%

Median grain size - Very Fine

Sorting - Good

Roundness - Grains are extensively altered by overgrowth. The original grains were probably rounded to subrounded

Matrix: 15.7%

Cement: 15.9%

Quartz 100%

Textural Maturity: Mature (It is suggest that most grains are second cycle, however) if only framework grains are counted, immature considering the extensive matrix.

Mineralogy

Framework Minerals:

Quartz - 60.3%

Types - (1) Contain euhedral grains including chlorite or muscovite
(2) Contain liquid inclusions with moving vapor bubbles
Apparently both igneous and metamorphic quartz is present.

Feldspar - 0.9%

Types - Both plagioclase and untwinned types

Tourmaline - 0.3%

Types - Both brown and green

Framework Minerals: (cont)

Glauconite - Tr.

Epidote - Tr.

Rock Fragments:

Chert - 1.7%

Schist or phyllite - Tr.

Mudstone - 0.5%

Carbonate grains - 1.1%

Compositional Maturity

The high quartz and chert content indicate a mature composition. It is suggested, however, that the maturity is in part derived from the fact that this is a second cycle sandstone.

Diagenesis

The matrix appears to be completely altered to authigenic chlorite and in addition authigenic quartz cement is pervasive.

Matrix Minerals

Except for silt sized quartz grains and a few spots where some questionable iron stained kaolinite can be seen the original matrix minerals seem to have gone to authigenic chlorite.

Cement Minerals

Quartz both as overgrowths and pore filling. However, matrix chlorite is a great aid in lithification.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Pre-existing sandstone seems to be the chief contributing rock. A little phyllite and mudstone would indicate minor crops of these rocks.

Climate and Relief - Modest relief and a temperate climate are about all that are required.

Depositional Environment and Transport Mechanism - Stream transportation to a marine or paralic environment of low energy.

Gilbert Classification

Percent matrix - 15.7% of rock

Quartz, quartzite and chert - 97.8% of framework

Feldspar and granitic rock fragments - 1.4%

Unstable Lithics - 0.8%

Rock name - Quartz Wacke

Sample Number RRR 922

Formation Kemik Sandstone Equivilent

Locality Northwest Alaska

Number of points counted 603

Slide Quality fair

Texture

Wentworth Size Classes

Very Fine 95%
Fine 5

Framework: 68.0%

Porosity - 1.5%

Median grain size - Very Fine

Sorting - Good

Roundness - Extensively modified by overgrowths, originally perhaps rounded to subrounded

Matrix: 18.0%

Cement: 12.4%

Quartz 100%

Textural Maturity: Mature if grains only are counted, immature considering the matrix.

Mineralogy

Framework Minerals:

Quartz - 63.7%

Types - (1) Contains euhedral muscovite crystals
(2) Contains liquid inclusions with moving vapor bubbles
Both igneous and metamorphic quartz grains present

Feldspar - 0.5%

Types - Plagioclase only was idendified

Mica - Tr.

Types - Only muscovite

Framework Minerals (cont)

Glauconite - Tr.

Zircon - Tr.

Rock Fragments:

Chert - 3.0%

Schist or phyllite - 0.3%

Compositional Maturity

Mature. The maturity, it is thought, stems from the second cycle nature of the sandstone.

Diagenesis

The original clay matric not completely changed to authigenic chlorite. Considerable quartz cement both as overgrowths and pore filling.

Matrix Minerals

It is probable that the original matrix consisted of silt sized quartz grains and clay material, along with a little organic matter. The clay minerals seem to be completely altered to chlorite.

X-ray analysis. In addition to the always present quartz peaks a peak at 14.4 A was at 14.1 A after glocolation and was still there after heating to 550°C for one half hour. There were also good peaks at 7.1 and 3.53 A. The mineral was termed chlorite.

As interesting as what was present was what was not present. No smectite, mica nor kaolinite.

Cement Minerals

Quartz both as overgrowth and pre filling. However, matrix chlorite was of considerable aid in lithification. Minor authigenic pyrite.

INFERENCE AND CONCLUSIONS

The similarity of this rock to RRR 918 was so great as to render seperate discussions superfluous. See RRR 918 for discussion.

Gilbert Classification

Percent matrix - 18.0% of rock

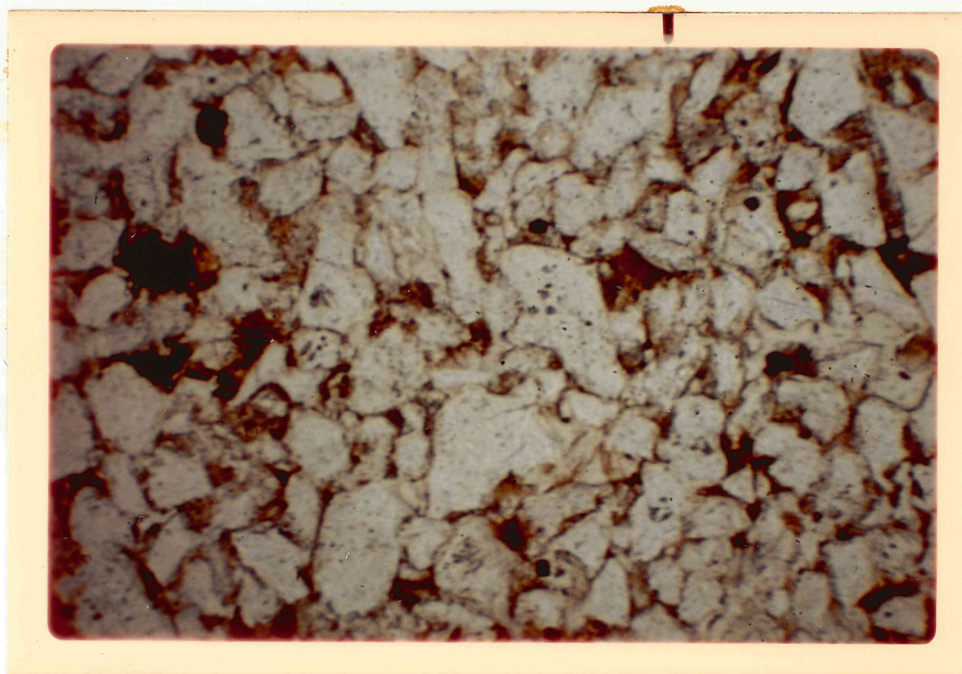
Quartz, quartzite and chert - 98.9%

Feldspar and granitic rock fragments - 0.7%

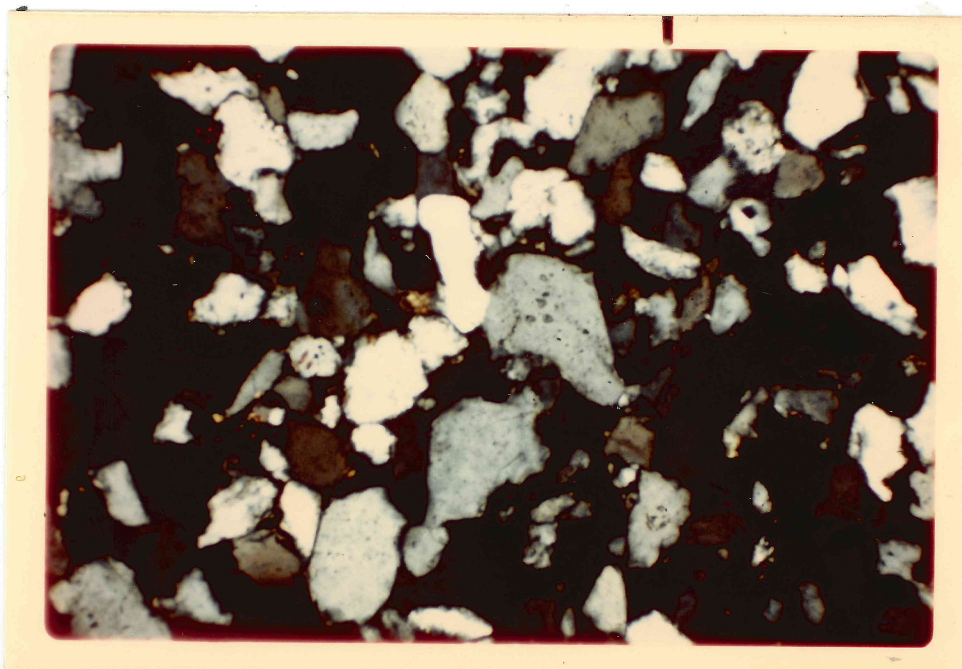
Unstable Lithics - 0.4%

Rock name - Quartz Wacke

Figure 3



Kemik Sandstone Equivalent. RRR 922, field 1 mm wide, parallel nicols. Clasts largely quartz, minor chert and feldspar. Matrix of quartz silt, authigenic chlorite and a little pyrite. Cement is quartz both as overgrowths and pore filling.



Same as above, crossed nicols.

KUKPOWRUK FORMATION

Thin Sections

RRR 931, 977, 978, 982, 1022, 1040, 1045, 1049, 1054, 1056, 1158, 1164, 1168 and 1173.

Age and Field Relations (Rose')

These rocks are from the Lower Cretaceous of northwestern Alaska, the marine correlative of the Corwin Formation. Samples 1022 through 1056 are from the upper part of the type section with the higher numbers representing higher stratigraphic positions as illustrated.

RRR 1056
1054
1049
1045
1040
1022

These Kukpowruk samples probably represent different strandline depositional environments. The source area for the sandstone lies to the south and southwest from the Ancestral Brooks Range.

RRR 1022 through 1056 as above.

Texture

The median grain size in all samples is fine or very fine. Sorting, so far as the sand is concerned, is good to fair. The matrix is 11% or over for all samples reaching a high of 23% hence all are wackes. All are also tightly cemented reducing the porosity to less than 3%,except for one sample. Grains are angular to subrounded or rounded but the original shape of the quartz grains have been altered by overgrowths and all are somewhat obscured by cement. Originally the grains might well have been subrounded.

Mineralogy

Clasts: The mineralogy of the clases is best shown in the table on the next page. The relatively high feldspar content is noteworthy.

Matrix: An X-ray analysis of the matrix minerals in RRR 1022 revealed considerable chlorite and kaolinite and minor mica in addition to the ubiquitous quartz. The same minerals seem characteristic of the matrix of the other samples examined in this suite. The quartz may be present as silt or cement.

Cement: Carbonate and quartz are the chief cementing minerals but authigenic chlorite appears in such large pure masses that it was also termed cement, although doubtless it is derived from the matrix.

	RRR 1022	RRR 1040	RRR 1045	RRR 1049	RRR 1054	RRR 1056	AVE.
Framework	61.2%	45.1%	56.6%	62.2%	66.7%	52.1%	57.3%
Quartz	22.2	16.4	30.1	32.1	25.6	22.2	24.8
Chert	17.0	5.7	2.7	8.7	11.6	4.1	8.3
Feldspar	6.5	12.4	15.6	11.8	13.7	13.2	12.2
Phyllite, mica chlorite	9.2	8.4	5.3	7.7	11.4	8.4	8.4
Mudstone	7.1	1.5	1.2	0.4	1.6	3.1	2.5
Carbonate	Tr.	0.6	1.7	0.6	Tr.	0.4	0.6
Volcanic	-	Tr.	-	0.4	1.2	0.6	0.4
Matrix	12.0	22.0	22.9	10.9	16.3	10.9	15.8
Cement	23.0	32.4	19.8	24.3	8.8	36.1	24.1
Quartz	80.5% of cement	24.4	40.7	40.7	60.6	19.0	44.6
Carbonate	12.5	60.0	46.9	37.6	9.8	77.8	40.5
Chlorite	7.0	15.8	12.3	21.6	29.5	3.2	14.9
Porosity	2.9	0.4	0.6	2.5	8.1	0.9	2.6
Classification	Lithic Wacke	Feld-spathic Wacke	Feld-spathic Wacke	Feld-spathic Wacke	Lithic Wacke	Feld-spathic Wacke	Feld-spathic Wacke

Distinctive Characteristics

The relatively high feldspar content and the abundant kaolinite in the matrix are distinctive. The chlorite in some specimens is unusually coarse, leading to its identification as cement rather than matrix chlorite, although it is probably true that the chlorite originated in matrix materials.

Provenance

Pre-existing sedimentary rocks, as suggested by Rose', and low rank metamorphics are the major rock types supplying clasts to these sandstones. Sandstones should supply the igneous derived quartz and some feldspar, cherty limestones and cherty organic rich or phosphatic mudstones are also involved. Occasional mafic volcanics and perhaps a granitic stock of limited extent are also indicated. Low rank metamorphic rocks are required as they are for almost all the Cretaceous sandstones studied.

The provenance rocks seem very similar to those required for the Corwin Formation.

Relief and Climate

Presence of the fragile phyllite, mudstone and volcanics indicate swift and short transport and perhaps an arid or cold climate, although these rocks are not particularly indicative of climate. Moderate to high relief is suggested.

Transportation and Deposition

Stream transportation and deposition in a marine or paralic environment of relatively low energy is suggested. Carbonate grains appear to be in part rounded rhombs of shell origin and in part polycrystalline grains which might have an origin in nearby limestones, although this last origin seems remote. Pyrite in one sample suggests a stagnant reducing environment.

Diagenetic History

Presence of abundant kaolinite indicates that diagenesis, in at least some of these samples, was less severe than in many of the other Cretaceous sandstones.

Depositional Environment and Transport Mechanism - Stream transport and probable deposition in a marine environment of modest energy, perhaps lagoonal or shallow neritic.

Gilbert Classification

Percent matrix - 12.0% of rock

Quartz, quartzite and chert - 63.5% of framework

Feldspar and granitic rock fragments - 10.8%

Unstable Lithics - 25.7%

Rock Name - Lithic Wacke

Sample Number RRR 1040

Formation Kukpowruk

Locality Upper part of type section, northwestern Alaska

Number of points counted 663

Slide quality good

Texture

Wentworth Size Classes

Very Fine 93%
Fine 7

Framework:

Porosity - 0.4%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to subangular. Some modification by overgrowths.

Matrix: 22.0%

Cement: 32.4%

Carbonate	60.0% of cement
Quartz	24.2
Chlorite	14.4
Mica	1.4

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 16.4%

Types - (1) Euhedral inclusions with phylosilicates. Common.
(2) Liquid-gas bubbles. Rare.
Both igneous and metamorphic quartz, but metamorphic most common.

Feldspar - 12.4%

Types - Plagioclase and untwinned

Micas - 1.8% Muscovite and biotite

Chlorite - Tr.

Rock Fragments:

Chert - 5.7%

Volcanic - Tr.

Schist or phyllite - 6.6%

Mudstone, black opaque (graphitic or phosphatic) - 1.5%

Carbonate grains - 0.6%

Compositional Maturity: Immature

Diagenesis

Quartz and carbonate cement, chlorite and perhaps some coarse mica. (Although termed authigenic the mica might well be detrital)

Matrix Minerals

Quartz silt, iron-stained kaolinite, chlorite, mica and organic matter.

Cement Minerals

Quartz both as overgrowths and pore filling, carbonate, some coarse chlorite and some questionable mica.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Chiefly sedimentary. Cherty phosphatic or organic mudstone, cherty limestone, sandstone. Abundant low rank metamorphics, and minor mafic volcanics. Perhaps minor granitics.

Climate and Relief - Moderate to high relief and moderately nearby source. perhaps a temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport into a very low energy marine environment, lagoonal or neritic.

Gilbert Classification

Percent matrix - 22.0% of rock

Quartz, quartzite and chert - 51.2%

Feldspar and granitic rock fragments - 28.6%

Unstable Lithics - 20.2%

Rock Name - Arkosic Wacke

Sample Number RHR 1045

Formation Kukpowruk

Locality Upper part of type section, northwestern Alaska

Number of points counted 655

Slide quality good

Texture

Wentworth Size Classes

Very Fine 96%
Fine 4

Framework: 56.6% of rock

Porosity - 0.6%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to subrounded, modified by quartz overgrowths.

Matrix: 22.9%

Cement: 19.8%

Carbonate - 46.9% of cement
Quartz 40.7
Chlorite 12.3

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 30.1%

Types - (1) Euhedral inclusions with phyllosilicates. Common.
(2) Liquid-gas bubbles. Rare.
Both metamorphic and igneous quartz, metamorphic most common.

Feldspar - 15.6%

Types - Plagioclase, microcline and untwinned

Micas - 0.9% Muscovite and biotite

Chlorite - Tr.

Rock Fragments:

Chert - 2.7%

Schist or phyllite - 4.4%

Mudstone, black graphitic or phosphatic - 1.2%

Carbonate grains - 1.7%

Remarks. Also counted as mudstone were some cloudy white to iron-stained opaque clay masses.

Compositional Maturity: Immature

Diagenesis

Quartz and carbonate cement and authigenic chlorite.

Matrix Minerals

Quartz silt, clay (kaolinite?) and chlorite.

Cement Minerals

Quartz both as overgrowths and pore filling, carbonate and some coarse chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Dark cherty organic rich or phosphatic mudstones or shales, cherty limestones, abundant low rank metamorphics, minor sandstones and perhaps some granitic rocks.

Climate and Relief - Moderate to high relief with source rocks reasonably close, perhaps a temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport to a very low energy marine environment.

Gilbert Classification

Matrix percent - 22.9% of rock

Quartz, quartzite and chert - 60.7% of framework

Feldspars and granitic rock fragments - 28.8%

Lithics of unstable nature - 10.4%

Rock Name - Arkosic Wacke

Sample Number RRR 1049

Formation Kukpowruk

Locality Upper part of type section, northwestern Alaska

Number of points counted 667

Slide quality good

Texture

Wentworth Size Classes

Very Fine 79%
Fine 21

Framework: 62.2% of rock

Porosity - 2.5%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to rounded. Obscured by quartz overgrowths and cement. Perhaps originally subrounded.

Matrix: 10.9%

Cement: 24.3%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 32.1%

Types - (1) Liquid-gas bubbles.
(2) Brown acicular crystals as inclusions. Common
(3) Euhedral inclusions and phyllosilicates.
Both igneous and metamorphic quartz common.

Feldspar - 11.8%

Types - Plagioclase, untwinned, myrmekite.

Micas - 0.7% Muscovite and biotite

Chlorite or glauconite - Tr.

Zircon - Tr.

Rock Fragments:

Chert - 8.7%

Volcanics - 0.4%

Schist or phyllite - 7.0%

Mudstone - 0.7%

Carbonate grains - 0.6%

Remarks. Volcanic. Mafic, plagioclase laths in a green chloritic matrix.
Mudstone. Black graphitic or phosphatic lumps.
Chert. Some clear some loaded with carbonate

Compositional Maturity: Immature

Diagenesis

Quartz and carbonate cement, authigenic chlorite in the matrix.

Matrix Minerals

Silt sized quartz and feldspar, sparse clay, authigenic chlorite, some organic material

Cement Minerals

Quartz, carbonate some coarse chlorite and minor albite.

INFERENCE AND CONCLUSIONS

Provenance

Rock Types - Sedimentary rocks include sandstone, cherty organic or phosphatic mudstone, perhaps cherty limestone. Low rank metamorphics, minor mafic volcanics and perhaps very minor granitics.

Climate and Relief - Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a marine environment of moderate energy, perhaps littoral lagoonal or near shore neritic.

Gilbert Classification

Percent matrix - 10.9% of rock.

Quartz, quartzite and chert - 67.0% of framework

Feldspars and granitic rock fragments - 19.5%

Unstable Lithics - 13.5%

Rock Name - Feldspathic Wacke (near Arenite)

Sample Number RRR 1054

Formation Kukpowruk

Locality Upper part of type section, northwestern Alaska

Number of points counted 691

Slide quality poor, quartz yellow, too many holes

Texture

Wentworth Size Classes

Very Fine 35%
Fine 61
Medium 4

Framework: 66.7% of rock

Porosity - 8.1% (Thought due in large part to plucking during manufacture of thin section)

Median grain size - Fine

Sorting - Fair

Roundness - Angular to rounded, shape of quartz grains obscured by overgrowths.

Matrix: 16.3%

Cement: 8.8%

Carbonate 9.8% of cement
Quartz 60.6
Chlorite 29.5

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 25.6%

Types - (1) Liquid-gas inclusions. Common
(2) Acicular aligned inclusions.
(3) Large euhedral inclusions of phyllosilicates.
Both metamorphic and igneous quartz common.

Feldspar - 13.7%

Types - Plagioclase, microcline, untwinned, micrographic grains.

Micas - 0.4% Muscovite and biotite

Garnet - Tr.

Rock Fragments:

Chert - 11.6%

Volcanic - 1.2%

Schist or phyllite - 11.0%

Mudstone - 1.6%   Siltstone - 1.6%   Total mud and silt - 3.2%

Carbonate grains - Tr.

Remarks. Chert. (1) Normal clear and cryptocrystalline
(2) Flamboyant chalcedony
(3) Brown cryptocrystalline
Volcanic. Plagioclase laths in a cryptocrystalline or chloritic groundmass.
Schist or phyllite - Dark and mica rich
Mudstone. (1) Black, opaque, phosphatic or graphitic
(2) Siltstone with quartz, feldspar, mica and clay matrix.
(3) Dark with aggregate polarization effects, argillite.

Compositional Maturity: Immature

Diagenesis

Quartz and carbonate cement with the quartz earlier, relatively coarse authigenic chlorite.

Matrix Minerals

Quartz silt, clay (kaolinite?), chlorite at times a black asphaltic or graphitic material, often noted filling vesicles.

Cement Minerals

Quartz both as overgrowths and pore filler, carbonate and coarse chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sedimentary sandstone, dark cherty mudstone or shale, perhaps cherty limestone. Low rank metamorphics, mafic volcanics, and perhaps minor granitic outcrops.

Climate and Relief - Moderate to high relief, probably temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a low energy marine environment.

Gilbert Classification

Percent matrix - 16.3% of rock

Quartz, quartzite and chert - 56.2% of framework

Feldspars and granitic rock fragments - 20.7%

Unstable Lithics - 23.1%

Rock Name - Lithic Wacke

Sample Number RRR 1056

Formation Kukpowruk

Locality Upper part of type section, northwestern Alaska

Number of points counted 698

Slide quality fair, too thick

Texture

Wentworth Size Classes

Very Fine 50%
Fine 50

Framework: 52.1% of rock

Porosity - 0.9%

Median grain size - Fine (see above)

Sorting - Good

Roundness - Angular to well rounded. Quartz grabns somewhat altered by overgrowths. Originally subrounded to rounded?

Matrix: 10.9%

Cement: 36.1%

Carbonate 77.8% of cement
Quartz 19.0
Chlorite 3.2

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 22.2%

Types - (1) Euhedral inclusions of phyllosilicates
(2) Liquid-gas bubbles
Both igneous and metamorphic quartz

Feldspar - 13.2%

Types - Plagioclase (andesine or albite), microcline and untwinned

Micas - 1.4% Muscovite and biotite

Chlorite - 0.4%

Tourmaline - Tr.

Rock Fragments:

Chert - 4.1%

Volcanic - 0.6%

Schist or phyllite - 6.6%

Mudstone - 3.1%

Polycrystalline carbonate grains - 0.4%

Remarks. Chert. Both clear and cloudy with many inclusions.
Phyllite or schist. Finegrained muscovite and quartz or coarser with biotite.
Volcanic. Plagioclase laths in a matrix now altered to clay.
Mudstone. Either black graphitic or phosphatic masses or siltstone with quartz and mica.
Carbonate grains. Polycrystalline.

Compositional Maturity - Immature

Diagenesis

Quartz and carbonate cement, chlorite both as matrix and cementing.

Matrix Minerals

Quartz silt, cloudy iron stained clay, chlorite and organic matter.

Cement Minerals

Quartz as both overgrowths and pore filling, carbonate and coarse chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstone, dark cherty mudstone or shale, perhaps cherty limestone. Low rank metamorphic, minor mafic volcanic and perhaps minor granitic outcrops.

Climate and Relief - Moderate to high relief and a nearby source, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport to a comparatively low energy marine environment.

Gilbert Classification

Percent matrix - 10.9% of rock

Quartz, quartzite and chert - 48.1% of framework

Feldspars and granitic rock fragments - 28.6%

Unstable Lithics - 23.3%

Rock Name - Arkosic Wacke

RRR 931, 977, 978, 982, 1158, 1164, 1168 and 1173

Texture

The median grain size of all samples is very fine to fine and sorting, so far as the sand is concerned, is good with only two or less grade sizes involved in five of the eight samples and only three in the remaining. The matrix is not high, averaging about 7.5%, but heavy cementation has filled the pores and kept the porosityy down to less than 4%. Grains were angular to rounded but the original shape of quartz grains is commonly altered by overgrowths. Originally the grains probably averaged subrounded.

Mineralogy

Clasts: The mineralogy of the clasts is best seen in the table on the following page. Quartz, chert, feldspar and carbonate grains are the most abundant and unstable fine grained rock fragments average slightly more than feldspar fragments. The carbonate grains are perhaps the most interesting and are thought to be largely of organic origin.

Matrix: An X-ray analysis of the matrix of RRR 1164 revealed Kaolinite, chlorite and mica in addition to quartz. The same minerals were noted petrographically in all the other samples. The mica, quartz and kaolinite are considered detrital, the chlorite authigenic.

Cement: Carbonate is predominate furnishing 70% of the cement with quartz 23% and authigenic chlorite 7%.

	RRR 931	977	978	982	1158	1164	1168	1173	Ave.
Framework	59.5%	52.4%	52.6%	68.8%	54.1%	53.4%	66.8%	75.1%	60.3%
Quartz	13.4	21.6	23.2	16.3	15.9	14.4	20.6	27.2	19.1
Chert	7.6	10.8	13.6	36.2	7.8	8.9	20.8	33.4	17.4
Feldspar	3.0	12.5	7.4	4.7	6.2	9.6	12.7	5.2	7.7
Phyllite, mica and chlorite	1.4	4.5	3.8	2.9	4.6	11.5	6.4	2.3	4.7
Mudstone	0.3	2.2	1.9	8.8	2.4	4.0	4.2	4.4	3.5
Carbonate	33.7	0.3	2.2	Tr.	17.0	4.6	1.2	2.6	7.7
Volcanic	-	0.4	0.4	-	-	Tr.	0.9	-	0.2
Matrix	10.6	6.1	7.0	3.6	2.7	6.7	13.3	10.2	7.5
Cement	16.5	37.7	35.9	27.5	41.6	38.9	15.0	6.5	27.4
Quartz (% of cement)	12.5	11.2	12.5	26.0	11.2	9.4	39.2	62.8	23.1
Carbonate	74.0	80.6	78.6	71.8	86.3	80.3	51.5	37.2	70.0
Chlorite	13.5	8.2	8.9	2.2	2.5	10.2	9.3	-	6.9
Porosity	13.4	3.8	4.5	-	1.6	0.9	4.8	8.2	4.6

Classification

RRR 931 - Calcarenite

RRR 977 - Feldspathic Arenite

RRR 978 - Lithic Arenite

RRR 982 - Lithic Arenite

RRR 1158 - Calcarenite

RRR 1164 - Lithic Arenite

RRR 1168 - Feldspathic Wacke

RRR 1173 - Lithic Wacke

Average - Lithic Arenite

Distinguishing Features

The high carbonate content of these rocks, both as grains and as cement, is distinctive. Two samples, RRR 931 and 1158, contained more than 50% carbonate and, hence, should be termed sandy limestones (very fine calcarenites). The relatively high feldspar content and low matrix content are also worthy of note.

Provenance

Sedimentary rocks as a source are very important. Cherty limestones and dark cherty mudstones or shales and sandstones containing igneous derived quartz and perhaps feldspar must be important. Low rank metamorphics are abundant and modest amounts of mafic volcanics must be available. Rare granitic grains coupled with the presence of microcline and micrographic intergrowths of quartz and alkali feldspar in nearly all of the rocks examined suggest a granitic outcrop.

Climate and Relief

Swift transportation of the fragile rock grains must involve swift flowing streams, hence considerable relief. Much fresh feldspar and mafic volcanics suggests a nearby source and perhaps a severe climate to slow chemical weathering.

Transportation and Deposition

Stream transportation and deposition in a marine or paralic environment of at least moderate energy is suggested. The high carbonate content, probably from shell fragments largely, suggests marine. Lagoon merging into beach might be indicated.

Diagenetic History

Solution and reprecipitation of quartz grains and carbonate shell material to form the abundant cement found in these rocks is the most apparent result of diagenesis. Quartz seems to be earliest. Authigenic chlorite, sometimes in coarse cementing masses is common but the presence of abundant kaolinite indicates diagenetic alteration of the matrix is by no means complete.

Classification

Two rocks were classified as limestones. If the organic origin of the carbonate grains was absolutely clear such rocks might be termed sandy biosparite. Without such assurance the rocks were termed very fine calcarenites.

The sandstones contained just enough matrix to lie on the arenite-wacke boundary and the feldspar and unstable fine grained rock grains were well balanced causing some rocks to be termed feldspathic, others lithic.

Sample Number RRR 931

Formation Kukpowruk

Locality Northwestern Alaska

Number of points counted 632

Slide quality poor, quartz yellow, many holes plucked in slide by grinding

Texture

Wentworth Size Classes

Very Fine 98%
Fine 2

Framework: 59.5% of rock

Porosity - 13.4%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to rounded, some quartz grains altered by overgrowths

Matrix: 10.6%

Cement: 16.5%

Carbonate 74% of cement
Quartz 12.5
Chlorite 13.5

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 13.4%

Types - (1) Contains euhedral inclusions and phyllosilicates
(2) Liquid-gas bubbles
Both igneous and metamorphic quartz common

Feldspar - 3.0% Plagioclase

Micas - Tr. Muscovite and biotite

Glauconite - 0.3%

Chlorite - Tr.

Rock Fragments:

Chert - 7.6%

Schist or phyllite 0.9%

Mudstone - 0.3%

Carbonate grains - 33.7%

Remarks. Chert. Some clear and cryptocrystalline, some flamboyant chalcedony, some containing carbonate.
Phyllite. Brown and fine grained but with good aggregate polarization. Some biotite schist.
Mudstone. Generally black and organic or phosphate rich.
Carbonate grains. Most commonly single crystals but some are polycrystalline. They range from angular to subrounded but are commonly surrounded by a reddish brown iron stained rim and appear to be honest clasts, not cement.

Compositional Maturity: Immature

Diagenesis

Quartz and carbonate cement and some authigenic chlorite.

Matrix Minerals

Some silt grains of quartz?, strongly iron stained clay and chlorite. Rendered somewhat confusing since carbonate cement impregnates the matrix. Organic matter, sometimes in large irregular masses.

Cement Minerals

Quartz in overgrowths and occasional vesicle fillings, abundant carbonate, some coarse chlorite and an unknown material consisting of a clear amber material with flamboyant extinction and gray interference color filling vesicles.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstone, cherty dark mudstone and perhaps cherty limestone. Low rank metamorphics.

Climate and Relief - At least moderate relief, climate not clear.

Depositional Environment and Transport Mechanism - Stream transport into a marine environment of moderate energy, perhaps paralic.

Classification

If the pores are excluded and all carbonate, both grains and cement, summed up it forms 53% of the rock. If the carbonate clasts are shell fragments this rock would be termed a Sandy Biosparite. If it is not deemed suitable to assume the carbonate grains are of organic origin then it would be best to term the rock a Very Fine Calcarenite.

If the carbonate grains, which form 56.6% of the framework, are ignored the rock could be classified as a sandstone as follows.

Percent matrix - 10.6% of rock

Quartz, quartzite and chert - 83.1% of framework

Feldspars and granitic rock fragments - 11.9%

Unstable Lithics - 5.0%

Rock Name - Feldspathic Wacke

Sample Number RRR 977

Formation Kukpowruk

Locality Northwestern Alaska

Number of points counted 685

Slide quality good

Texture

Wentworth Size Classes

Very Fine 82%
Fine 18

Framework: 52.4% of rock

Porosity - 3.8%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to rounded, some quartz grains altered by overgrowths

Matrix: 6.1%

Cement: 37.7%

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 21.6%

Types - (1) Liquid gas bubbles
(2) Inclusions of Euhedral crystals
(3) Polycrystalline with parallel elongate crystals
Both igneous and metamorphic quartz, metamorphic most common.

Feldspar - 12.5%

Types - Plagioclase, microcline, untwinned.

Micas - 1.6% Muscovite and biotite

Chlorite in coarse grains - 1.0%

Glauconite - Tr.

Zircon - Tr.

Rock Fragments:

Chert - 10.8%

Volcanic - 0.4%

Schist or phyllite - 1.9%

Mudstone - 2.2%

Carbonate grains - 0.3%

Remarks. Chert. Clear or brown some flamboyant chalcedony.
Volcanic. Plagioclase laths in a chloritic groundmass. Several grains appear to be devitrified glass.
Schist or phyllite. Normal muscovite schist, some very dark phyllite, organic rich.
Mudstone. Some light colored claystone some black and organic rich.

Compositional Maturity: Immature

Diagenesis

Carbonate, quartz and minor chlorite cement.

Matrix minerals

Silt sized quartz and feldspar grains, cloudy iron stained clay, dark organic matter and chlorite.

Cement Minerals

Carbonate, quartz and coarse chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherty black mudstones, cherty limestones, sandstone, abundant low rank metamorphics, volcanics both mafic and silicic and perhaps minor granitics.

Relief and climate - Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation into a marine environment of considerable energy, perhaps a bar or tidal channel.

Gilbert Classification

Percent matrix - 6.1% of rock

Quartz, quartzite and chert - 65.5% of framework

Feldspar and granitic rock fragments - 25.4%

Unstable Lithics - 9.1%

Rock Name - Arkose or Arkosic Arenite

Sample Number ERR 978

Formation Kukpowruk

Locality Northwest Alaska

Number of points counted 690

Slide quality - poor, quartz yellow, carborundum grit bound in slide

Texture

Wentworth Size Classes

Very Fine 69%
Fine 31

Framework: 52.6% of rock

Porosity - 4.5%

Median grain size - Very Fine

Sorting - good

Roundness - Angular to well rounded, quartz grains shape obscured by overgrowths. Originally perhaps subrounded to well rounded

Matrix: 7.0%

Cement: 35.9%

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 23.2%

Types - (1) Contains euhedral inclusions, comparatively clean quartz. Common
(2) Liquid-gas bubbles. Uncommon
(3) Oriented brown acicular inclusions
Both metamorphic and igneous quartz common

Feldspar - 7.4%

Types - Plagioclase, perthite, untwinned

Micas - 1.6% Muscovite and biotite

Coarse chlorite - Tr.

Zircon - Tr.

Rock Fragments:

Chert - 13.6%

Volcanic - 0.4%

Schist or phyllite - 2.2%

Mudstone - 1.9%

Carbonate grains - 2.2%

Remarks. Chert. Some clear and normal, some with elongate supbarallel grains, some brown and some with carbonate inclusions.
Schist. Many loaded with subparallel mica flakes and graphitic material.
Mudstone. Some brown some very black and opaque apparently loaded with organic matter.
Carbonate. One type grain apparently micrite a second type is composed of coarser grains forming polycrystalline grains. The commonest is made of single crystals.

Compositional Maturity: Immature

Diagenesis

Diagenetic activity chiefly marked by the cement, carbonate, quartz and modest chlorite.

Matrix Minerals

Silt sized quartz and feldspar grains, clay, organic matter and chlorite.

Cement Minerals

Carbonate, quartz and coarse chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Dark, organic rich, cherty mudstones and shale, perhaps cherty limestone, sandstone, abundant low rank metamorphics, minor volcanics and perhaps very minor granitic outcrops.

Climate and Relief - Moderate to high relief and temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a relatively high energy marine or paralic environment, perhaps tidal channel or bar.

Gilbert Classification

Percent matrix - 7.0% of rock

Quartz, quartzite and chert - 75.6% of framework

Feldspars and granitic fragments - 15.2%

Unstable Lithics - 9.2%

Rock Name - Feldspathic Arenite

Sample Number RRR 982

Formation Kukpowruk

Locality Northwestern Alaska

Number of points counted 658

Slide quality good

Texture

Wentworth Size Classes

Very Fine	33%
Fine	54
Medium	13

Framework: 68.8% of rock

Porosity - 0%

Median grain size - Fine

Sorting - Fair

Roundness - Angular to rounded, quartz grains altered by overgtowths.

Matrix: 3.6%

Cement: 27.5%

Carbonate	71.8% of cement
Quartz	26.0
Chlorite	2.2

Textural Maturity: Mature

Mineralogy

Framework Minerals:

Quartz - 16.3%

Types - (1) Euhedral inclusions. Common
(2) Liquid-gas bubbles.
(3) Contains many irregular inclusions
Both igneous and metamorphic quartz common.

Feldspar - 4.7%

Types - Plagioclase, micrographic intergrowths, untwinned

Micas - 0.6% Muscovite and biotite

Chlorite grains - Tr.

Rock Fragments:

Chert - 36.2%

Schist or phyllite - 2.3%

Mudstone - 8.8%

Polycrystalline carbonate grains - 0.6%

Remarks. Chert. (1) Normal cryptocrystalline either clear or brown
(2) Contains carbonate
(3) Flamboyant chalcedony
Schist. Some quartz rich consisting of quartz and mica.
Mudstone. Several kinds.
(1) Siltstone, quartz and mica with clay
(2) Black organic rich, may have quartz veinlets
(3) Light brown cryptocrystalline

Compositional Maturity: Immature

Diagenesis

Largely quartz and carbonate cement, modest chlorite.

Matrix Minerals

Quartz silt, iron stained clay (kaolinite?), organic matter and chlorite.

Cement Minerals

Quartz, carbonate and minor authigenic chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherty phosphatic or organic mudstones or shales, cherty limestones and sandstones. Abundant low rank metamorphics and perhaps some granitic rocks.

Climate and Relief - Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport into marine or paralic environment of high energy, perhaps tidal channel or bar.

Gilbert Classification

Percent matrix - 3.6% of rock

Quartz, quartzite and chert - 76.8% of framework

Feldspars and granitic rock fragments - 6.9%

Unstable Lithics - 16.3%

Rock Name - Subfeldspathic Lithic Arenite

Sample Number RRR 1158

Formation Kukpowruk

Locality Northwestern Alaska

Number of points counted 666

Slide quality good

Texture

Wentworth Size Classes

Very Fine 100%

Framework: 54.1% of rock

Porosity - 1.6%

Median grain size - Very Fine

Sorting - Excellent

Roundness - Angular to rounded, quartz grains altered by overgrowths

Matrix: 2.7%

Cement: 41.6%

Carbonate	86.3%	of cement
Quartz	11.2	
Chlorite	2.5	

Textural Maturity: Mature

Mineralogy

Framework Minerals:

Quartz - 15.9%

Types - (1) Euhedral crystals and chlorite as inclusions
(2) Liquid-gas bubbles
Both igneous and metamorphic quartz

Feldspar - 6.2%

Types - Plagioclase, microcline, untwinned

Micas - 1.5% Muscovite and biotite

Chlorite - Tr.

Rock Fragments:

Chert - 7.8%

Schist or phyllite - 3.1%

Mudstone - 2.4%

Carbonate grains - 17.0%

Remarks. Mudstone. Usually dark almost opaque organic or phosphatic rich, some amber, translucent but isotropic.
Carbonate grains. Mostly single crystals, some polycrystalline, many rounded and rimmed by red iron oxide.

Compositional Maturity: Immature.

Diagenesis

A great deal of carbonate and quartz cement, minor authigenic chlorite.

Matrix Minerals

Some quartz silt, cloudy, opaque, iron stained clay, some fine mica, authigenic chlorite and organic matter.

Cement Minerals

Quartz both as overgrowths and vesicle filling, abundant carbonate and minor coarse chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sedimentary chiefly. Sandstone, cherty black mudstone and perhaps cherty limestone. Abundant low rank metamorphic and perhaps minor granitic rocks.

Climate and Relief - Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport to a moderately high energy paralic or marine environment. Bar, littoral or tidal channel?

Classification

Excluding pores, carbonate forms 53.7% of this rock, hence it might well be termed a limestone. If the single crystal grains are shell fragments it should be classified as a Sandy Biosparite. If this assumption is not made it might best be termed a Very Fine Calcarenite.

Classification (continued)

Excluding the carbonate grains and the abundant carbonate cement and classifying the rock on the basis of its matrix and remaining framework grains the following is obtained.

Percent matrix - 2.7% of rock

Quartz, quartzite and chert - 66.9% of remaining framework

Feldspar and granitic rock fragments - 17.4%

Unstable Lithics - 15.7%

Rock Name - Feldspathic Arenite

Sample Number RRR 1164

Formation Kukpowruk

Locality Northwestern Alaska

Number of points counted 653

Slide quality fair

Texture

Wentworth Size Classes

Very Fine 64%
Fine 36

Framework: 53.4% of rock

Porosity - 0.9%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to rounded, some quartz grains altered by overgrowths

Matrix: 6.7%

Cement: 38.9%

Carbonate 80.3% of cement
Quartz 9.4
Chlorite 10.2

Textural Maturity: Submature to mature

Mineralogy

Framework Minerals:

Quartz - 14.4%

Types - (1) Liquid-gas bubbles
(2) Many irregular inclusions
(3) Euhedral chlorite or muscovite inclusions
Both igneous and metamorphic quartz present

Feldspar - 9.6%

Types - Plagioclase, untwinned, micrographic intergrowths of quartz and alkali feldspar.

Micas - 0.6% Muscovite and biotite

Rock Fragments:

Chert - 8.9%

Volcanic - Tr.

Schist or phyllite - 10.9%

Quartzite - 0.3%

Mudstone - 4.0%

Carbonate grains - 4.6%

Granitic fragments - Tr.

Remarks. Chert. (1) Clear or pale brown cryptocrystalline
(2) Carbonate and chlorite inclusions
Volcanic. Mafic, plagioclase phenocrysts in a red, altered groundmass.
Schist or phyllite. Muscovite rich, good schistose or phyllitic texture.
Mudstone. (1) Black, opaque, organic or phosphatic.
(2) Siltstone, with quartz and feldspar cemented by chlorite.
(3) Siltstone with mica.
(4) Siltstone with carbonate cement.
Carbonate grains. Mostly single crystal, a few polycrystalline.

Compositional Maturity: Immature

Diagenesis

Much quartz and carbonate cement, minor authigenic chlorite.

Matrix Minerals

An X-ray analysis of the matrix minerals exhibited, in addition to the usual quartz peaks: A 14 A peak which would not expand on glycolation and was not affected by heat treatment. Chlorite.

A 7.2 A peak destroyed by heating accompanied by a secondary 3.57 A near the secondary chlorite 3.53 peak. Kaolinite.

A good 10 A mica peak.

The petrographic microscope revealed Quartz silt, iron stained clay (kaolinite), mica, chlorite and organic matter.

Cement Minerals

Chiefly carbonate with quartz and some coarse chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Abundant sedimentary and low rank metamorphic rocks and minor mafic volcanics and perhaps granitics. The sedimentary rocks include sandstone, cherty organic rich mudstones and perhaps cherty limestones.

Climate and Relief - Moderate to high relief and temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a paralic or marine environment of reasonably high energy.

Gilbert Classification

Percent matrix - 6.7% of rock

Quartz, quartzite and chert - 48.9% of framework

Feldspars and granitic rock fragments - 20.0%

Unstable Lithics - 31.1%

Rock Name - Lithic Arenite

Sample Number RRR 1168

Formation Kukpowruk

Locality Northwestern Alaska

Number of points counted 645

Slide quality fair, too many holes

Texture

Wentworth size Classes

Very Fine	24%
Fine	70
Medium	6

Framework: 66.8% of rock

Porosity - 4.8%

Median grain size - Fine

Roundness - Angular to rounded, quartz grains altered by overgrowths, suggest originally subangular to rounded.

Sorting - Fair

Matrix: 13.3%

Cement: 15.0%

Carbonate	51.5% of cement
Quartz	39.2
Chlorite	9.3

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 20.6%

Types - (1) Liquid-gas bubbles. Common.
(2) Contains brown acicular inclusions
(3) Euhedral inclusions, some phyllosilicates
Both igneous and metamorphic quartz common.

Feldspar - 12.7%

Types - Plagioclase, microcline, untwinned

Micas - 0.5% Muscovite, biotite

Zircon - Tr.

Rock Fragments:

Chert - 20.8%

Volcanic - 0.9%

Schist or phyllite - 5.9%

Mudstone - 4.2%

Carbonate grains - 1.2%

Granitic grains - Tr.

Remarks. Chert. Clear to brown and organic rich.
Volcanic. (1) Devitrified glass, perhaps silicic
(2) Plagioclase laths in a weathered groundmass.

Mudstone. (1) Siltstone, quartz, feldspar and mica
(2) Black, opaque graphitic or phosphatic.
(3) Brown, almost argillite.
Carbonate grains. Mostly single crystals, some polycrystalline. Rounded with red iron oxid rims.

Compositional Maturity: Immature

Diagenesis

Much carbonate and quartz cement, a little chlorite.

Matrix Minerals

Silt grains of quartz and feldspar, iron stained kaolinite, organic matter and chlorite.

Cement Minerals

Abundant carbonate and quartz and minor chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstone, cherty black mudstone or shale, cherty limestone. Abundant low rank metamorphics, minor volcanics and granitic rock.

Relief and Climate - Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport to a marine or paralic environment of moderate energy.

Gilbert Classification

Percent matrix - 13.3% of rock

Quartz, quartzite and chert - 63.6%

Feldspar and granitic rock fragments - 19.5%

Unstable Lithics - 16.9%

Rock Name - Feldspathic Wacke

Sample Number RRR 1173

Formation Kukpowruk

Locality Northwestern Alaska

Number of points counted 658

Slide quality Very poor. Too thin, too many holes, carborundum grit included in section.

Texture

Wentworth Size Classes

Very Fine	37%
Fine	62
Medium	1

Framework: 75.1% of rock

Porosity - 8.2%

Median grain size - Fine

Sorting - Fair

Roundness - Angular to rounded. Quartz overgrowths modify quartz grains. Perhaps originally subangular to rounded.

Matrix: 10.2%

Cement: 6.5%

Carbonate	37.2% of cement
Quartz	62.8

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 27.2%

Types - (1) Liquid-gas bubbles and brown acicular inclusions
(2) Clean quartz with small euhedral inclusions
(3) Polycrystalline with parallel elongate grains
Both igneous and metamorphic quartz with metamorphic most common.

Feldspar - 5.2%

Types - Plagioclase, microcline, untwinned, micrographic grains.

Micas - 0.5% Muscovite

Zircon - Tr.

Rock Fragments:

Chert - 33.4%

Schist or phyllite - 1.8%

Mudstone - 4.4%

Carbonate grains - 2.6%

Remarks. Chert. Some clean, some mixed with carbonate.
Schist or phyllite. Mica rich, some with dark opaque material, graphite?
Mudstone. Some dark and opaque but with quartz veinlets, some dark with organic matter but fine grained and showing some aggregate polarization; argillite?
Carbonate grains. Largely single crystal grains but some polycrystalline, all rimmed with red iron oxide.

Compositional Maturity: Immature

Diagenesis

Chiefly indicated by the quartz and carbonate cement.

Matrix Minerals

Silt sized quartz, often very rich in organic matter, clay and fine mica, minor authigenic chlorite.

Cement Minerals

Quartz and carbonate.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherty dark mudstones or shales, cherty limestones, sandstones, abundant low rank metamorphics, perhaps granitic rocks.

Climate and Relief - Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechainsm - Stream transportation to a marine or paralic environment of modest energy.

Gilbert Classification

Percent matrix - 10.2% of rock.

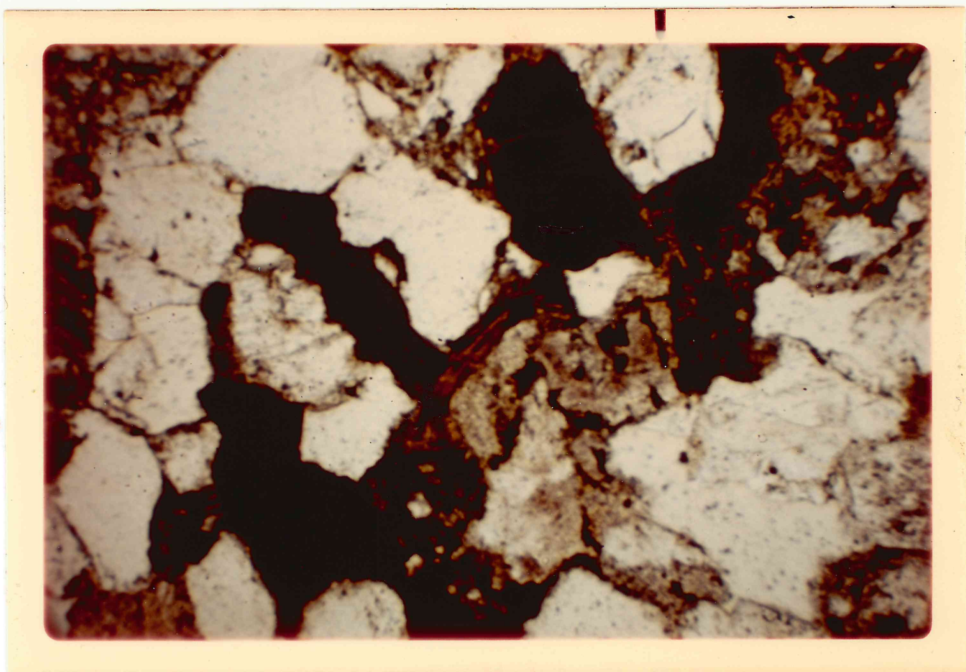
Quartz, quartzite and chert - 84.2%

Feldspars and granitic rock fragments - 7.2%

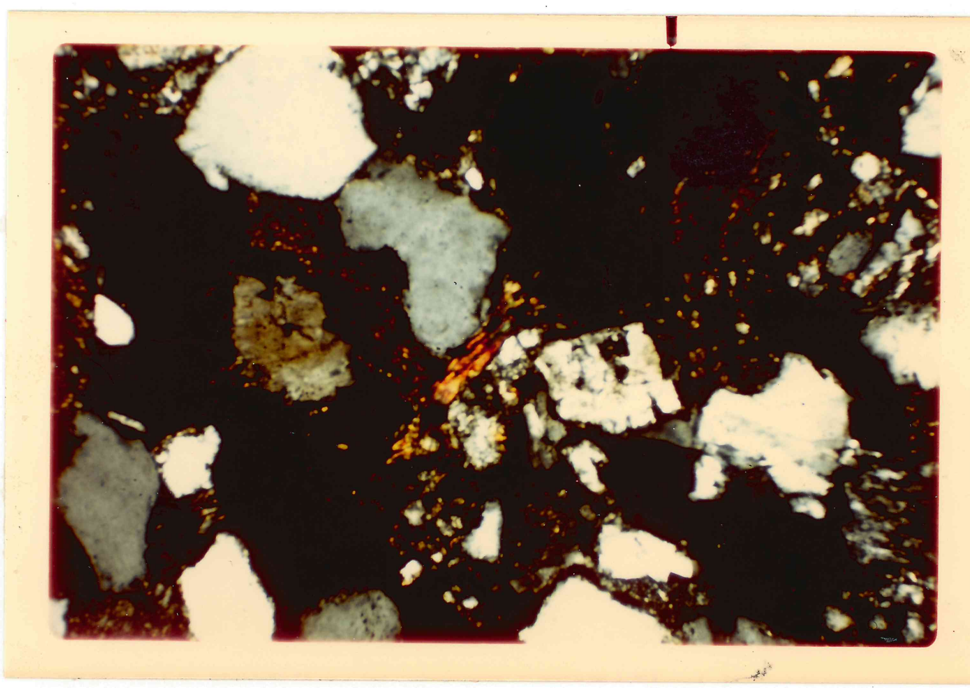
Unstable Lithics - 8.6%

Rock Name - Quartz Wacke

Figure 4

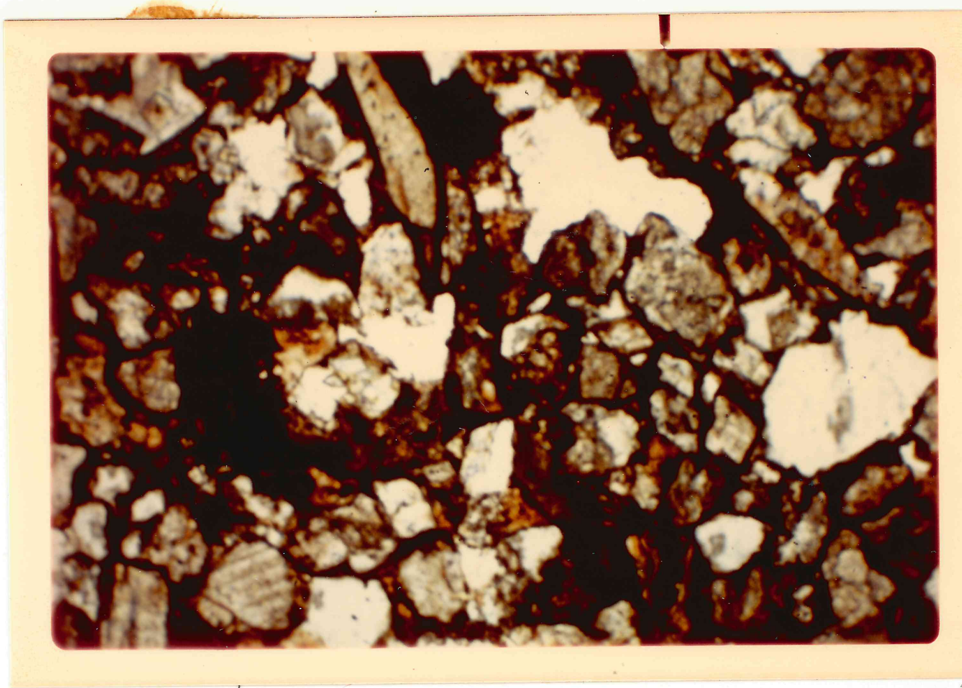


Kukpowruk Formation from the upper part of the type section. RRR 1054, field 1 mm wide, parallel nicols. Clasts of quartz, feldspar, phyllite, biotite, dark organic rich mudstone. Matrix of clay and silt grains. Cement chiefly quartz overgrowths.

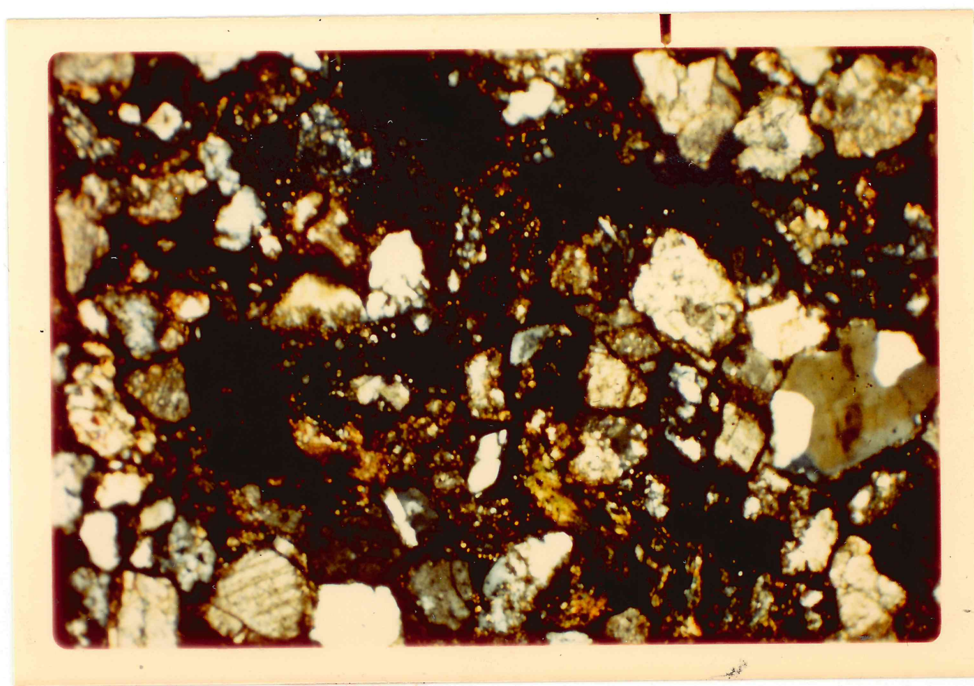


Same as above, nicols crossed.

Figure 5

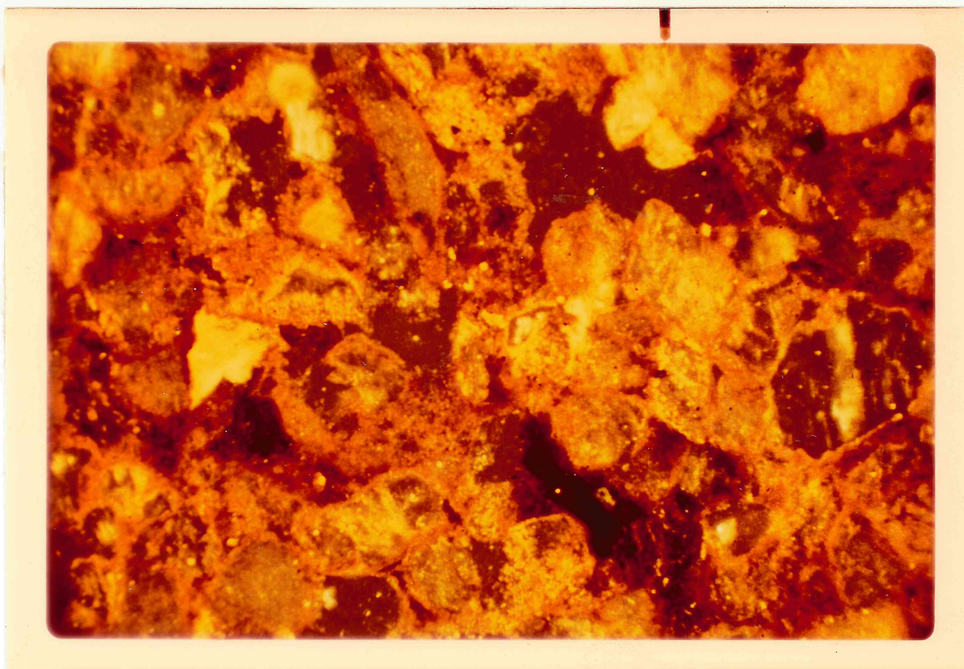


Kukpowruk Formation from northwestern Alaska. RRR 931, field 3.5 mm wide, parallel nicols. Clasts of quartz, chert, feldspar and carbonate grains. Matrix of iron stained kaolinite. Cement carbonate, quartz overgrowths and chlorite.



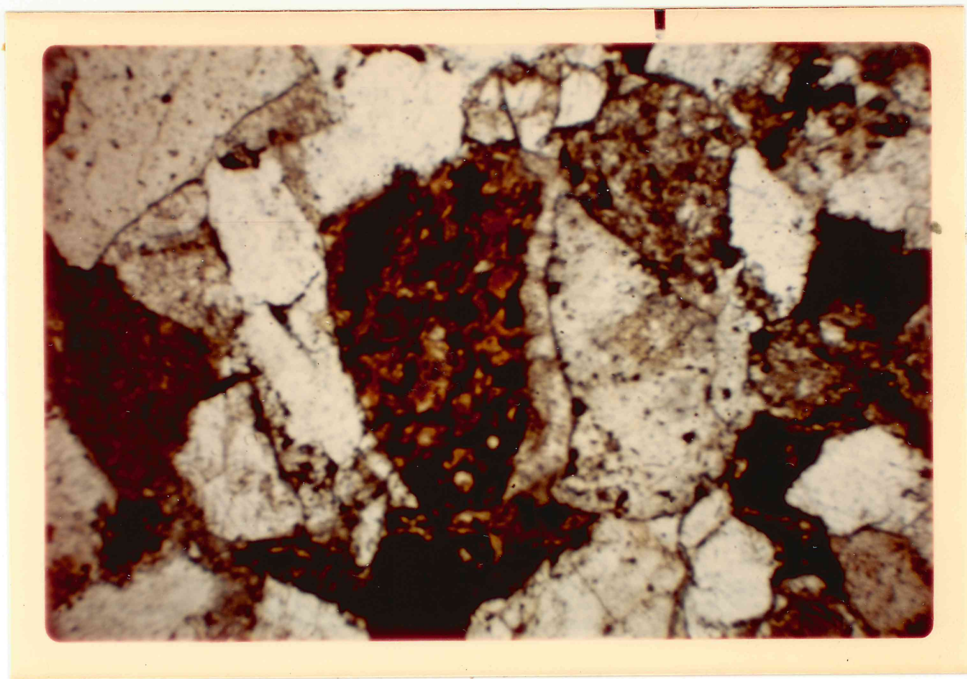
Same as above, nicols crossed.

Figure 5a

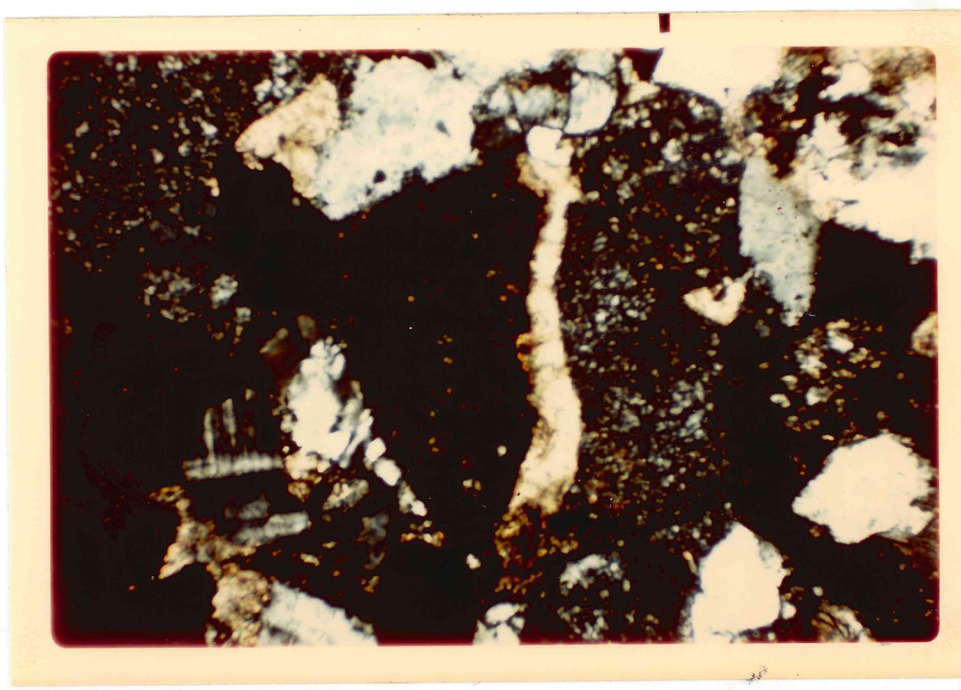


Kukpowruk Formation, RRR 931, field 3.5 mm wide as in Figure 29 but taken with reflected light.

Figure 6



Kukpowruk Formation from northwestern Alaska. RRR 1168, field 1 mm wide, parallel nicols. Clasts of black impure chert, normal clear chert, microcline and quartz. Cement of quartz and carbonate.



Same as above, nicols crossed.

CORWIN FORMATION

Thin Sections

RRR 991, 992, and 995. RRR 905, 966, 970, and 999.

Age and Field Relations (Rose')

These rocks are Lower Cretaceous, collected from western Alaska while camped at the Driftwood Airstrip. The clasts are thought to be derived from the Ancestral Brooks Range: chert from the Lisburne, Shublik and Siksikpuk Formations, quartz from the Noatak and Utukok Formations and quartzite from the Noatak and pre-Devonian metamorphics. The sandstones are thought to be continental and deltaic.

Samples RRR 991, 992, and 995 are from a 60 foot sandstone section made of several point bar deposits, sample 991 is the lowest stratigraphically.

RRR 991, 992, 995

Texture

The texture varies with the sample. RRR 991, at the base of the section, is the coarsest with a median grain size of fine and exhibits the poorest sorting with four grade sizes of sand but has the least matrix. RRR 992 has a median grain size of very fine and three grade sizes and ranks in the middle so far as matrix is concerned. RRR 992 has 92% very fine grains and only two grade sizes but contains the most matrix (11.9% matrix). All samples have grains ranging from angular to rounded but the grain shapes are obscured by quartz overgrowths and abundant interstitial carbonate cement. Thorough cementation reduces the porosity to 3% or less. Framework content decreases upward from 80% in 991 to only 47% in 995. Cement increases upward from 15% in 991 to 40% in 995. Carbonate grains, probably the source of the carbonate cement, also increase upward.

Mineralogy

The mineralogy is best shown in the table on the next page. A systematic change can be noted going from base to top.

	RRR 991	RRR 992	RRR 995
Framework	80.4%	60.1%	47.0%
Quartz	5.7	24.8	22.1
Chert	56.0	21.7	4.0
Feldspar	1.8	7.8	8.9
Phyllite, mica and chlorite	1.0	3.0	2.4
Mudstone	11.7	0.6	0.1
Carbonate	3.1	1.3	9.3
Volcanic	Tr.	-	0.1
Matrix	1.5%	9.7%	11.9%
Cement	14.9%	29.7%	40.0%
Carbonate	51.0% of cement	62.0% of cement	71.1% of cement
Quartz	49.0	31.0	16.3
Chlorite	-	7.0	-
Asphalt ?	-	-	12.6
Classification	Lithic Arenite	Feldspathic Arenite	Feldspathic Wacke (close to arenite)

Two materials of considerable interest are the carbonate grains and the organic (asphaltic?) cement. The carbonate grains consist of both polycrystalline and single grains, a few are even micritic. It is not always easy to distinguish grains from cement and mistakes in identification have probably been made. If the masses were rounded and especially if they had iron-stained borders they were considered grains.

The dark masses of organic material are commonly concentrated along bedding planes, although also occurring in vesicles. The organic substance appears to have had some mobility at one time and may now be of asphaltic nature.

X-ray analysis of the matrix of RRR 995 revealed chlorite and mica along with the ever present quartz.

Distinctive Characteristics

These sandstones appear to be some of the best washed of the Cretaceous rocks, with a matrix content of less than 12%. The polycrystalline carbonate grains in all samples and unusually high chert content of 991 and 992 are somewhat unusual, as is the organic matter in 995.

Provenance

The polycrystalline and micritic carbonate grains were most interesting. In marine Cretaceous rocks previously studied rounded rhombohedral grains were taken as Inoceramus prisms or other shall masses. Fresh water organisms might be called upon to furnish the carbonate grains in these fluviatile rocks but it also seems possible to consider a nearby source for carbonate rock fragments. The universally high chert content of RRR 991 and 992 might suggest a cherty limestone nearby. It might also be that the so-called deltaic sediments actually got close enough to tidewater for marine organisms to play a part, in other words the sediments might be paralic.

The high content of chert, mudstone, igneous derived quartz grains, and perhaps the carbonate grains, point to a nearby sequence of sedimentary rocks, as was pointed out by Rose'. Low rank metamorphic and a trace of volcanics must also have been present.

It is interesting to note the systematic change in type of clasts encountered going from base to top of this section of sandstone. An increase in quartz and feldspar going up might reflect an increase in sandstone exposed to erosion while the marked decrease in chert and mudstone might indicate destruction of the cherty mudston supplying those materials. The change might also indicate a changing drainage pattern for the streams supplying the debris.

Climate and Relief

Swift streams coming from a nearby and reasonably high land mass along with a severe climate could aid in the swift delivery of the fragile phyllite, limestone and volcanic clasts and the relatively fresh feldspar.

Transportation and Deposition

These were adequately treated by Rose' in the field description. I would like to suggest the possibility that some of the sediments were paralic, however.

Diagenetic History

The X-ray analysis of the matrix of RRR 995 indicated only chlorite, quartz and carbonate can be thought of as authigenic.

Classification

Both RRR 991 and 992 were classified as arenites and RRR 995 with a matrix content of only 12% was close. Classifications were:

RRR 991 - Subfeldspathic Lithic Arenite
992 - Feldspathic Arenite
995 - Feldspathic Wacke

Sample Number RRR 991

Formation Corwin

Locality Driftwood Airstrip (point bar sequence, lowest member)

Number of points counted 616

Slide quality poor, quartz yellow, many bubbles

Texture

Wentworth Size Classes

Very Fine	8%
Fine	60
Medium	31
Coarse	1

Framework: 80.4% of rock

Porosity - 3.4%

Median grain size - Fine

Sorting - Poor

Roundness - Angular to rounded, obscured by overgrowths and cement

Matrix: 1.5%

Cement: 14.9%

Carbonate	51%
Quartz	49

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 5.7%

Types - (1) Liquid-gas inclusions. Uncommon
(2) Many irregular inclusions. Common
(3) Euhedral inclusions, including biotite
(4) Contains green chloritic masses
(5) Polycrystalline with elongate grains and included chlorite.
Both igneous and metamorphic common.

Feldspar - 1.8% Plagioclase

Mica - Tr. Muscovite

Rock Fragments:

Chert - 56.0%

Volcanic - Tr.

Schist or phyllite - 1.0%

Mudstone - 11.7%

Carbonate grains, polycrystalline - 3.1%

Quartzite - 0.2%

Remarks There are so many interesting rock clasts that it was thought necessary to include a description of some.

Chert (1) Normal, colorless
(2) Dark with streaks of clay and organic matter
(3) Dark with dolomite rhombs and sometimes pyrite.
(4) Amber, much organic matter but not black.
(5) With aligned grains and interlayering muscovite

Mudstones or shales. Tend to be silicified with veinlets and nests of fine grained quartz.
(1) Clay and organic matter with streaky laminations
(2) Almost solid dark and opaque with some clay inclusions lighter than the rest
(3) Almost colorless, cryptocrystalline
(4) With dark nodules (looks like phosphorite)
(5) Amber but isotropic, some darker nodules
(6) Dark but with quarta silt grains, one with a silicified shell fragment.

Polycrystalline and micritic limestone grains, some are partially silicified.

Volcanic all badly altered.
(1) Plagioclase laths still faintly visible in red clay mass
(2) Devitrified silicic glass
(3) Feldspar (badly altered) and quartz in same grain.

Quartzite Polycrystalline with strongly sutured contacts.

Compositional Maturity: Immature

Diagenesis

A little chlorite in the sparse matrix. Quartz and carbonate cement abundant.

Matrix Minerals

Sparse. Quartz silt and occasional clay masses. Some chlorite.

Cement Minerals

Quartz and carbonate. Quartz may be as overgrowths or vesicle filling, sometimes shows terminations into vesicle; seems earlier than carbonate.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - There must be abundant chert and mudstone from sedimentary rocks. Polycrystalline and micritic limestone clasts may be from very nearby limestones. Sandstones must be available in at least limited amounts to supply the igneous quartz. Low rank metamorphics and sparse volcanics complete the requirements.

Climate and Relief - Moderate to high relief nearby and a severe climate desirable.

Depositional Environment and Transport Mechanism - Stream transport and deposition in a reasonably high energy environment. The field evidence would suggest a stream channel deposit.

Gilbert Classification

Percent matrix - 1.5% of rock

Quartz, quartzite and chert - 81.1% of framework

Feldspar and granitic rock fragments - 2.3%

Unstable lithics - 16.6%

Rock Name - Subfeldspathic Lithic Arenite

Sample Number RRR 992

Formation Corwin

Locality Driftwood Airstrip (point bar sequence, middle member)

Number of points counted 637

Slide quality poor, quartz yellow

Texture

Wentworth Size Classes

Very Fine	74%
Fine	25
Medium	1

Framework: 60.1% of rock

Porosity - 0.5% Sorting - Fair

Median grain size - Very Fine

Roundness - Angular to sub-rounded, obscured by overgrowths and cement

Matrix: 9.7%

Cement: 29.7%

Carbonate	62%
Quartz	30
Chlorite	7

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 24.8%

Types - (1) Euhedral inclusions of chlorite, common
(2) Abundant irregular inclusions, some with liquid-gas bubbles, common.
Both igneous and metamorphic quartz common

Feldspar - 7.8%

Types - Both plagioclase and untwinned

Chlorite grains - 0.5%

Mica - 1.1% Muscovite

Rock Fragments:

Chert - 21.7%

Remarks. See report on 991 for details on rock fragments.

Schist or phyllite - 1.4%

Mudstone, some very organic rich - 2.5%

Polycrystalline carbonate (some micritic) - 1.3%

Compositional Maturity - Immature

Diagenesis

Modest chlorite and abundant quartz and carbonate.

Matrix Minerals

Iron-stained clay, chlorite and quartz silt, organic matter.

Cement Minerals

Quartz both as overgrowths and pore filling, carbonate and occasionally chlorite when it appears unusually coarse and interstitial rather than in the matrix.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Abundant sedimentary rocks furnishing chert, mudstone and second cycle igneous quartz and perhaps feldspar. Some low rank metamorphic for metamorphic quartz, mica and schist or phyllite. Although no volcanic clasts present, the rather abundant plagioclase suggests mafic volcanics. Perhaps limestone.

Climate and Relief- Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport and deposition in a reasonably high energy environment. The field evidence would suggest a stream channel.

Gilbert Classification

Percent matrix 9.7% of rock

Quartz, quartzite and chert - 79.8% of framework

Feldspars and granitic rock fragments - 13.5%

Unstable lithics - 6.7%

Rock Name - Feldspathic Arenite

Sample Number RRR 995

Formation Corwin

Locality Driftwood Airstrip (point bar sequence, upper member)

Number of points counted 673

Slide quality fair, quartz sometimes yellow

Texture

Wentworth Size Classes

Very Fine 92%
Fine 8

Framework: 47.0% of rock

Porosity - 1.0%

Median grain size - Very Fine

Sorting - good

Roundness - Angular to well rounded, overgrowths and cement confusing

Matrix: 11.9%

Cement: 40.0%

Carbonate 71.1%
Asphalt? 12.6
Quartz 16.3

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 22.1%

Types - (1) Euhedral inclusions and chlorite. Common
(2) Liquid-gas bubbles. Common
Both igneous and metamorphic quartz common

Feldspar - 8.9%

Types - Plagioclase and untwinned

Mica - 1.5% Muscovite

Carbonate grains (single units, counted in with carbonate rocks)

Zircon - Tr.

Rock Fragments:

Chert - 4.0%

Volcanic - 0.1%

Schist or phyllite - 0.9%

Mudstone - 0.1%

Carbonate grains - 9.3% (polycrystalline, micritic, single)

Compositional Maturity: Immature

Diagenesis

Chiefly quartz and carbonate, some chlorite.

Matrix Minerals

Quartz silt, organic matter, mica, chlorite and clay.
X-ray analysis - A 14 A peak which did not expand on glycolation and did not collapse on heating along with a 7.1 and 3.53 A peaks would indicate chlorite. An excellent 10 A peak indicating mica and the usual quartz peaks.

Cement Minerals

Carbonate, quartz, asphalt and some coarse interstitial chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sedimentary rocks such as sandstone, cherty mudstone and perhaps limestone. Low rank metamorphics and mafic volcanics.

Climate and Relief - Moderate to high relief and temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport and deposition in an environment of modest energy. The field evidence suggests a stream channel.

Gilbert Classification

Percent matrix - 11.9% of rock

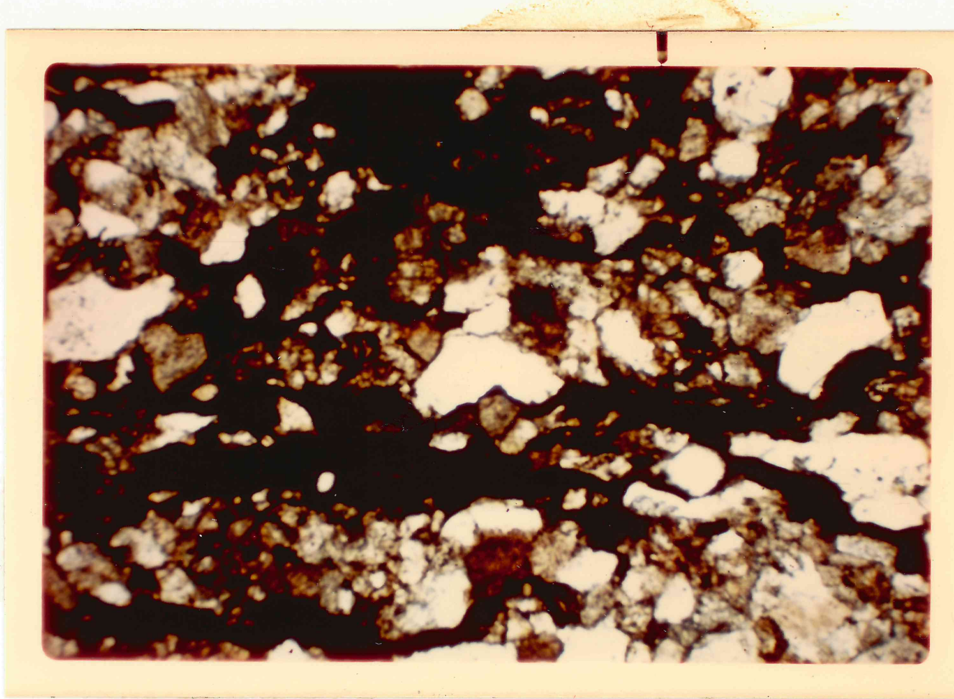
Quartz, quartzite and chert - 72.3% of framework

Feldspars and granitic fragments - 24.6%

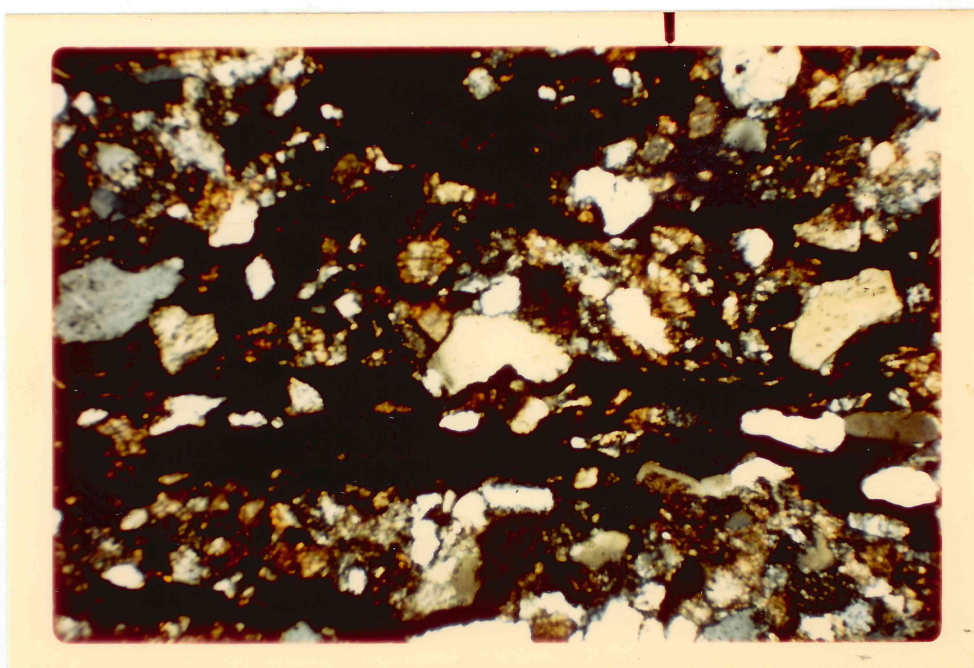
Unstable lithics - 3.1%

Rock Name - Feldspathic Wacke (very close to Feldspathic Arenite)

Figure 7

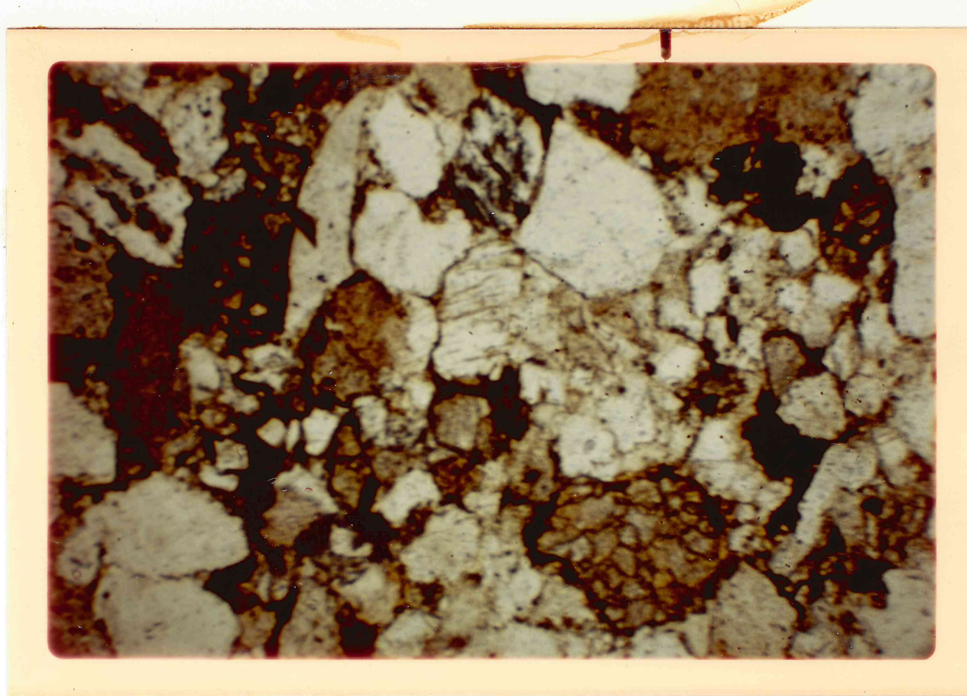


Corwin Formation, Driftwood Airstrip, top of a point bar. RRR 995, field 1 mm wide, parallel nicols. Clasts of quartz, chert and carbonate grains. Asphaltic streaks and masses form the cement.

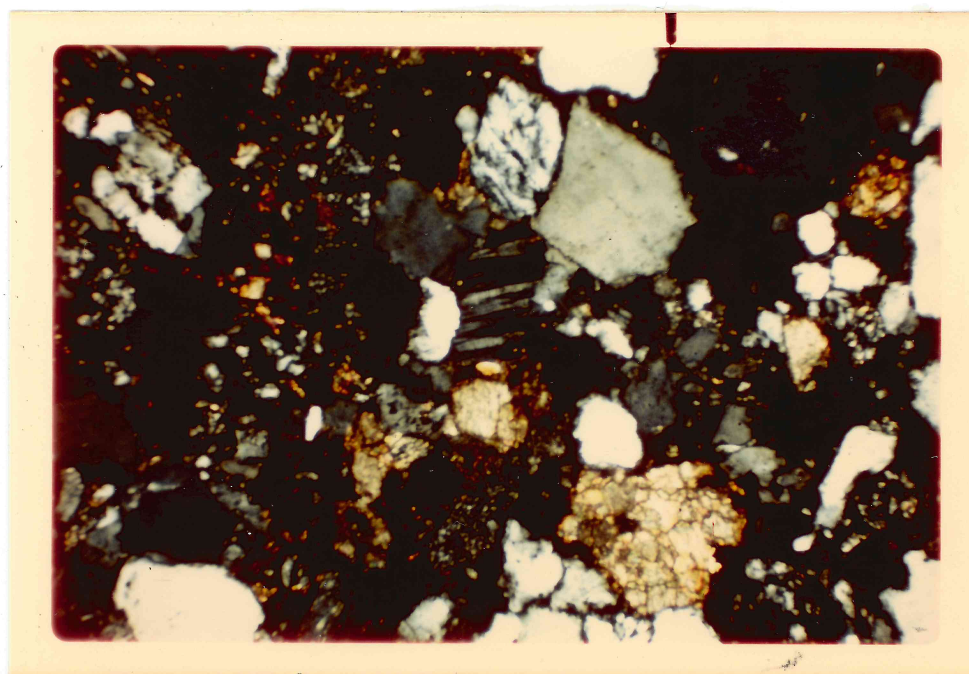


Same as above, crossed nicols.

Figure 8



Corwin Formation, Driftwood Airstrip. RRR 966, field 1 mm wide, parallel nicols. Clasts of carbonate grains, quartz, chert, and feldspar. Matrix of silt sized quartz and iron-stained clay. Cement of quartz and carbonate.



Same as above, nicols crossed.

RRR 905, 966, 970 and 999

Texture

The textures of these four samples are very similar. All are composed largely of fine to very fine sand sizes and the sorting is good to fair. Grains are angular to rounded but quartz grains are modified by overgrowths. The matrix content is modest, ranging from 8.4% to 11.3%. Cementation is variable hence the porosity varies from 1.2% to 11.3%

Mineralogy

Clasts: Quartz and chert are abundant forming from 68 to 86% of the framework. Feldspar is more common than unstable rock fragments in three of the four samples forming 10-15% of the framework. Phyllite, mica, mudstone and carbonate grains are found in all samples but volcanic fragments are found in one only.

Matrix: Clay, quartz silt, chlorite, mica and abundant organic matter are common to all specimens examined.

Cement: The cementing minerals are carbonate and quartz with the former the most abundant.

Distinguishing Characteristics

The abundance of chert, carbonate grains, feldspar and carbonate cement and the low percentages of matrix are distinctive and it is noticable that these Corwin rocks are very similar in these respects to all Corwin rocks studied.

Provenance

Sedimentary rocks are the dominant source rock but low rank metamorphics are also important and volcanic rocks, especially mafic volcanic rocks, are present in the provenance. Granitic rock fragments present in two of the four samples might be second generation from a sandstone but might be from a limited outcrop of granitic rock as a stock or batholith.

Climate and Relief

Moderate to high relief, a nearby source and probably a severe climate would be conducive to the supply of the type of debris found in these rocks.

Transportation and Deposition.

Transportation by running water and channel deposition are indicated by the field evidence quoted by Rose' and by the lack of matrix noted in the rocks. The abundance of carbonate grains suggests consideration of a paralic environment for some of the rocks, however.

Diagenetic History

Modest development of authigenic chlorite and extensive solution and redeposition of quartz and carbonate to develop the extensive cement is the diagenetic summary for these rocks.

Classification

All samples might readily be termed arenites, but two cross over into the wacke subdivision. Feldspar and unstable rock fragments are reasonably well balanced but feldspars are generally most abundant.

RRR 905 - Subfeldspathic Lithic Wacke

RRR 966 - Feldspathic Wacke

RRR 970 - Feldspathic Arenite

RRR 999 - Feldspathic Arenite

Sample Number RRR 905

Formation Corwin

Locality Driftwood Airstrip

Number of points counted 655

Slide quality good

Texture

Wentworth Size Classes

Very Fine	12%
Fine	50
Medium	38

Framework: 73.6% of rock

Porosity - 9.9%

Median grain size - Fine

Sorting - Fair

Roundness - Angular to well rounded, some alteration by overgrowths

Matrix: 11.3%

Cement: 5.2%

Carbonate	17.6%
Quartz	82.4

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 15.1%

Types - (1) Polycrystalline with alligned grains and some chlorite
(2) Single grains, with chlorite inclusions
(3) Contain irregular inclusions, some with liquid-gas bubbles. Common.
Both igneous and metamorphic quartz. Most of the larger grains are igneous.

Feldspar - 1.7%

Types - Plagioclase, perthite, untwinned.

Rock Fragments:

Chert - 46.9%

Volcanic - 0.3%

Schist or phyllite - 1.8%

Mudstone (at least three varieties) - 8.0%

Remarks. The variety of rock types is impressive and should be considered in some detail.

Chert. (1) Flamboyant chalcedony
(2) Coarse granular (almost quartzite)
(3) Fine granular
(4) Carbonate rich
(5) Dark, clay or organic rich
(6) Subparallel grains and phyllosilicate inclusions

Argillite or mudstone
(1) Very dark, organic rich, some silt grains and mica, occasional veinlets of fine quartz.
(2) Light mudstone or argillite also cut by quartz veinlets.
(3) Siltstone with clay and mica and quartz veinlets.

Quartzite. Coarse with strongly sutured grain boundaries.

Volcanics.
(1) Devitrified acidic volcanic
(2) With long slender plagioclase laths and admixed quartz.

Compositional Maturity: Immature

Diagenesis

There is little evidence of diagensis except for the quartz and carbonate cement.

Matrix Minerals

A fairly coarse matrix of quartz silt, small mica shreds, iron-stained clay and dark organic matter, some of which appears asphaltic.

Cement Minerals

Carbonate and quartz.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sedimentary rocks as a source are most prominent. Cherty, organic mudstone and siltstone, sandstone, low rank metamorphics and minor volcanics.

Relief and Climate - Moderate to high relief and temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation and deposition in a reasonably high energy environment, perhaps a river bar or channel.

Gilbert Classification

Percent matrix - 11.3% of rock

Quartz, quartzite and chert - 86.2% of framework

Feldspar and granitic rock fragments - 2.1%

Unstable Lithics - 11.7%

Rock Name - Subfeldspathic Lithic Wacks

Sample Number RRR 966

Formation Corwin

Locality Driftwood Airstrip

Number of pooints counted 661

Slide Quality good

Texture

Wentworth Size Classes

Very Fine 65%
Fine 35

Framework: 63.7% of rock

Porosity - 1.2%

Median grain size - Very Fine

Sorting - Good

Roundness - Subangular to well rounded. Many quartz grains obscured by overgrowths. Perhaps subrounded originally.

Matrix: 10.4%

Cement: 24.7%

Carbonate 38.1%
Quartz 61.9

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 26.0%

Types - (1) Euhedral inclusions, often phylosillicates
(2) Inclusions of brown acicular crystals
(3) Liquid-gas bubbles
Metamorphic and igneous quartz both common.

Feldspar - 9.5%

Types - Plagioclase, microcline, some micrographic grains.

Micas - 0.3% Muscovite

Zircon - Tr.

Rock Fragments:

Chert - 12.4%

Schist or phyllite - 3.3%

Mudstone and argillite - 4.2%

Carbonate grains, some polycrystalline - 6.8%

Remarks

Chert. Of various kinds, colorless to pale brown, some carbonate rich.
Schist. Mostly muscovite schist.
Mudstone. From moderate brown to dark opaque and either organic or phosphatic rich. Some almost phosphorites with amber but transluscent and isotropic portions. Some beginning to show alignment of cryptocrystalline grains giving mass extinction and almost argillite.
Carbonate. Many polycrystalline but rounded.

Compositional Maturity: Immature

Diagenesis

Abundant quartz and carbonate cement and the usual authigenic matrix chlorite.

Matrix Minerals

Opaque white to iron-stained clay, quartz silt and chlorite. At times somewhat coarse mica. Organic matter.

Cement Minerals

Quartz and carbonate. The matrix chlorite also aids in the lithifaction of the sandstone.

INFERENCE ANC CONCLUSIONS

Provenance

Rock types - Chiefly sedimentary rocks, sandstones, cherty mudstones and limestones. Also low rank metamorphics.

Climate and Relief - Fragile mudstone and phyllite grains suggest rapid transport from a nearby source, hence moderate to high relief. Climate probably temperate to severe.

Depositional Environment and Transport Mechanism - Stream transport to a fluviatile environment of reasonably high energy, perhaps a bar or channel.

Gilbert Classification

Percent matrix - 10.4% of rock

Quartz, quartzite and chert - 69.2% of framework

Feldspar and granitic rock fragments - 17.2%

Unstable Lithics - 13.6%

Rock Name - Feldspathic Wacke.

However, the matrix is so close to the 10% boundary that even nearby samples might well be classed as arenites.

Sample Number RRR 970

Formation Corwin

Locality Driftwood Airstrip

Number of points counted 646

Slide quality poor, many holes.

Texture

Wentworth Size Classes

Very Fine 48%
Fine 49
Medium 3%

Framework: 63.9% of rock

Porosity - 11.3%

Median grain size - Fine

Roundness - Angular to rounded but many quartz grains obscured by overgrowths. Perhaps originally subrounded.

Sorting - Fair

Matrix: 8.4%

Cement: 16.4%

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 25.1%

Types - (1) Euhedral inclusions including chlorite
(2) Brown acicular inclusions
(3) Many irregular inclusions
(4) Liquid-gas bubbles
Both metamorphic and igneous quartz, igneous most common

Feldspar - 9.4%

Types - Plagioclase, microcline, grains in micrographic intergrowth

Mica - 1.1% Muscovite

Rock Fragments:

Chert - 21.2%

Schist or phyllite - 1.9%

Quartzite - 0.1%

Granite - 0.1%

Mudstone - 4.0%

Carbonate, both single and polycrystalline grains - 0.9%

Remarks

Chert.
(1) Colorless, normal grain size
(2) Pale brown, normal grains
(3) With carbonate rhombs included
(4) Dirty, with iron stained clay
(5) Elongate grains with muscovite (seems to grade into schist or phyllite)

Mudstone.
(1) Amber, isotropic, collophanite?
(2) Pale brown very fine grained
(3) Laminated, organic rich, black nodules, quartz veinlets, considerable silt.

Carbonate.
(1) Rounded single grains, often with iron stained borders
(2) Polycrystalline, often badly iron stained, rounded.

Compositional Maturity: Immature

Diagenesis

Abundant cement of quartz and carbonate and the usual matrix chlorite.

Matrix Minerals

Quartz silt, iron stained clay, chlorite.

Cement Minerals

Abundant quartz as overgrowths and pore filling followed by carbonate. Lithification aided by matrix chlorite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Largely sedimentary: cherty limestones and mudstones, sandstone and low rank metamorphics. Perhaps a granitic stock.

Relief - Moderate to high, with temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport to a reasonably high energy environment of fluviatile nature, perhaps a channel deposit.

Cilbert Classification

Percent matrix - 8.4% of rock

Quartz, quartzite and chert - 77.3%

Feldspars and granitic rocks - 16.0%

Unstable Lithics - 6.7%

Rock Name - Feldspathic Arenite

Sample Number RRR 999

Formation Corwin

Locality Driftwood Airstrip

Numbers of points counted 638

Slide quality fair, some bubbles

Texture

Wentworth Size Classes

Very Fine 46%
Fine 54

Framework: 63.2% of rock

Porosity - 3.3%

Median grain size - Fine

Sorting - Good

Roundness - Angular to rounded, quartz grains often obscured by overgrowths and cement

Matrix: 8.5%

Cement: 25.1%

Carbonate - 69.4%
Quartz 30.6

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 26.6%

Types - (1) Liquid gas bubbles common
(2) Many irregular inclusions
(3) With included chlorite
Both igneous and metamorphic present, igneous most common

Feldspar - 6.3%

Types - Plagioclase, microcline, micrographic grains

Micas - 1.2% Muscovite

Rock Fragments:

Chert - 22.3%

Schist or phyllite - 1.1%

Quartzite - 0.3%

Mudstone - 4.4%

Granitic - 0.2%

Carbonate, some polycrystalline - 0.8%

Remarks.

Chert. (1) Flamboyant chalcedony
(2) Colorless to faintly colored, normal cryptocrystalline
(3) Contains carbonate rhombs

Mudstone.
(1) Dark, opaque with quartz veinlets. Apparently very organic rich.
(2) Amber, isotropic with black nodules, collophanite?
(3) Pale brown cryptocrystalline
(4) Rich in quartz silt and mica as well as clay.

Phyllite. Almost coarse enough to be termed schist, much muscovite.

Granitic. Very fine grained with quartz and untwinned feldspar.

Carbonate. Either single grains or polycrystalline, rounded.

Compositional Maturity: Immature

Diagenesis

Abundant quartz and carbonate cement and matrix chlorite.

Matrix Minerals

Quartz silt, clay both cloudy white and iron-stained, organic matter and authigenic chlorite.

Cement Minerals

Carbonate and quartz cement and relatively coarse authigenic chlorite. The chlorite included with matrix minerals in percentage analysis.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Chiefly sedimentary. Cherty limestones and mudstone, sandstone and perhaps a granitic stock. Low rank metamorphics.

Climate and Relief - Moderate to high relief and probably a nearby source, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport to a fluviatile environment of considerable energy, channel or bar.

Gilbert Classification

Percent matrix - 8.5% of rock

Quartz, quartzite and chert - 80.5% of framework

Feldspars and granitic rocks - 10.5%

Unstable Lithics - 9.0%

Rock Name - Feldspathic Arenite

NEOCOMIAN OF THE UMIAT AREA

AND THE CANNING RIVER

FORTRESS MOUNTAIN FORMATION

Thin Sections.

RRR 608, 870. Fortress Mountain #2 and #3.

Age and Field Relations (Rosé).

Fortress Mountain Formation from the Umiat area. Probably from a southern source (ancestral Brooks Range) deposited during Neocomian time. The chief contributors are thought to be the Shublik, Siksikpuk and Lisburne Formations and both intrusive and extrusive igneous rocks.

Texture.

Two samples (Fortress Mountain #2 and RRR 870) contain sparse matrix and are classed as arenites. Fortress Mountain #3 and RRR 680 contain abundant matrix and are termed wackes. So far as the framework is concerned, all possess four size classes from coarse to very fine, hence are poorly sorted. Some of the larger grains are rounded to subrounded and some of the smaller angular. The majority of the grains are perhaps termed subangular.

Fortress Mountain #2 and RRR 608 have a porosity near 5% while the other two are nearly devoid of pores. The two arenites should make good reservoir rocks if uncemented.

Mineralogy.

Clasts: Chert is the most common, forming about 40% of all clasts. This is followed by volcanics 28%, mudstone 25% and feldspar 5%. Occasional grains of metamorphics, mica and pyroxene are found.

Matrix: Largely quartz in silt sized grains and a green chloritic looking material probably the result of authigenesis. An X-ray pattern run on the clay sized fraction of Fortress Mountain #3 suggests that in that rock the green matrix material was vermiculite. Optically the mineral fits vermiculite also. Weaver (1958) has suggested that vermiculite in marine rocks is probably developed from non-micaceous sources such as volcanic debris. In Fortress Mountain #3 it can be observed forming in both the matrix and in volcanic clasts.

Cement: Three authigenic minerals are noted. (1) Vermiculite (or chlorite) as thin rims around clasts or as reorganized matrix, (2) quartz largely as pore filling and (3) albite. The quartz and albite are found together and are definately later than the vermiculite rimming clasts. They often form terminating crystals extending into pores. The albite is so coarse that it twins polysynthetically.

Distinctive characteristics.

The coarse grain size and poor sorting, prominence of volcanic lithics, lack of quartz grains, lack of matrix in two samples and the very unusual albite cement along with the unusual vermiculite make the Fortress Mountain most unusual.

Provenance.

(1) The presence of several varieties of chert, cherty siltstone, mudstone with very fine quartz veinlets and dark organic or phosphatic rich mudstone reinforce the suggestion of Rose' that the Lisburne, Shublik and Siksikpuk Formations were major contributors to the Fortress Mountain.

(2) Andesitic volcanics varying from masses of dark devitrifying glass through porphyries into holocrystalline clasts almost coarse enough to be termed diorite were common indicating an extensive andesitic terraine. Minor devitrified glass of a silicic nature indicate some variations in volcanic activity.

(3) A few granitic fragments with microcline and rare perthite might indicate minor stocks or batholitic masses or might be second cycle from arkosic sandstones.

(4) Rare phyllite or schist, polycrystalline quartz grains and minor mica probably indicate some low rank metamorphic terraine. Phyllite grains are thought too fragile to be second cycle.

Relief and Climate.

Sorting, angularity of grains and the composition of the clasts are those of a very immature sandstone and suggest a nearby source area with high relief, steep gradients and probably a rigorous climate. Under such conditions the abundant volcanic rocks could be broken up physically and quickly removed before chemical weathering could destroy the unstable clasts.

Transportation and Deposition.

Medium to coarse grain size, poor sorting and angularity with a wide variety of clasts suggests rapid stream transportation from a provnance with heterogeneous rocks and rapid burial after reaching the site of deposition. In two cases enough winnowing took place to remove much of the matrix, in the others the matrix remains suggesting a low energy environment.

Stream transport with some sediment lodged in a high energy environment, such as a beach or tidal channel long enough for the matrix to be winnowed out, the rest deposited in a low energy environment such as lagoonal or near shore neritic seems a logical explanation

Diagenetic history.

(1) Considerable alteration of original matrix material and, in some samples, volcanic clasts to a green material has taken place. In some instances the green material forms a thin rim about clasts, cementing them together. Samples of Fortress Mountain #3 were available and the clay sized fraction was run on the X-ray. A broad peak at 14.3 Å which did not change on glycolation collapsed to 12 A on heating to 550°C for one half hour. It is suggested that this is vermiculite. Coarse grains of this material yielded interference colors ranging up to first order blue, too high for chlorite.

(2) Minor carbonate is present in RRR 870 deposited after the vermiculite but prior to quartz and albite.

(3) Quartz and albite fill interstices and extend as terminated crystals into large pores. They appear to have been precipitated sumultaneously.

Classification.

Samples RRR 870 and Fortress Mountain #2 are classified as Subfeldspathic Lithic Arenites, RRR 608 a Subfeldspathic Lithic Wacke and Fortress Mountain #3 a Volcanic Wacke.

Sample Number RRR 608

Formation Fortress Mountain Fm.

Locality Umiat

Number of points counted 624

Slide quality good

Texture

Wentworth size classes

Very Fine	18%
Fine	12
Medium	32
Coarse	38

Framework: 76.4% of rock

Porosity - 4.8%

Median grain size - Medium

Sorting - poor

Roundness - angular to rounded

Matrix: 13.7% (this counts green authigenic material as matrix)

Cement: 5.1%

Quartz 76% of total cement
Albite 12
Vermiculite? 12

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 1.0%

Types - (1) Some containing pale green euhedral crystals of mica
(2) Polycrystalline units with marked difference in size of units.
All metamorphic.

Feldspar - 3.0%

Types - (1) Microcline (2) Plagioclase (3) Perthite

Micas - Tr.

Types - Biotite only

Mineralogy (cont.)

Rock Fragments:

Chert - 34.1%

Volcanic - 14.9%

Schist or phyllite - Tr.

Quartzite - Tr.

Mudstone - 18.9%

Wacke - 2.7%

Chert. Both fine and coarse grained and clear to dark.
Volcanic. Chiefly andesitic varying from dark devitrifying glass through porphyries into holocrystalling rocks coarse enough to be termed diorite. Some devitrified silicic glass. Ferromagnesian minerals usually altered to chlorite but occasionally pyroxene can be recognized.
Granitic. A few large grains containing microcline, quartz and andesine.
Silicified mudstone.
Feldspathic wacke. A few grains

Compositional Maturity

Immature

Diagenesis

Chloritic material (or vermiculite) in the matrix appears to be an early alteration product, sometimes this material rims rock fragments. Quartz and albite were added later chiefly as pore fillings.

Matrix Minerals

Quartz silt, dark clay and a green authigenic material (vermiculite?)

Cement Minerals

Quartz and albite are added cementing minerals. The authigenic green matrix material also aids in cementing the rock together.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherts or cherty limestones, organic or phosphatic rich mudstones, fine grained wackes or siltstones, abundant andesites and some silicic volcanics. There may be an occasional granitic pluton and there are minor low rank metamorphics.

Relief - Moderate to high

Climate - Probably severe to temperate, cold or dry suggested.

Depositional Environment and Transport Mechanism - A ahort rapid transport of the many unstable grains, probably by streams, and rapid deposition in a reasonably high energy paralic environment seems reasonable.

Gilbert Classification

Percent matrix - 13.7% of entire rock

Quartz, quartzite, and chert - 47.7% of framework materials

Feldspars and granitic rock fragments - 4.0%

Unstable Lithics - 48.3%

Rock Name - Subfeldspathic Lithic Wacke

Remarks

The rock samples in this sandstone are particularly interesting and large enough to examine carefully. Worthy of note are:

Andesites of a variety of types; holocrystalline with intergranular texture, porphyritic with pilotaxitic matrix, amygdaloidal with the vesicles filled with green chloritic material, fragments almost coarse enough to be termed biotite diorite and dark devitrifying glass. Pyroxenes in these rocks are badly altered.

Silicic Volcanics are represented in light glass, some devitrifying, and some poorly preserved pumice.

Sandstones or siltstones of a feldspathic wacke nature.

Carbonaceous or phosphatic claystones and siltstones commonly with fine quartz veinlets and obviously silicified. Often these appear to be almost 50-50 chert and silt.

Chert of a variety of colors and crystallization. Some finely cryptocrystalline some with flamboyant chalcedony.

Granitic fragments, one good graphic granite others merely grains of quartz associated with a feldspar.

Sample Number RRR 870

Formation Fortress Mountain Fm.

Locality Umiat

Number of points counted 766

Slide quality good

Texture

Wentworth size classes

Very Fine	9%
Fine	27
Medium	45
Coarse	19

Framework: 71.1%

Porosity - 1.2%

Sorting - Poor

Median grain size - Medium

Roundness - angular to well rounded

Matrix.: 7.7%

Cement: 20.0%

Carbonate	80.4%
Quartz	15.0
Albite	4.6

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Quartz - 1.0%

Types - (1) Contains pale green euhedral crystals or
(2) Formed of polycrystalline grains of markedly different size.
All thought to be metamorphic.

Feldspar - 1.0%

Types - (1) Andesine (2) Microcline

Rock Fragments:

Chert - 32.4%

Volcanic - 21.5%

Quartzite - Tr.

For rock types see description for sample RRR 608

Mineralogy (cont.)

Rock Fragments (cont.)

Mudstone - 10.6%

Coarse granitic - 2.0%

Fine wacke - 2.5%

Compositional Maturity

Immature

Diagenesis

Early vermiculite found both in the matrix and rimming rock fragments is followed by pore filling of quartz, albite and carbonate.

Matrix Minerals

Silt sized quartz and feldspar, cloudy clay commonly tinted pink with hematite and authigenic vermiculite?

Cement Minerals

Carbonate, quartz and albite. Authigenic vermiculite both in the matrix and rimming lithics help cement the rock together.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherts or cherty limestones, mudstones often carbonaceous or phosphatic, fine grained wacke, fine grained low rank metamorphics, minor plutonites of granitic nature and extensive volcanics, chiefly andesitic but minor silicics.

Relief - Moderate to high.

Climate - Rocks such as this are not good climatic indicators, they do indicate rapid erosion, transportation and deposition. Granted the immature composition a temperate to severe climate might be preferred.

Depositional Environment and Transport Mechanism - A short rapid transport, probably by streams, and rapid deposition in a reasonably high energy marine environment. Some winnowing is seen to remove all but 8% or so of the matrix. Tidal channels, a beach or bar or even a deltaic environment might suffice.

Gilbert Classification

Percent matrix - 7.7% of entire rock

Quartz, quartzite, and chert - 47.0% of framework materials

Feldspars and granitic rock fragments - 4.2%

Unstable Lithics - 48.8%

Rock Name - Subfeldspathic Lithic Arenite

Sample Number Fortress Mountain # 2

Formation Fortress Mountain

Locality Umiat

Number of grains counted 612

Slide quality good

Texture

Wentworth Size Classes

Very Fine	14%
Fine	12
Medium	32
Coarse	42

Framework: 79.0% of rock

Porosity - 5.9%

Median grain size - Medium

Sorting - poor

Roundness - angular to subrounded

Matrix: 9.2%

Cement: 5.9%

Quartz 90% of total cement
Albite 10

Textural Maturity: Submature

Mineralogy

Framework Minerals:

Feldspar - 1.0%

Type - Andesine

Rock Fragments

Chert - 37.1%

Volcanic - 21.2%

Mudstone - 21.2%

Wacke - 1.6%

Compositional Maturity

Immature

Mineralogy (cont.)

Diagenesis

Some authigenic vermiculite? in the matrix, quartz and albite filling pores.

Matrix Minerals

Silt sized grains, largely quartz and vermiculite? No X-ray evidence for the vermiculite is available for this sample but it is so similar to the vermiculite in Fortress Mountain # 3 which does have X-ray verification and it has such a high birefringence that it is so named.

Cement Minerals

Quartz and albite.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherts or cherty carbonates, andesites and quartz diorites, silicified dark mudstones probably carbonaceous or phosphatic, feldspathic wacke. Minor source of low rank metamorphics.

Relief - Reasonably high in order to ensure rapid erosion and transportation of the unstable debris making up this rock.

Climate - This rock is not a good climatic indicator but temperate to severe is preferred.

Depositional Environment and Transport Mechanism - A short rapid transport of the many unstable grains, probably by streams. Rapid deposition in a relatively high energy marine or paralic environment allowing some winnowing. A beach or bar or tidal channel or perhaps a stream channel.

Gilbert Classification

Percent matrix - 9.2% of rock

Chert, Quartz, and quartzite - 45.2% of framework

Feldspars and granitic rock fragments - 1.2%

Unstable Lithics - 53.6%

Rock name - Subfeldspathic Lithic Arenite

Sample Number Fortress Mountain # 3

Formation Fortress Mountain

Locality Umiat

Number of grains counted 678

Slide quality good

Texture

Wentworth Size Classes

Very Fine	21%
Fine	48
Medium	30
Coarse	1

Framework: 71.9%

Porosity - 0%

Median grain size - Fine

Sorting - Poor

Roundness - Angular to subrounded

Matrix: 25.2%

Cement: 2.7%

Quartz 90% of total cement
Albite 10

Textural Maturity: Immature

Mineralogy

Framework Minerals

Quartz - 3.1%

Types - (1) Contains green euhedral crystals
(2) Polycrystalline grains with marked difference in grains
Consider the quartz predominately metamorphic

Feldspar 8.9%

Types - Plagioclase only identified

Mica - Tr.

Type - Biotite only

Pyroxene - 0.4%

Mineralogy (cont.)

Rock Fragments

Chert - 13.3%

Volcanic - 24.2%

Schist or phyllite - 0.7%

Mudstone - 13.6%

Wacke - 3.0%

Rock fragments identical to those found in RRR 608.

Compositional Maturity

Immature

Diagenesis

Green vermiculite in the matrix and quartz and albite filling pores as cement are the authigenic minerals.

Matrix Minerals

It is probable that the original matrix consisted of silt sized quartz grains and some clay. Presently the clay seems to have given way to vermiculite.

X-ray analysis.

In addition to the usual quartz peak a broad peak at 14.3 A did not change upon glycolation but collapsed to 12 A upon heating to 550°C for one half hour. Weaver has suggested that such vermiculite occurring in marine rocks is derived from non-micaceous sources (ie biotite) such as volcanic material. This is thought to be the answer. Vermiculite is found both in the matrix and in the weathered portions of some of the volcanic grains. Optical proof for the green mineral being vermiculite rather than a chlorite lies in its high birefringence, commonly ranging up to first order blue.

Cement Minerals

Quartz and albite with matrix vermiculite aiding in cementing the rock

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherts or cherty limestones, phosphorites or organic rich mudstones or both, feldspathic wackes, abundant mafic volcanics, minor low rank metamorphics.

Relief - Moderately high to ensure rapid erosion and transportation of the unstable debris represented in this rock.

Climate - This rock is not a good climatic indicator but a temperate to severe climate is preferred to delay destruction of the unstable debris.

Depositional Environment and Transport Mechanism - Short rapid stream transport into a relatively low energy marine environment or paralic environment. Lagoonal, neritic or even deltaic.

Gilbert Classification

Percent matrix - 25.2% of rock

Quartz, quartzite and chert - 24.8% of framework

Unstable Lithics - 61.7%

Feldspar and granitic rock fragments - 13.5%

Rock name - Volcanic Wacke

Remarks

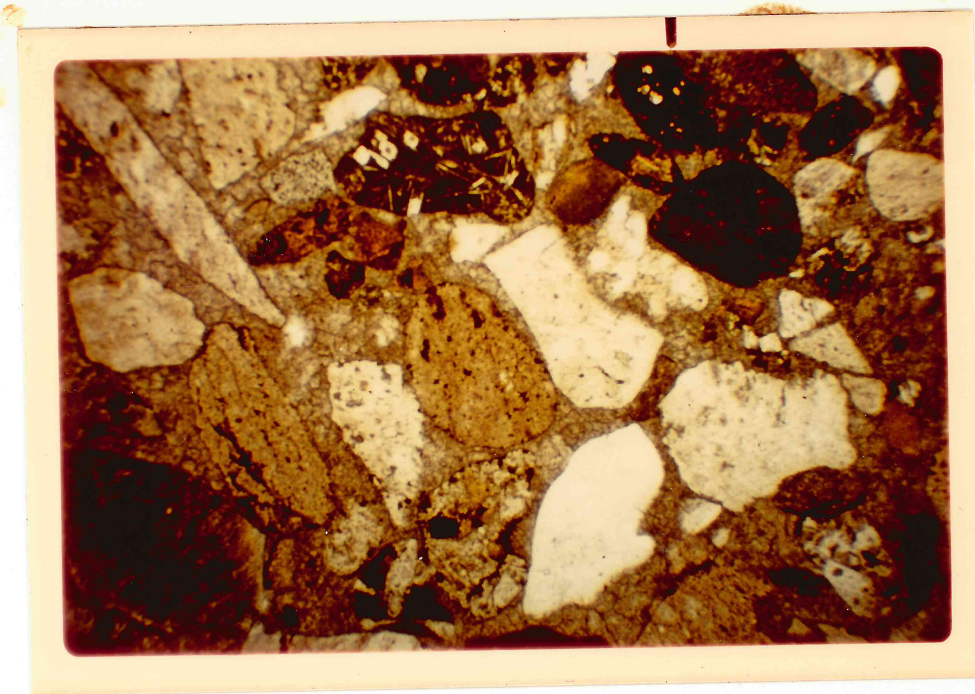
Many framework grains were badly altered and what must have been the original matrix is now thoroughly altered to vermiculite. Certain assumptions were made.

(1) Shapeless opaque masses are thought to be organic rich or phosphatic rich patches of the matrix, if extremely irregular.

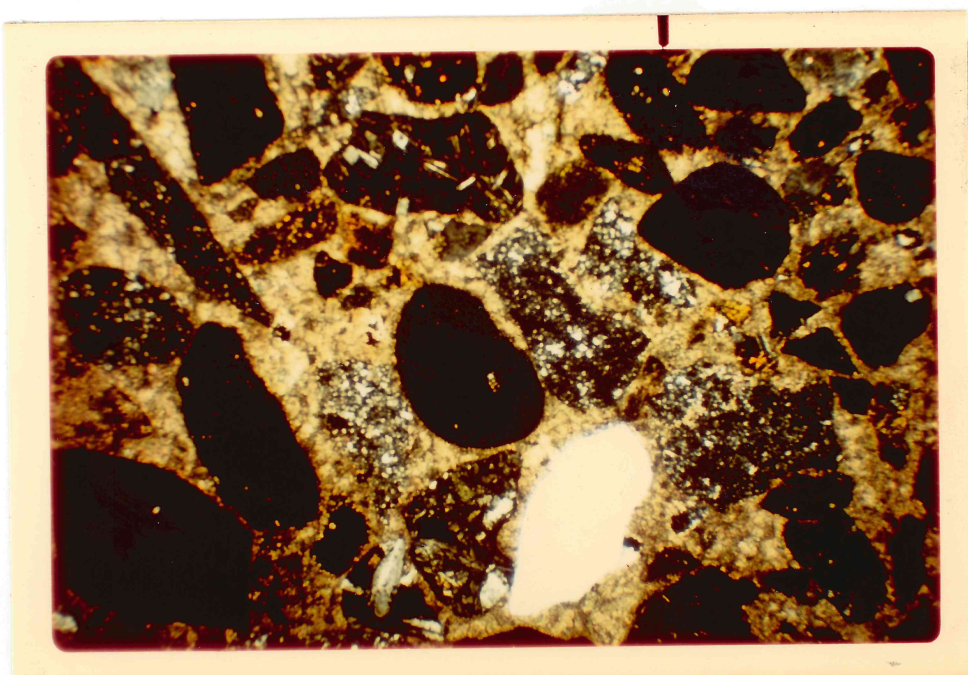
(2) Some large well shaped (often rounded) green masses were taken as completely vermiculized (or chloritized) framework grains.

(3) Irregular masses of vermiculite in interstitial positions might be altered matrix or some might be introduced cement. They were counted as matrix.

Figure 9

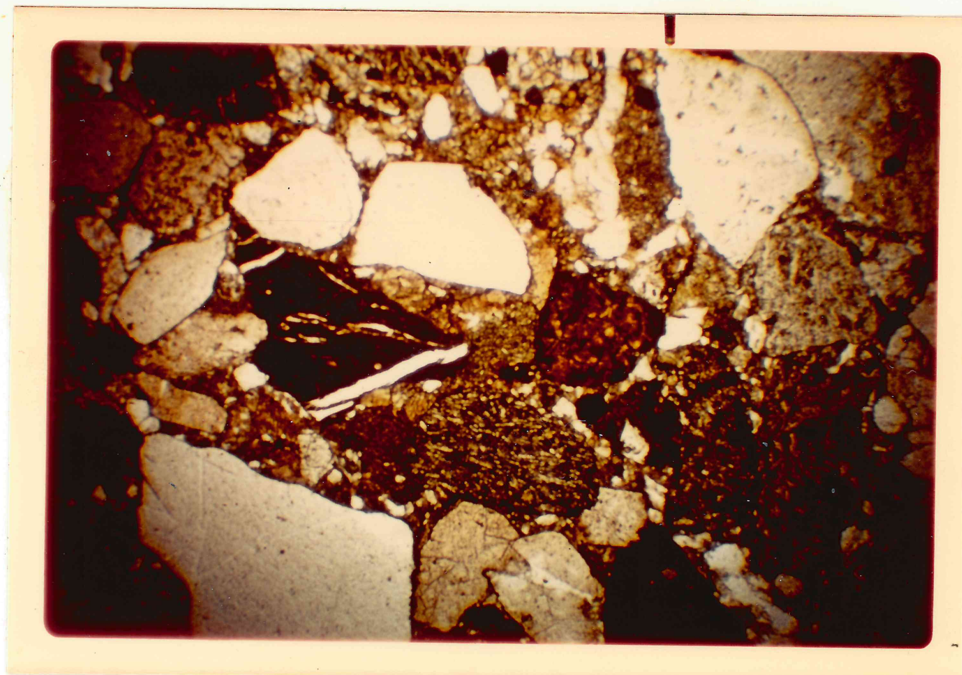


Fortress Mountain Formation. RRR 870, field 3.5 mm wide, parallel nicols. Clasts of light and dark chert, quartz and volcanics in carbonate cement.

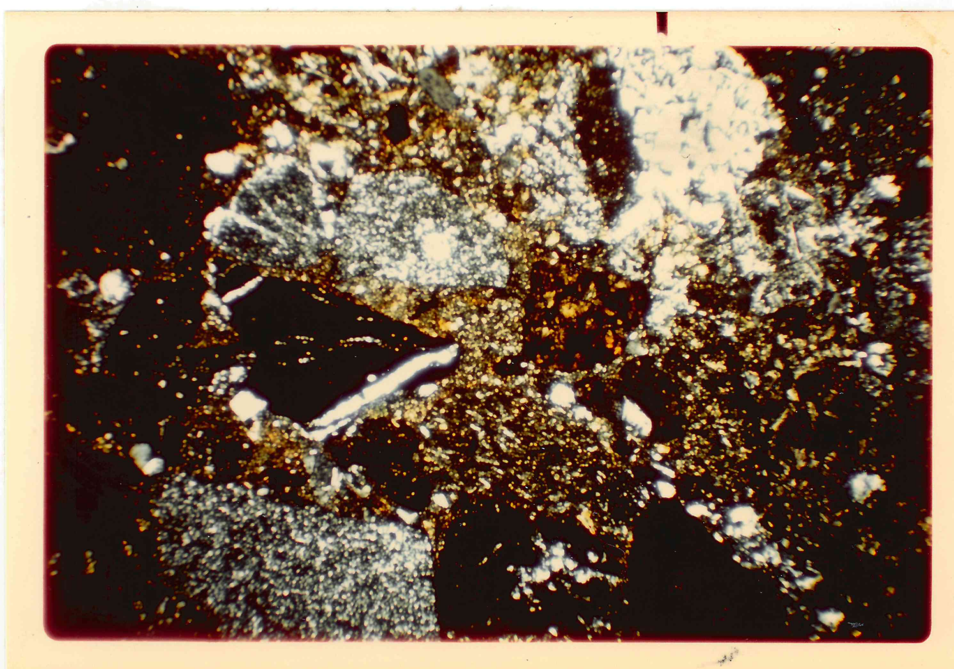


Same as above but nicols crossed.

Figure 10

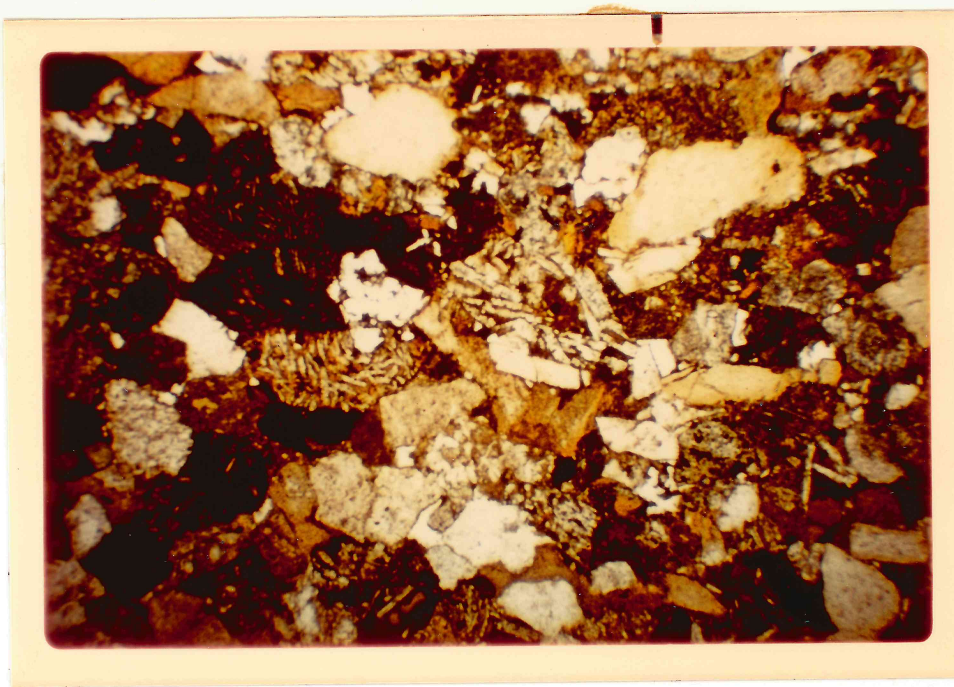


Fortress Mountain Formation. RRR 608, field 3.5 mm wide, parallel nicols. Clasts of chert, volcanics, dark organic rich or phosphatic mudstone with quartz veinlets. Matrix of silt sized quartz, dark clay and vermiculite?. Cement not apparent.

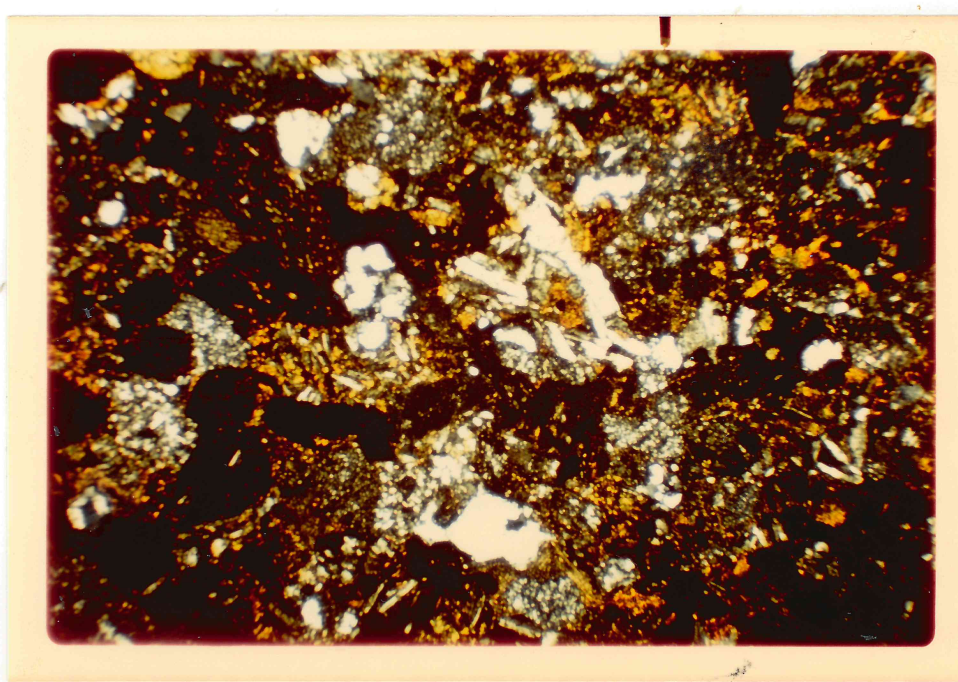


Same as above, nicols crossed.

Figure 11

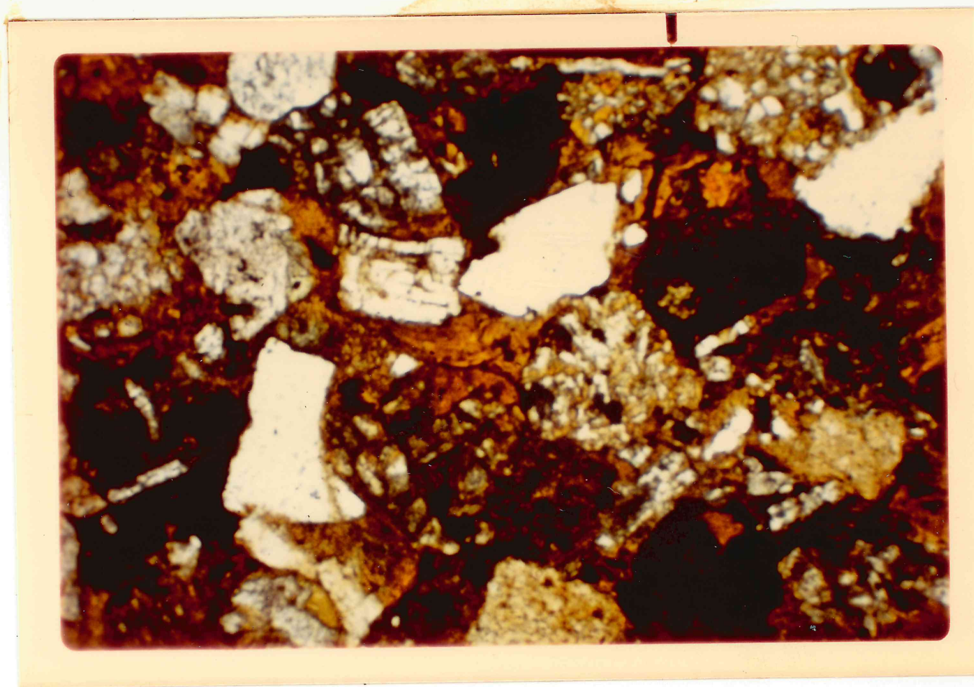


Fortress Mountain Formation. Ft. Mtn. #3, field 3.5 mm wide, parallel nicols. Clasts of chert, volcanics, and quartz. Matrix largely vermiculite apparently formed authigenically from the matrix. Cement not apparent.

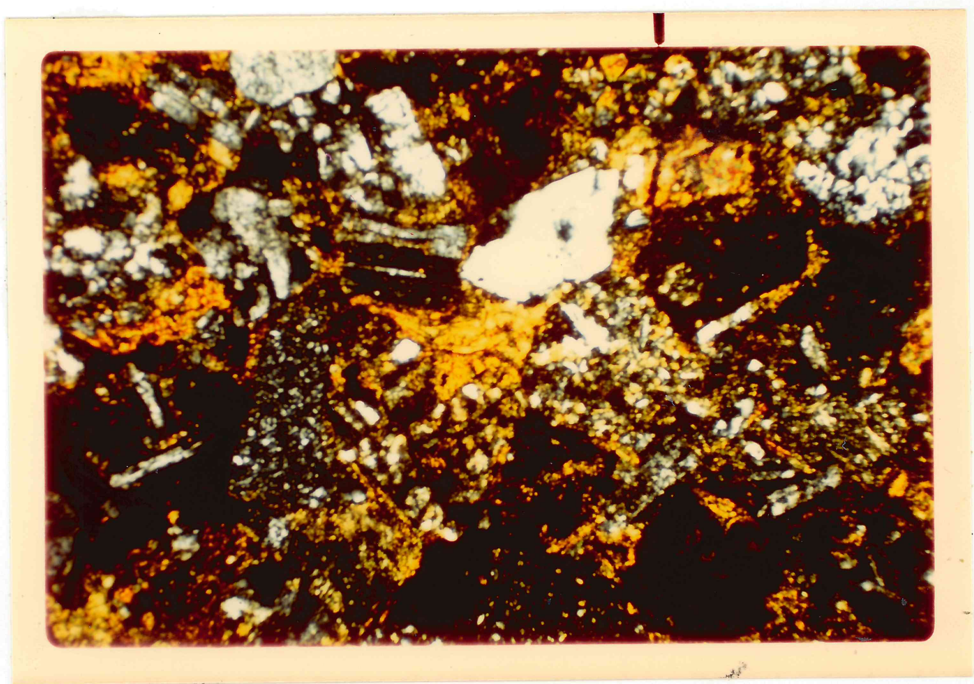


Same as above, crossed nicols.

Figure 12

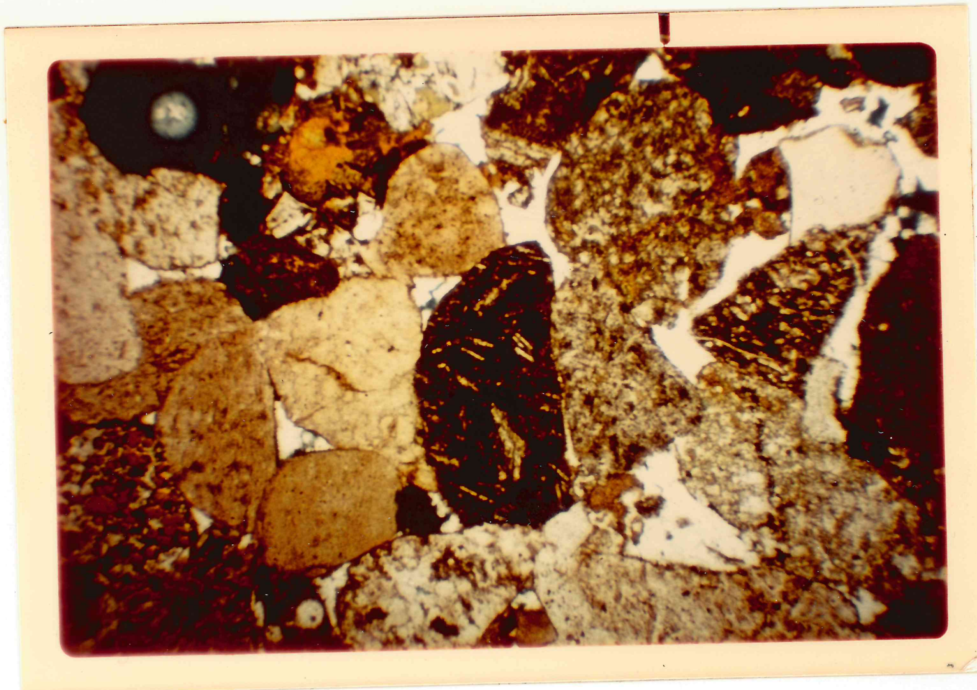


Fortress Mountain Formation. Ft. Mtn. #3, field 1 mm wide, parallel nicols. Clasts of chert, volcanics, quartz, feldspar and dark mudstone. Authigenic vermiculite developed from the matrix serving as the cement.

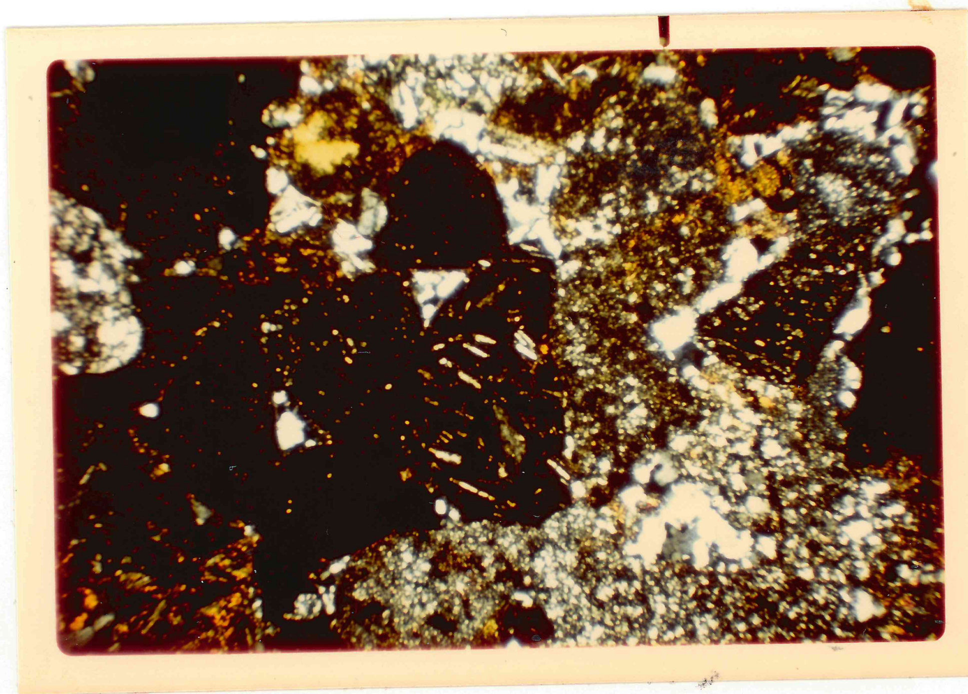


Same as above, nicols crossed.

Figure 13

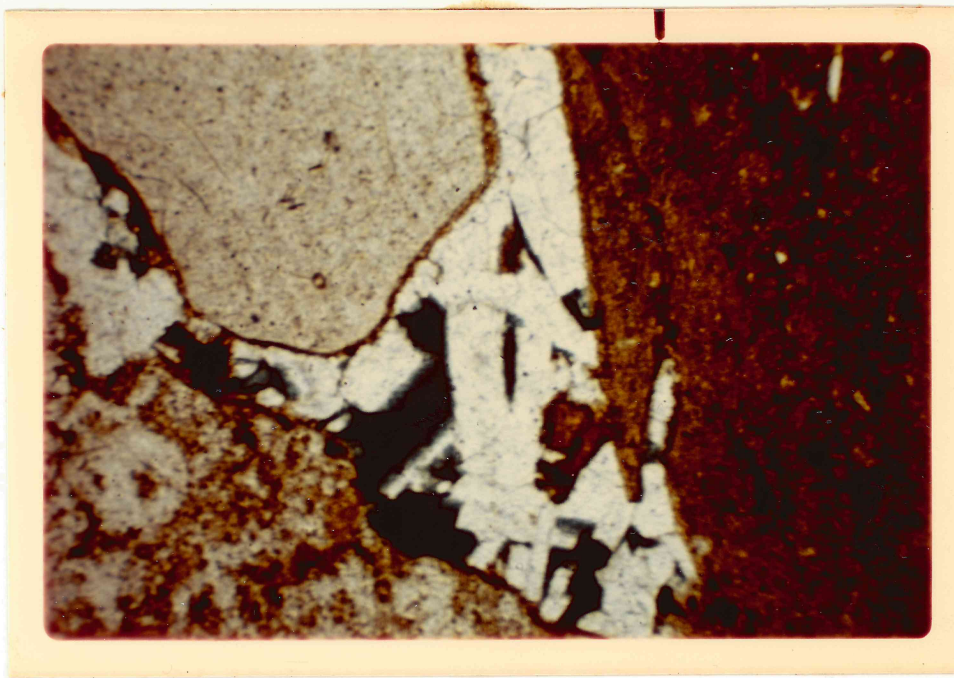


Fortress Mountain Formation. Ft. Mtn. #2, field 3.5 mm wide, parallel nicols. Clasts of light and dark chert, volcanics and dark mudstone set in a cement of quartz and albite.

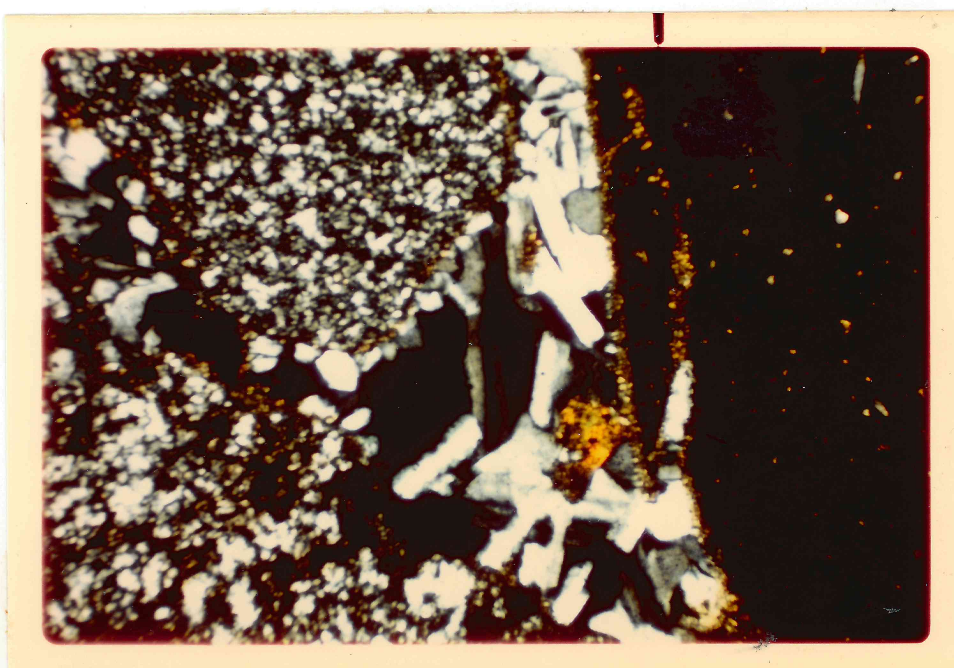


Same as above, crossed nicols.

Figure 14

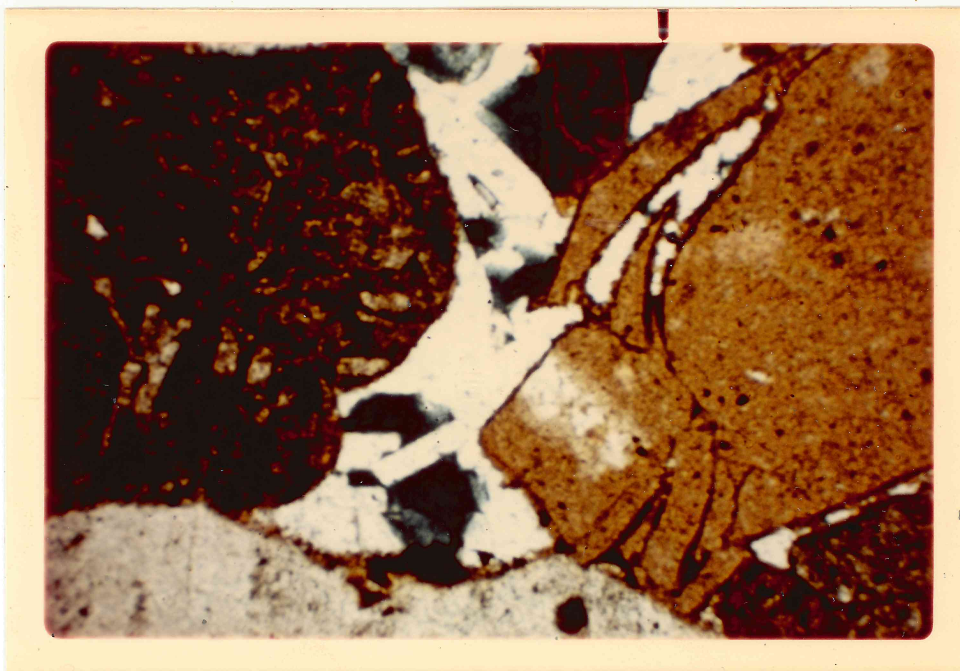


Fortress Mountain Formation. Ft. Mtn. #2, field 1 mm wide, parallel nicols. Pore filled with authigenic quartz and albite cement with vermiculite? rimming chert and dark mudstone.

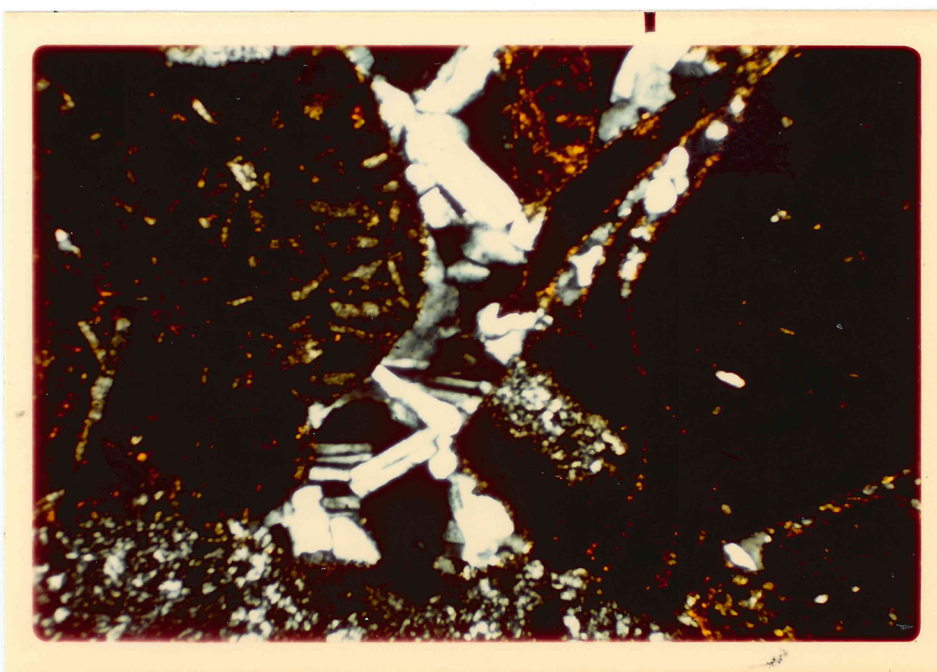


Same as above, crossed nicols.

Figure 15



Fortress Mountain Formation. Ft. Mtn. #2, field 1 mm wide, parallel nicols. Rim of chloritic (vermiculite?) material on chert, pore filled with quartz and albite.



Same as above, crossed nicols.

KEMIK SANDSTONE

Thin Sections.

RRR 459 and 502.

Age and Field Relations (Rose')

The Kemik Sandstone of Neocomian age was collected near the Canning River. It is thought that the source of the sand is from the ~~south~~ north, perhaps the Sadlerochit Formation.

Texture.

One sample was termed an arenite and the other a wacke but aside from the content of matrix the two rocks are very similar. Glauconite and collophane grains in the framework tend to be well rounded and the quartz and chert might go rounded to subrounded except for extensive quartz overgrowths which destroy their original shape. Only two grade sizes are encountered, fine and very fine. Porosity is low due chiefly to extensive cementation.

Mineralogy.

Clasts: Quartz predominates and appears to be largely derived from an igneous source. Grains with inclusions of liquid containing moving vapor bubbles or irregular and acicular inclusions are very common. A few grains with muscovite are indicative of a metamorphic source. Chert and phyllite grains are common and glauconite and collophane not uncommon.

Matrix: Silt sized quartz grains, greenish brown clay, abundant organic matter and occasional masses of coarse mica (probably authigenic) make up the matrix.

Cement: Quartz cement predominates. Practically all quartz and chert grains have overgrowths and in some instances fine grained quartz is found in the matrix. Some mica in the matrix may be authigenic. Asphaltic material in pores and along bedding laminations are found in RRR 502.

Distinctive Characteristics.

The very fine grain size and the good sorting, predominance of quartz grains in the framework, abundant rounded grains of glauconite and collophane and the pervasive quartz cement are distinctive. The asphalt in RRR 502 is most distinctive.

Provenance.

Rose' suggests the Sadlerochit as a major contributor and the high quartz and glauconite content of the Kemik would also suggest this. The collophane might indicate some erosion of the Shublik or Lisburne and the phyllite indicates an outcrop of the Neruokpuk Formation or its equivilent. Rather than suggesting an eroding limestone, the occurrance of occasional to many carbonate grains in this and other marine sandstones of Cretaceous age is probably due to Inoceramus prisms or other shell material.

Relief and Climate.

A nearby source and rapid transport indicative of high relief and rapid streams is indicated by the presence of many fragile grains such as phyllite, collophane and glauconite. Although not absolutely indicated a severe to temperate climate would aid is preserving fragile grains.

Transportation and Deposition.

The fine grains would require only moderate currents. Some reworking is suggested for RRR 502, perhaps in the littoral zone or in tidal channels, while rapid deposition in a low energy environment is suggested for RRR 459. Original stream transportation with depositionin a near-shore marine environment, rather active for one sample, a lagoon or neritic zone for the other.

Diagenetic History.

The matrix minerals seem but mildly affected by diagenesis but deposition of quartz cement as overgrowths and as quartz permeating the matrix is extensive. Original pores seem to be almost totally destroyed by such cementation.

Classification.

RRR 502 was termed a Quartz Arenite and RRR 459 a Quartz Wacke.

Sample Number RRR 459

Formation Kemik Sandstone

Locality Canning River

Number of points counted 618

Slide quality good

Texture

Wentworth Size Classes

Very Fine 93%
Fine 7

Framework: 79.0% of rock

Porosity - 2.3%

Median grain size - Very Fine

Sorting - Good

Rounding - Largely destroyed by overgrowths but suggest originally at least subrounded

Matrix: 13.8%

Cement: 14.0%

Quartz 100%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 68.0%

Types - (1) Some with muscovite
(2) With liquid inclusions containing moving bubbles, common
(3) With acicular and irregular inclusions, common
Suggest the majority are of igneous origin.

Feldspar - Tr.

Micas - 0.8%

Types - Muscovite only

Collophane - 4.7%

Glauconite - 3.5%

Opaques - 1.3%

Mineralogy (cont)

Rock Fragments:

Chert - 2.8%

Schist or Phyllite - 5.8%

Compositional Maturity

The rather high proportion of fragile phyllite, glauconite and collophane (taken to be detrital) indicate an immaturity regardless of the high quartz content.

Diagenesis

The pervasive quartz and a little coarse mica indicate mild diagenesis.

Matrix Minerals

Silt sized quartz grains, green to greenish brown clay minerals, some relatively coarse mica and considerable organic matter.

Cement Minerals

Pervasive quartz both as overgrowths and in the matrix.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstones containing quartz, some of it of igneous origin, and glauconite, cherty limestone with associated phosphorites and some low rank metamorphics (see discussion for RRR 502)

Climate and Relief - At least moderate relief and temperate climate.

Depositional Environment and Transport Mechanism - Rapid stream transportation to allow retention of the fragile phyllite, glauconite and collophane followed by deposition in a marine environment or relatively low energy, perhaps lagoonal or near shore neritic.

Gilbert Classification

Percent matrix - 13.8% of rock

Quartz, quartzite and chert - 92.4%

Feldspars and granitic rock fragments - 0%

Unstable Lithics - 7.6%

Rock name - Quartz Wacke

Sample Number RRR 502

Formation Kemik Sandstone

Locality Canning River

Number of points counted 678

Slide quality fair, a little thin

Texture

Wentworth Size Classes

Very Fine	82%
Fine	18
Medium	Tr.

Framework: 73.0% of rock

Porosity - 0.9%

Median grain size - Very Fine

Sorting - Good

Roundness - In part destroyed by overgrowths but would suggest originally at least subrounded to rounded

Matrix: 7.3%

Cement: 18.9%

Quartz	71.4%
Asphalt	28.6

Textural Maturity: Mature (It is suggested that most grains are second cycle, however)

Mineralogy

Framework Minerals:

Quartz - 54.6%

Types - (1) Some with muscovite and elongate polycrystalline grains
(2) Many with liquid globules containing moving vapor bubbles.
(3) Many with acicular and irregular inclusions
Suggest the majority are of igneous origin.

Feldspar - 0.3%

Types - Only plagioclase identified

Framework Minerals (cont)

Micas - 1.0%

Types - Only muscovite identified

Glauconite - 1.3%

Collophane - 1.0%

Epidote - Tr.

Tourmaline - Tr.

Carbonate - Tr.

Rock Fragments

Chert - 8.8%

Schist or Phyllite - 3.7%

Compositional Maturity

The high quartz and chert would indicate a mature composition but the fragile phyllite, glauconite and collophane must be accounted for. Suggest second cycle quartz and maybe chert and the other materials added last from a heterogeneous source.

Diagenesis

The pervasive quartz and a little mica (possible authigenic) suggest only mild diagenesis. The glauconite and collophane are thought to be detrital.

Matrix Minerals

Silt sized quartz grains, iron stained clay, a little coarse mica and a great deal of organic material form the matrix.

Cement Minerals

Quartz and an unknown black opaque material, thought to be asphalt.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Suggest quartz and glauconite from the Sadlerochit, collophane and perhaps some chert from the Lisburne or Shublik and some low rank metamorphics from the Neruokpuk or its equivilent.

Climate and Relief - Modest relief and a temperate climate are all that is required.

Depositional Environment and Transport Mechanism - Reasonably rapid stream transportation and deposition in a near shore marine environment that will allow some winnowing.

Gilbert Classification

Percent matrix - 7.3% of rock

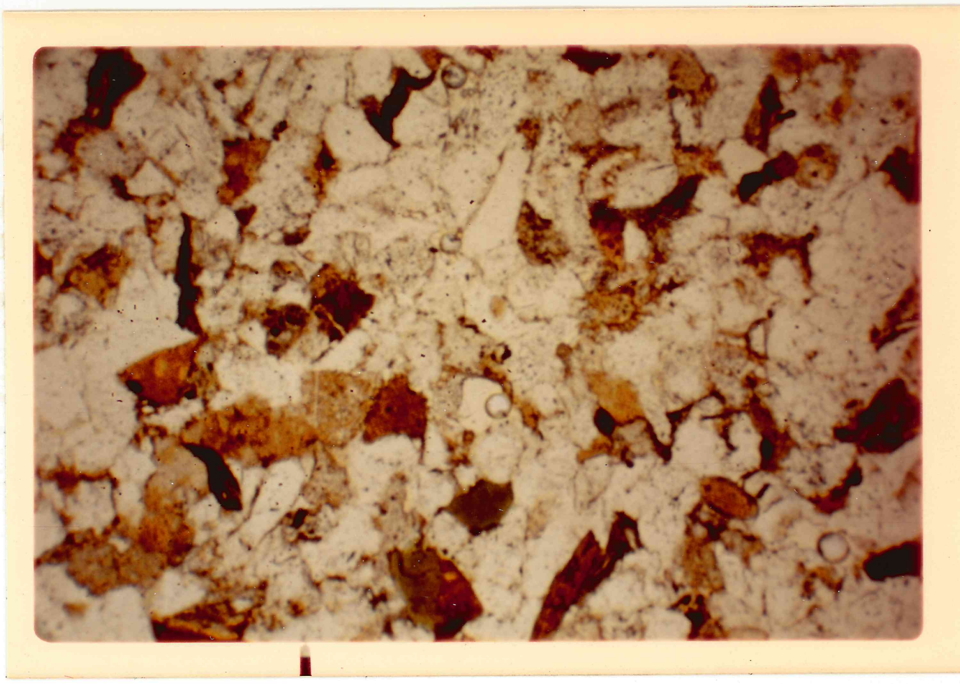
Quartz, quartzite and chert - 91.0% of framework

Feldspar and granitic rock fragments - 0.4%

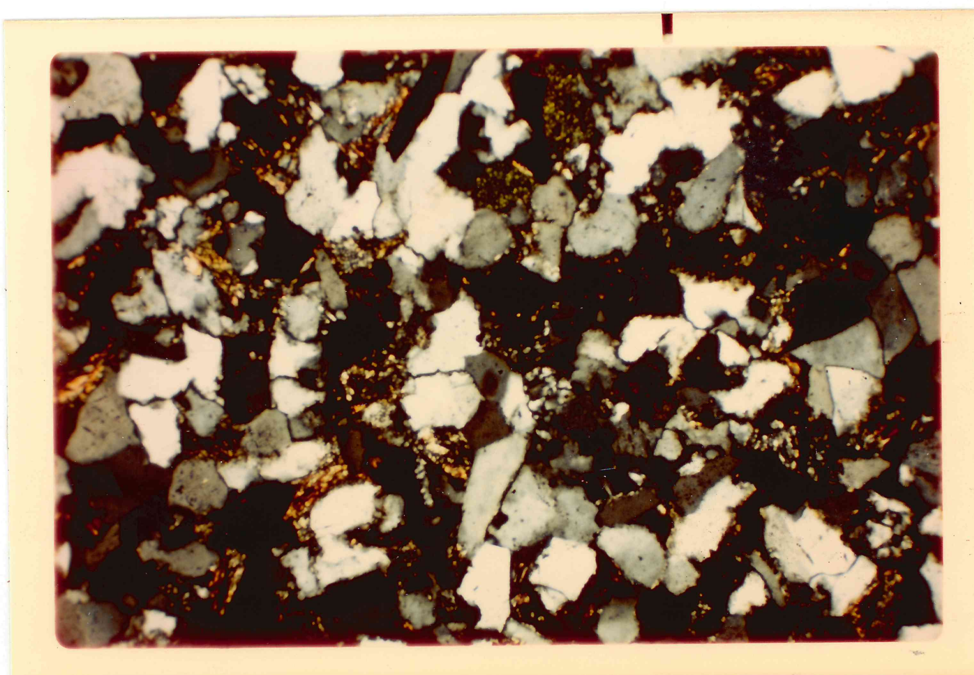
Unstable Lithics - 9.6%

Rock name - Quartz Arenite

Figure 16



Kemik Sandstone. RRR 459, field 1 mm wide, parallel nicols. Clasts of quartz, chert, glauconite, collophane and phyllite. Matrix of silt and greenish clay. Cement of quartz overgrowths.



Same as above, crossed nicols.

ALBIAN AND "MIDDLE CRETACEOUS"

GRANDSTAND FORMATION

Thin Sections

RRR 809, 811 and 812

Age and Field Relations (Rose')

The rocks collected from the Grandstand type section in the Umiat area are of Albian age. They are said to be strand line deposits coming from the ancestral Brooks Range.

Texture

All samples consist largely of the two grade sizes fine and very fine. Grains may be angular to rounded but the original shapes of many of the quartz grains are modified by overgrowths. The original roundness may have been subrounded to rounded. The low porosity of 4 to 6% is due largely to a high matrix content, perhaps 13 to 20%.

Mineralogy

Clasts: In all three samples quartz and chert make up about 85% of the clasts; schist or phyllite, mudstone (perhaps some is argillite), and dark organic rich lumps make up most of the remainder. Mica and feldspar are present but found in small quantities and carbonate grains are rare.

The quartz clasts may be of both metamorphic and igneous origin but the metamorphic predominates.

Matrix: An X-ray analysis of the clay sized material found in RRR 811 revealed, in addition to quartz, chlorite, mica and kaolinite. Iron oxide and organic matter are also common. The quartz seems to be present both as silt grains and as interstitial cement.

Cement: Quartz is found as overgrowths and as anhedral masses in the matrix. Growing in the matrix is some rather coarse green chlorite and mica thought to be authigenic. Carbonate is present but rare.

Distinctive Characteristics

The kaolinite and the rather coarse mica of the matrix are a bit unusual. The occurrance of only fine and very fine grade sizes of clasts composed of over 85% quartz and only minor chert in these three samples is not unique but is somewhat unusual. These rocks appear to be unusually organic rich, the material occurring both as fine matrix material and as lumps.

Provenance

The high quartz content would suggest a quartz sandstone, perhaps the Sadlerochit, the schist or phyllite and the mica, and perhaps some of the metamorphic quartz suggest an outcrop of the Neruokpuk Formation. Dark mudstone or argillite and organic rich lumps might be from the carbonaceous shales of the Shublik, as might some of the chert. Rare carbonate grains are thought to be shell material.

Relief and Climate

Presence of the fragile schist, phyllite and mudstone might indicate rapid transport from nearby areas and hence topographic highs. The rock is not particularly climate diagnostic and reveals little but a possible temperate climate.

Transportation and Deposition

Transportation by streams to a marine environment of low energy and rich in or capable of receiving much organic material, perhaps a lagoon.

Diagenetic History

Diagenesis seems mild but pervasive. Kaolinite and organic matter are still present in considerable amounts. Quartz as overgrowths and anhedral grains in the matrix is perhaps the most important cement. Carbonate cement is rare a probably comes from solution and reprecipitation of the carbonate material of shell fragments.

X-ray analysis indicate the presence of chlorite, mica and kaolinite in the matrix. Although the mica is coarse and some thought was given to an authigenic origin it was finally considered detrital as was the kaolinite. The chlorite, like so much of the chlorite in these Cretaceous rocks, is considered authigenic.

Classification

The three samples are all similar and all are classified as Subfeldspathic Lithic Wackes.

Sample Number RRR 809

Formation Grandstand

Locality Type Area

Number of points counted 641

Slide quality good

Texture

Wentworth Size Classes

Very Fine 82%
Fine 18

Framework: 67.1%

Porosity - 5.6%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to rounded, somewhat modified by overgrowths.

Textural Maturity : Immature

Matrix : 20.1%

Cement: 7.2%

Quartz 100%

Mineralogy

Framework Minerals:

Quartz - 47.0%

Types - (1) Contains euhedral green inclusions, mica? Common
(2) Polycrystalline, commonly with over 6 grains
(3) Acicular inclusions arranged in parallel lines. Rare.
Quartz chiefly metamorphic but some igneous.

Feldspar - 2.7%

Types - Plagioclase, microcline, untwinned

Mica - 0.8% Muscovite only

Rock Fragments:

Chert - 5.8%

Rock Fragments: (cont)

Schist or phyllite - 6.4% Biotite and muscovite schist common

Mudstone - 4.5% Some strongly organic rich mudstone, seem almost like organic lumps.

Compositional Maturity: Immature

Diagenesis

Quartz cement both as overgrowths and mosaics of anhedral grains in the matrix.. Abundant chlorite is probably authigenic.

Matrix Minerals

Silt sized quartz grains, some quartz cement, mica and chlorite, organic matter. The mica is thought detrital the chlorite authigenic.

Cement Minerals

Quartz both as overgrowths and in the matrix.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstone, organic mudstone or shale, low rank metamorphics and perhaps chert or cherty limestone.

Climate and Relief - Moderate to high relief to bring in the fragile metamorphics and mudstone, perhaps a temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation into a low energy marine or paralic environment.

Gilbert Classification

Percent matrix - 20.1% of rock

Quartz, quartzite and chert - 84.6% of framework

Feldspars and granitic rock fragments - 4.3%

Unstable Lithics - 11.1%

Rock Name - Subfeldspathic Lithic Wacke

Sample Number RRR 811

Formation Grandstand

Locality Type Area

Number of points counted 651

Slide quality good

Texture

Wentworth Size Classes

Very Fine	61%
Fine	38
Medium	1

Framework: 72.4%

Porosity - 7.7%

Median grain size - Very fine

Sorting - Fair

Roundness - Angular to rounded. Modest alteration by overgrowths. Perhaps originally subrounded

Matrix: 12.4%

Cement: 4.8%

Quartz 100%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 53.5%

Types - (1) Contains euhedral green inclusions. Common.
(2) With liquid-gas inclusions. Rare.
(3) Contains strings of bubbles. Not uncommon.
Both igneous and metamorphic sources.

Feldspar - 0.9%

Types - Plagioclase only

Micas - 0.6%

Types - Both muscovite and biotite

Rock Fragments

Chert - 7.1%

Schist or phyllite - 6.9%

Mudstone - 6.0% Some very organic rich, almost like organic lumps.

Siltstone - Tr.

Compositional Maturity: Immature

Diagenesis

Quartz is common both as overgrowths and as anhedral grains growing in the matrix. The ubiquitous chlorite is probably also authigenic.

Matrix Minerals

X-ray analysis. (1) A 14 A peak unchanged through glycolation and heat treatment was taken as chlorite. An accompanying 3.53 peak was taken as additional evidence for chlorite. (2) A distinct 3.57 A peak strongly suggests kaolinite. (3) A good 10 A mica peak. (4) The usual quartz peaks.

Quartz silt as well as cement could be seen in the microscope along with cloudy kaolinite, unusually coarse mica and the light green chlorite.

Cement Minerals

Quartz both as overgrowths and mosaics of anhedral quartz grains in the matrix or in pores.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstone, organic mudstone, perhaps cherty, and low rank metamorphics.

Relief and Climate - Moderate to high relief, temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transport into a marine or paralic environment of low energy.

Gilbert Classification

Percent matrix - 12.4% of rock

Quartz, quartzite and chert - 84.5% of framework

Feldspars and granitic rock fragments - 1.2%

Unstable Lithics - 14.3%

Rock Name - Subfeldspathic Lithic Wacke

Sample Number RRR 812

Formation Grandstand

Locality Type Area

Number of points counted 647

Slide quality fair, many grains have plucked

Texture

Wentworth Size Classes

Very Fine 32%
Fine 65
Medium 3

Framework: 68.5%

Porosity - 8.5%

Median grain size - Fine

Sorting - Fair

Roundness - Angular to rounded, well hidden by overgrowths

Matrix: 17.8%

Cement: 5.3%

Quartz 100%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 46.5%

Types - (1) Polycrystalline with many grains of different size
(2) Contains euhedral green inclusions. Common
(3) Contains liquid-gas bubbles. Not uncommon
Both igneous and metamorphic sources, the latter the most common

Feldspar - 0.6% Plagioclase

Micas - 1.2% Muscovite

Chlorite grains - Tr.

Carbonate grains - Tr.

Rock Fragments:

Chert - 8.5%

Schist or phyllite - 7.1%

Mudstone - 4.0% Many extremely organic rich, resembling organic lumps.

Siltstone - Tr.

Compositional Maturity: Immature

Diagenesis

Quartz cement and the usual chlorite in the matrix. Mild diagenesis.

Matrix Minerals

Some organic rich cloudy clay (kaolinite?), much organic matter, quartz silt, mica and the usual pale green chlorite.

Cement Minerals

Quartz both as overgrowths and as nests of anhedral grains in pores or in the matrix. Traces of carbonate cement.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstone, organic rich mudstone, perhaps cherty, and low rank metamorphics.

Climate and Relief - Moderate to high relief, temperate to severe climate.

Transportation and Depositional Environment - Stream transport into an organic rich, low energy marine or paralic environment.

Gilbert Classification

Percent matrix - 17.8% of rock

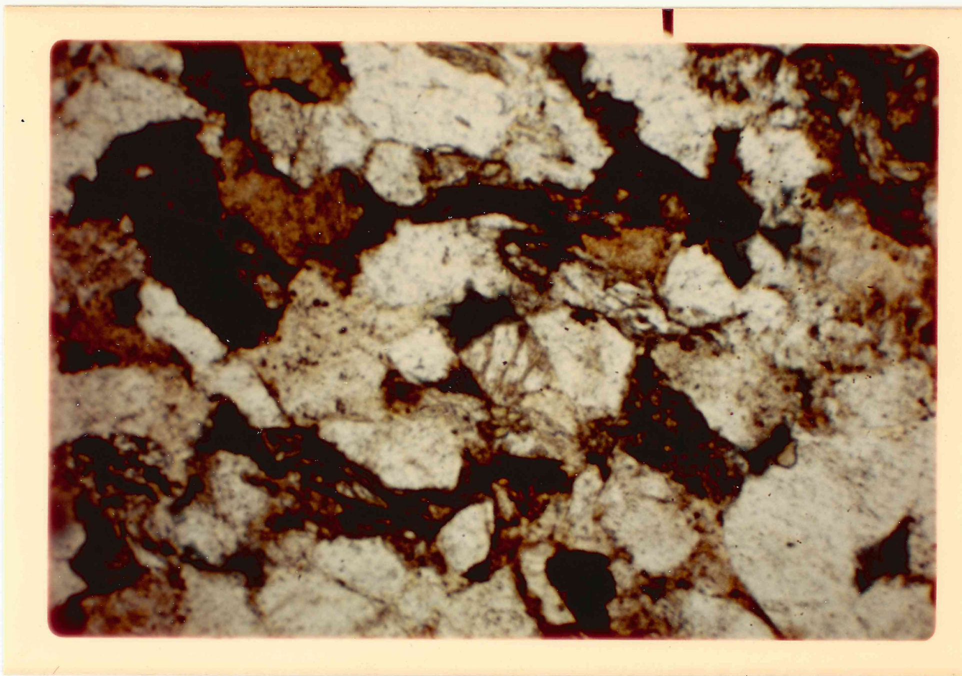
Quartz, quartzite and chert - 84.8% of framework

Feldspars and granitic rock fragments - 0.9%

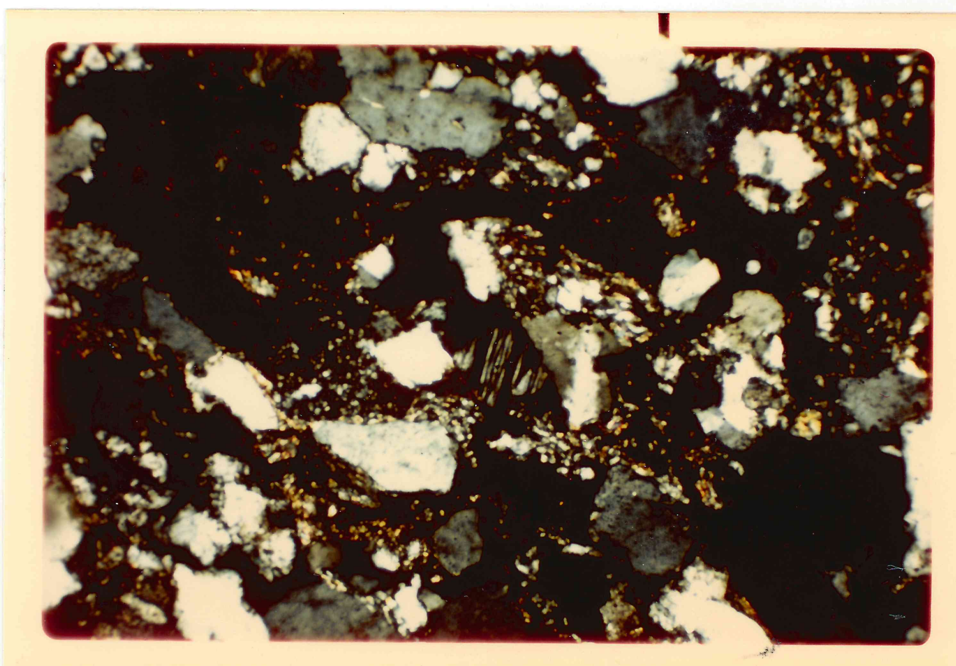
Unstable Lithics - 14.3%

Rock Name - Subfeldspathic Lithic Wacke

Figure 17

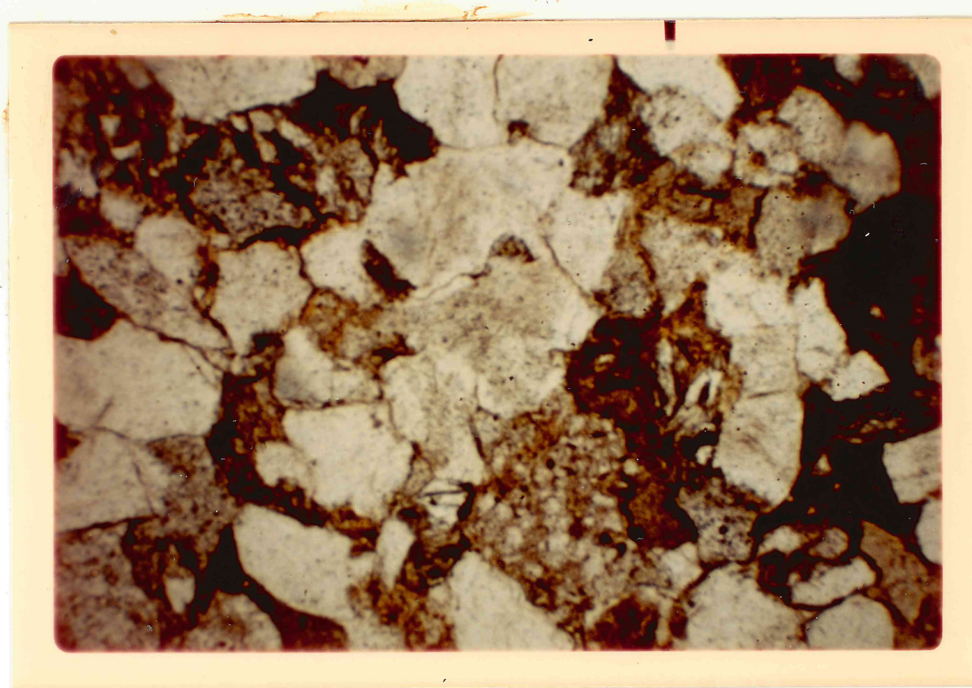


Grandstand Formation from the Type Area. RRR 809, field 1 mm wide, parallel nicols. Clasts of quartz, chert, phyllite, clay lumps and microcline. Matrix of quartz silt and clay. Cement largely quartz overgrowths.

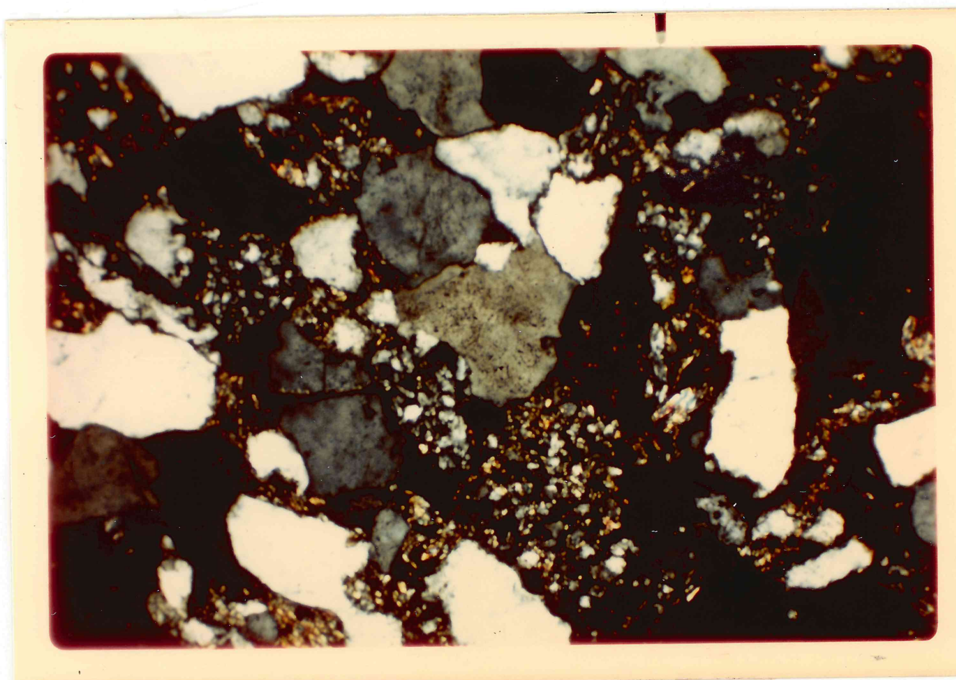


Same as above, crossed nicols.

Figure 18



Grandstand Formation from the Type Area. RRR 811, field 1 mm wide, parallel nicols. Clasts of quartz, chert, mudstone and phyllite. Matrix of quartz silt and clay. Cement quartz.



Same as above, nicols crossed.

KILLIK FORMATION

Thin Sections

RRR 778 and 779.

Age and Field Relations (Rose')

The Killik Formation is said to be the continental correlative of the Grandstand Formation of Albian age. Collected from the Umiat Area, the Killik is presumably from the same source as the Grandstand, the Ancestral Brooks Range.

Texture

The two samples vary in that RRR 778 has three grade sizes with appreciable mediu grained sand while RRR 779 has but two grade sizes and 81% is very fine sand. Both have angular to rounded grains but the quartz grains have been badly modified by overgrowths. Both have 69% framework, 15-20% matrix and appreciable cement. The porosities are very low due both to the abundant matrix and cement.

Mineralogy

Clasts: In both samples quartz forms over 50% of the framework (52 and 55%), chert and schist or phyllite are also important but vary within somewhat wider limits (chert 20 to 23% and schist or phyllite 7 to 24%). Organic mudstones or argillites, often silicified, are common to both as are modest amounts of feldspar and mica. They differ in that 779 contains appreciable amounts of carbonate grains and some glauconite.

Matrix: No X-ray analyses were available. Petrographic examination indicated quartz silt, organic matter, iron stained clay (kaolinite?), somewhat coarse mica and the usual pale green chlorite.

Cement: Quartz as overgrowths and anhedral grains in interstices is common to both and in addition RRR 779 contains considerable carbonate cement.

Distinctive Characteristics

The Killik bears a strong resemblance to the Grandstand and the Ninuluk. It contains kaolinite and coarse mica in the matrix and is unusually fine grained and rich in organic matter. It differs in that it is lower in quartz and richer in chert and phyllite. The Grandstand had no carbonate grains or cement but RRR 779 has both.

Provenance

The reasonably high quartz content including much igneous quartz and a little glauconite suggests Sadlerochit. Abundant schist or phyllite, matrix mica and metamorphic quartz indicate low rank metamorphics, perhaps the Neruokpuk, and dark organic rich chert and mudstone suggest Shublik.

Relief and Climate

The presence of fragile phyllite and mudstone indicates rapid transport for a short distance and suggest topographic highs. The very limited feldspar might suggest a temperate climate or, more likely, a source area limited in feldspar.

Transportation and Deposition

If continental, the Killik sandstones were stream transported to a low energy organic rich environment, probably a floodplain or swamp. However, some doubt must be expressed concerning the origin of RRR 779. The presence of 1.4% carbonate grains shggest shell fragments and the size of some of the larger grains might indicate Inoceramus prisms. The very strong similarity between Killik and Grandstand samples is also interesting. Even if marine, however, the environment would still be low energy organic rich, perhaps lagoonal.

Diagenetic History

Quartz as overgrowths and anhedral grains in the matrix is common. Original clay (kaolinite?) appears to have been in part converted to authigenic chlorite. The carbonate cement in RRR 779 is probably due to solution from the common carbonate grains and reprecipitation in pores or impregnating the matrix.

Classification

Both sandstone samples were classified as Subfeldspathic Lithic Wackes.

Sample Number RRR 778

Formation Killik

Locality Umiat Area

Number of points counted 635

Slide quality fair, some yellow in quartz

Texture

Wentworth Size Classes

Very Fine 21%
Fine 66
Medium 13

Framework: 69.0%

Porosity - 2.2%

Median grain size - Fine

Sorting - Fair

Roundness - Angular to rounded, obscured on quartz grains by overgrowths

Matrix: 18.1%

Cement: 10.1%

Quartz 100%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 35.7%

Types - (1) Contains liquid-gas inclusions
(2) Many small bubbles in "fingerprint" patterns
(3) Contains included muscovite
Both igneous and metamorphic grains common

Feldspar - Tr. Plagioclase

Mica - Tr. Muscovite

Rock Fragments:

Chert - 15.7%

Schist or phyllite - 4.9%

Argillite - 8.8%

Remarks. In addition to chert, some interesting rock fragments were:
(1) Dark organic rich mudstone with veinlets and pockets of fine-grained quartz.
(2) Argillite, like mudstone but with aggregate polarization.

Rock Fragments: (cont)	Remarks (cont)
Mudstone - 3.6% or siltstone	(3) Rather coarse phyllite, muscovite rich. (4) Coarse siltstone, quartz grains in a chloritic matrix

Compositional Maturity: Immature

Diagenesis

Abundant quartz cement and matrix chlorite. Kaolinite still abundant in the matrix showing incomplete chloritization.

Matrix Minerals

Quartz silt, iron-stained kaolinite, rather coarse mica, matrix chlorite.

Cement Minerals

Quartz, both as overgrowths and anhedral grain masses in interstices.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstones, carbonaceous and partially silicified mudstone or argillite, low rank metamorphics, cherty rocks.

Climate and relief - Moderate to high relief, temperate climate.

Transportation and Depositional Environment - Stream transport into an organic rich, low energy continental? environment, perhaps floodplain or swamp.

Gilbert Classification

Percent matrix - 18.1% of rock

Quartz, quartzite and chert - 75.5%

Feldspar - Tr.

Lithics of unstable nature - 24.5%

Rock Name - Subfeldspathic Lithic Wacke

Sample Number RRR 779

Formation Killik

Locality Umiat Area

Number of points counted 703

Slide quality good

Texture

Wentworth Size Classes

Very Fine 81%
Fine 19

Framework: 69% of rock

Porosity - 1.4%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular. Badly altered by overgrowths, perhaps subangular to subrounded originally

Matrix: 14.4%

Cement: 15.2%

Quartz - 73.8%
Carbonate - 26.2%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 36.8%

Types - (1) Contains liquid-gas bubbles.
(2) Contains euhedral muscovite
(3) Polycrystalline, elongate grains with muscovite
Both igneous and metamorphic quartz present

Feldspar - 1.0% Plagioclase

Micas - 1.1% Muscovite only

Carbonate grains - 1.4%

Glauconite - Tr.

Rock Fragments:

Chert - 6.5%

Schist or phyllite - 16.4%

Mudstone and organic lumps - 5.6%

Compositional Maturity : Immature

Diagenesis

Quartz and carbonate cement and matrix chlorite.

Matrix Minerals

Quartz silt, iron-stained clay, chlorite.

Cement Minerals

Quartz both as overgrowths and as mosaics of anhedral grains in interstices and in the matrix and carbonate.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstones, organic mudstones and argillite some cherty, low rank metamorphics.

Climate and Relief - Moderate to high relief, temperate climate.

Transportation and Depositional Environment - Stream transport into an organic rich low energy environment. If the environment is continental, as suggested by Rose', floodplain or swamp is suggested. The carbonate grains might suggest marine or paralic. If such is the case lagoonal is suggested.

Gilbert Classification

Percent matrix - 14.4% of rock

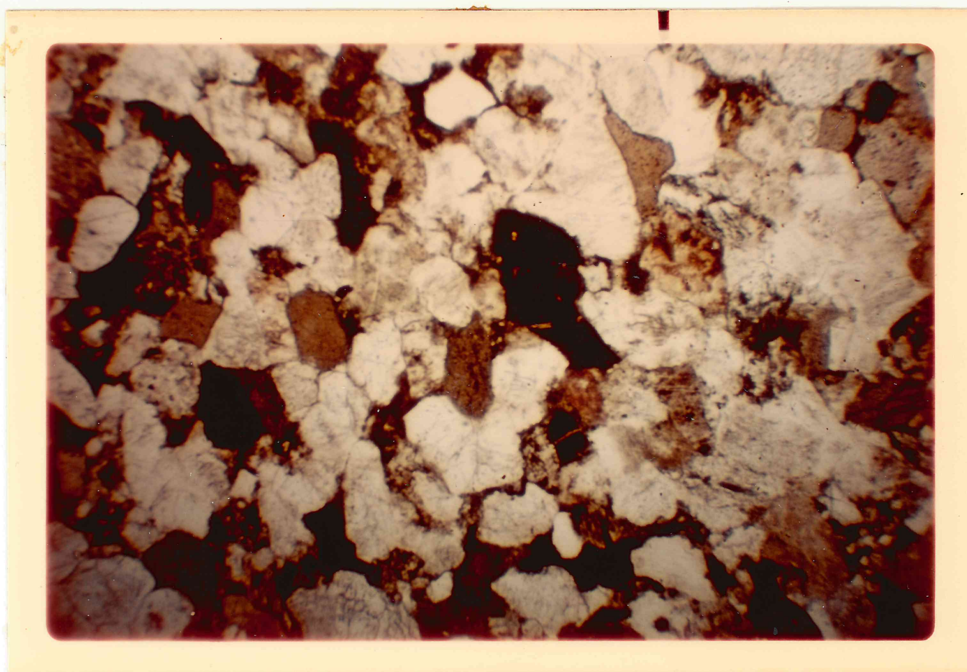
Quartz, quartzite and chert - 69.5%

Feldspar - 1.6%

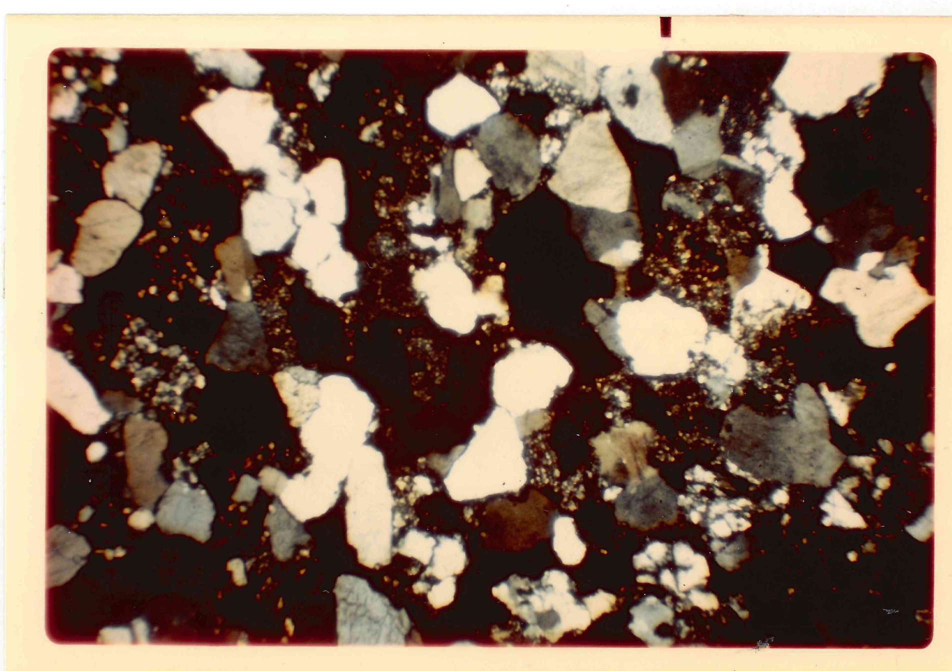
Unstable Lithics - 28.9%

Rock Name - Subfeldspathic Lithic Wacke

Figure 19

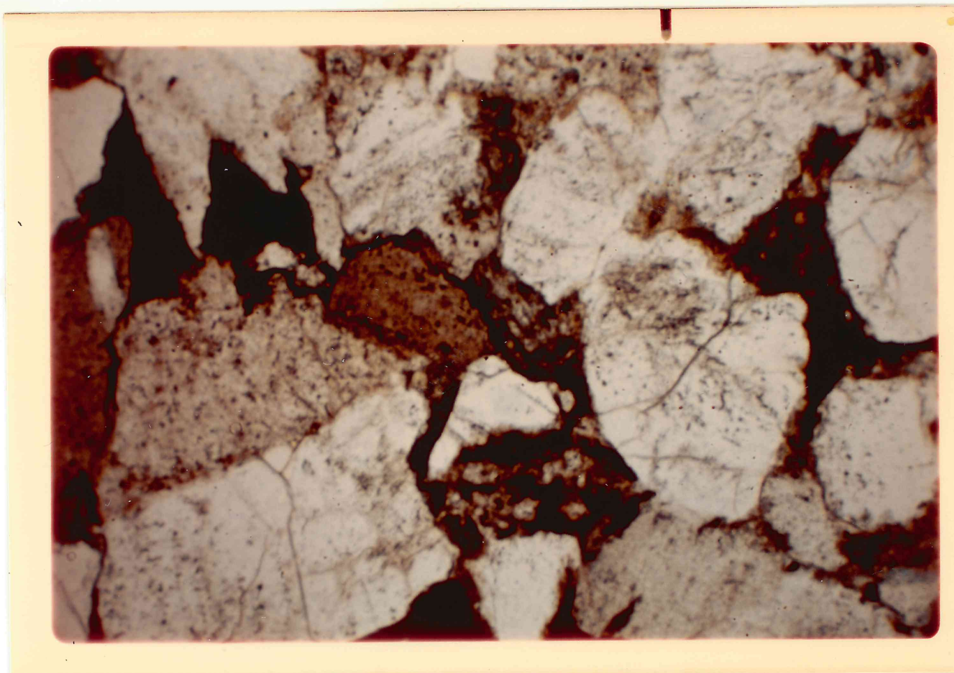


Killik Formation, Umiat Area. RRR 778, field 3.5 mm wide, parallel nicols. Clasts of quartz, varieties of chert, phyllite, feldspar and dark to opaque organic mudstone. Matrix of organic rich clay and quartz silt. Cement of quartz overgrowths.

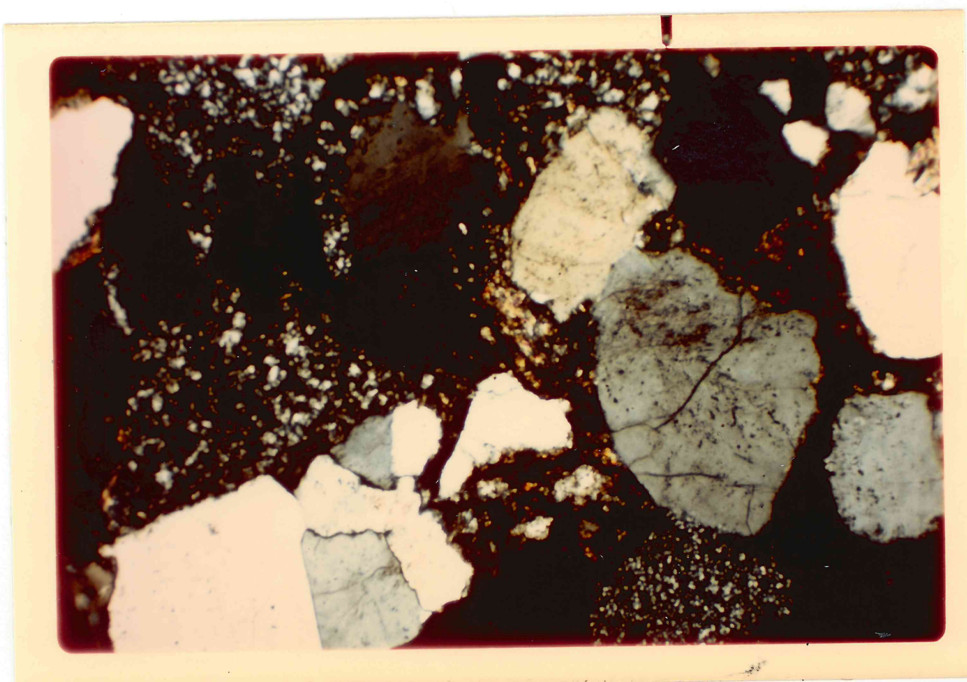


Same as above, crossed nicols.

Figure 20



Killik Formation, Umiat Area. RRR 778, field 1 mm wide, parallel nicols. Clasts of quartz, chert, phyllite and organic rich mudstone. Matrix of organic rich clay and quartz silt. Cement of quartz overgrowths. Diagenetic chlorite developing in the matrix.



Same as above, crossed nicols.

NINULUK FORMATION

Thin Sections

RRR 655, 669 and 678.

Age and Field Relations (Rose')

The Ninuluk Formation of the Umiat Area is of Middle Cretaceous age. It is interpreted as a nearshore marine deposit, its source the Ancestral Brooks Range to the south.

Texture

It is composed predominately of very fine grained sand. The grains are angular to subrounded but quartz grains have been altered by overgrowths. With a matrix of 10-15% and abundant quartz and carbonate cement the porosity of the Ninuluk is low ranging from 2 to 7%.

Mineralogy

Clasts: Quartz is the most abundant framework mineral forming 53% of the clasts. Phyllite is next with 22% and chert forms 11%. Feldspar forms a surprisingly large 5.5% of the clasts, mudstone and argillite 4.2%, carbonate grains 2% and mica 2%.

Matrix: An X-ray analysis of the matrix of RRR 669 revealed, in addition to quartz, considerable amounts of kaolinite, chlorite and mica. The quartz is found both as silt and cement in the martix. Organic matter was abundant.

Cement: Both carbonate and quartz cement are abundant and in RRR 678 and minor albite overgrowths on plagioclase was noted. Authigenic matrix chlorite aids in the lithification of the rock.

Distinctive Characteristics

The Ninuluk bears a strong resemblence to the Killik and is similar to the Grandstand. The matrix appears to be unusually rich in kaolinite and the clasts richer in phyllite, mica and feldspar than the others but the differences are rather minor.

Provenance

The unusually high content of phyllite and mica as clasts and much mica in the matrix along with the prevelance of metamorphic quartz suggests a large nearby expanse of low rank metamorphics, perhaps the Neruokpuk Formation. Mudstone, chert, reworked quartz and feldspar grains would suggest Lisburne, Shublik and Sadlerochit.

Climate and Relief

Fragile phyllite and mudstone and considerable feldspar suggest a nearby source and rapid movement, hence at least moderate relief and temperate to severe climate.

Transportation and Deposition

Stream transportation to a low energy organic rich environment, marine or paralic, perhaps lagoonal.

Diagenetic History

An original matrix of kaolinite, quartz silt, mica and humus has been at least partially changed to chlorite. Extensive solution of quartz and shell fragments with subsequent reprecipitation has firmly cemented the sandstone and essentially destroyed the porosity.

Classification

Two samples were classified as Subfeldspathic Lithic Wackes, the third as Lithic Wacke.

Sample Number RRR 655

Formation Ninuluk

Locality Umiat Area

Number of grains counted 712

Slide quality good

Texture

Wentworth Size Classes

Very Fine 56%
Fine 44

Framework: 66.3% of rock

Porosity - 6.7%

Median grain size - Very Fine

Sorting - Good

Roundness - Originally subangular to rounded, now obscured by overgrowths.

Matrix: 14.0%

Cement: 12.9%

Quartz 28.3%
Carbonate 71.7%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 40.2%

Types - (1) Contains liquid-gas inclusions
(2) Pollycrystalline with parallel elongate grains
(3) Contains euhedral muscovite. Very common
Both igneous and metamorphic quartz, the latter most common

Feldspar - 3.2% Plagioclase, often badly altered

Mica - 0.8% Muscovite only

Carbonate grains - Tr.

Zircon - Tr.

Rock Fragments:

Chert - 10.8%

Schist or phyllite - 5.6%

Mudstone (dark and organic rich) - 2.5%

Argillite - 3.1%

Remark Contains a large fragment of Inoceramus shell, probably the origin of much of the carbonate debris found in Ninuluk samples.

Compositional Maturity: Immature

Diagenesis

Authigenic matrix chlorite noted. Abundant quartz and carbonate cement.

Matrix Minerals

Quartz silt, kaolinite, mica and chlorite with abundant humus.

Cement Minerals

Quartz, both as overgrowths and pore filling, and carbonate.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstone to furnish the abundant quartz and badly weathered feldspar, chert and organic mudstone, low rank metamorphics.

Climate and Relief - Moderate to high relief, temperate to severe climate.

Transportation and Depositional Environment - Stream transport to an organic rich low energy marine environment.

Gilbert Classification

Percent Matrix - 14.0% of rock

Quartz, quartzite and chert - 78.0%

Feldspar - 4.9%

Unstable Lithics - 17.1%

Rock Name - Subfeldspathic Lithic Wacke

Sample Number RRR 669

Formation Ninuluk

Locality Umiat Area

Number of points counted 644

Slide quality good

Texture

Wentworth Size Classes

Very Fine 68%
Fine 32

Framework: 80.4% of rock

Porosity - 1.5%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to subrounded but overgrowths mask the original texture. Perhaps originally subrounded?

Matrix: 11.6%

Cement: 6.4%

Quartz 63.4%
Carbonate 36.6%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 36.0%

Types - (1) Pollycrystalline, many grains elongate, some muscovite. Common.
(2) Contains euhedral muscovite. Common.
(3) Contains liquid-gas bubbles.
Chiefly metamorphic quartz but some igneous.

Feldspar - 1.9%

Types - Plagioclase (some andesine) and microcline

Mica - 1.7% Muscovite

Chlorite - 0.5% Large single grains

Carbonate grains - Tr.

Rock Fragments:

Chert - 5.1%

Schist or phyllite - 32.8%

Argillite - 1.5%

Mudstone - 0.8%

Remarks. A reasonably coarse muscovite schist is very common. Pale brown phyllite or argillite exhibiting aggregate polarization is also common. Some grains called quartz were almost rich enough in muscovite to term schist.

Compositional Maturity: Immature

Diagenesis

Quartz and carbonate cement and authigenic chlorite in the matrix.

Matrix Minerals

X-ray analysis. The very common 14.15 A peak which is unaffected by glycolation but increased in intensity when herated to 550° C for ½ hour, accompanied by a 3.52 A peak. Chlorite. A 10 A peak unaffected by glycolation or heating: mica. A 7 A peak accompanied by a 3.57 A peak: kaolinite. All in addition to the ubiquitous quartz peaks.

In addition to the above humus is also present. The quartz commonly as silt grains.

Cement

Quartz chiefly as overgrowths and carbonate.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Must have an extensive outcrop of low rank metamorphics along with cherty mudstone or shale and minor sandstone.

Climate and Relief - Moderate to high relief, temperate to severe climate.

Transportation and Depositional Environment - Stream transported to an organic rich low energy marine environment.

Gilbert Classification

Percent Matrix - 11.6% of rock

Quartz, quartzite and chert -53.2% of framework

Feldspar and granitic rock fragments - 2.5%

Unstable Lithics - 44.4%

Rock Name - Subfeldspathic Lithic Wacke

Sample Number RRR 678

Formation Ninuluk

Locality Umiat Area

Number of points counted 577

Slide quality good

Texture

Wentworth Size Classes

Very Fine 99%
Fine 1

Framework: 63.4% of rock

Porosity - 3.3%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to subrounded but altered by overgrowths. Perhaps subangular originally.

Matrix: 15.2%

Cement: 18.0%

Quartz 24.0%
Carbonate 73.1%
Albite 2.9%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 30.0%

Types - (1) Inclusions of euhedral muscovite
(2) Polycrystalline grains
Careful search did not disclose a quartz grain that could be attributed to igneous sources.

Feldspar - 6.4%

Types - (1) Plagioclase, perhaps andesine
(2) Microcline
(3) Untwinned

Micas - 1.7% Both muscovite and biotite

Zircon - Tr.

Garnet - Tr.

Rock Fragments:

Chert - 6.9%

Schist or phyllite - 6.9%

Mudstone - 0.7%

Carbonate grains - 10.7%

Compositional Maturity: Immature

Diagenesis

Quartz and carbonate cement common, albite overgrowths rare and some authigenic matrix chlorite.

Matrix Minerals

Quartz silt, kaolinite, organic matter and authigenic chlorite often impregnated by the cementing minerals quartz and carbonate.

Cement Minerals

Quartz and carbonate are common, albite overgrowths on plagioclase is interesting but rare.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Abundant low rank metamorphics, cherty mudstone and minor sandstone.

Climate and Relief - Modest to high relief, temperate to severe climate.

Transportation and Depositional Environment - Stream transportation into an organic rich low energy marine environment.

Gilbert Classification

Percent matrix - 15.2% of rock

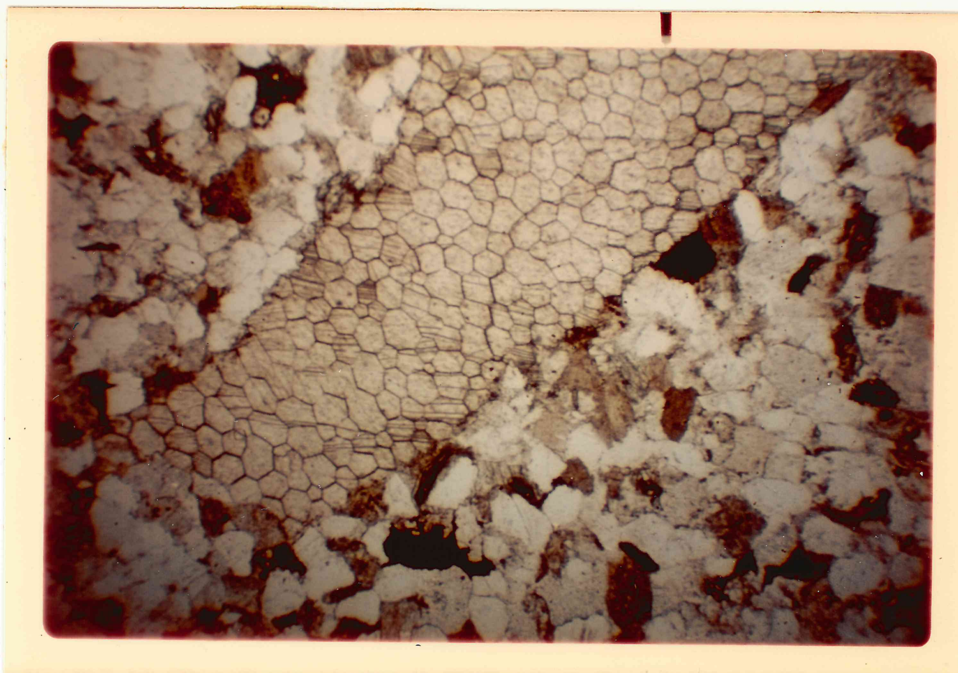
Quartz, quartzite and chert - 72.5% of framework

Unstable Lithics - 15.0%

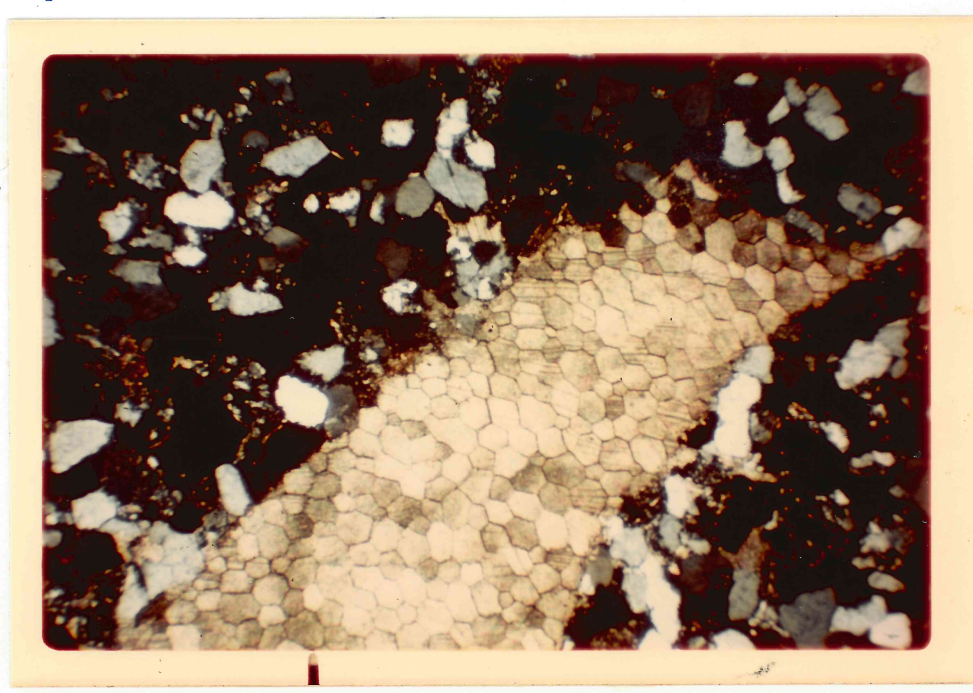
Feldspar and granitic rock fragments - 12.5%

Rock Name - Lithic Wacke

Figure 21

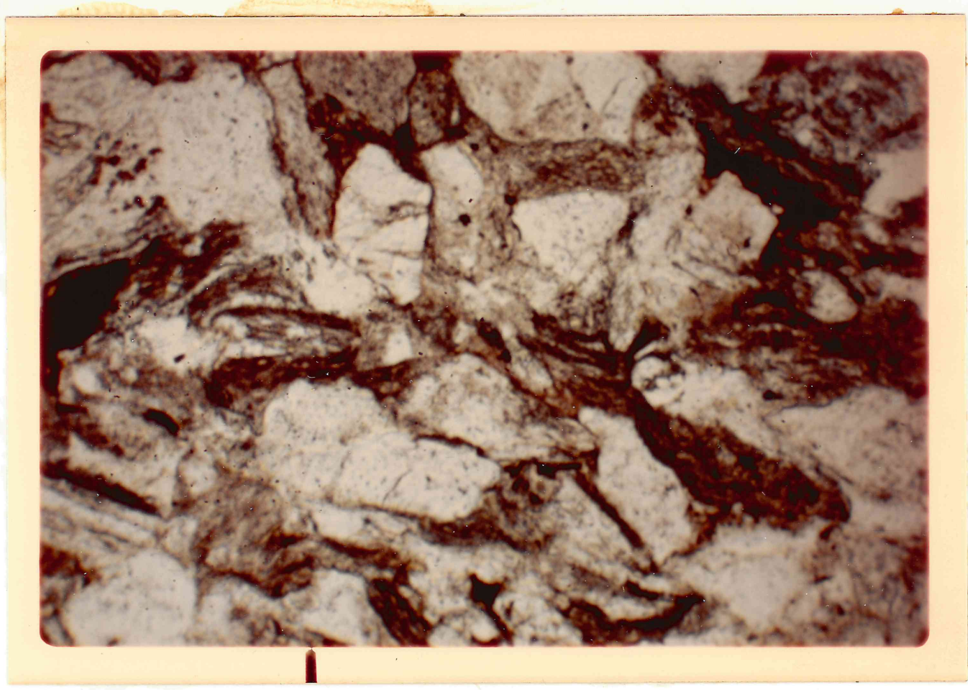


Ninuluk Formation, Umiat Area. RRR 655, field 3.5 mm wide, parallel nicols. Prismatic layer of pelecypod shell (probably Inoceramus) cut perpendicular to the prisms, parallel to the shell surface. Such coarse prisms may account for the "carbonate grains" reported from so many Cretaceous sandstones.

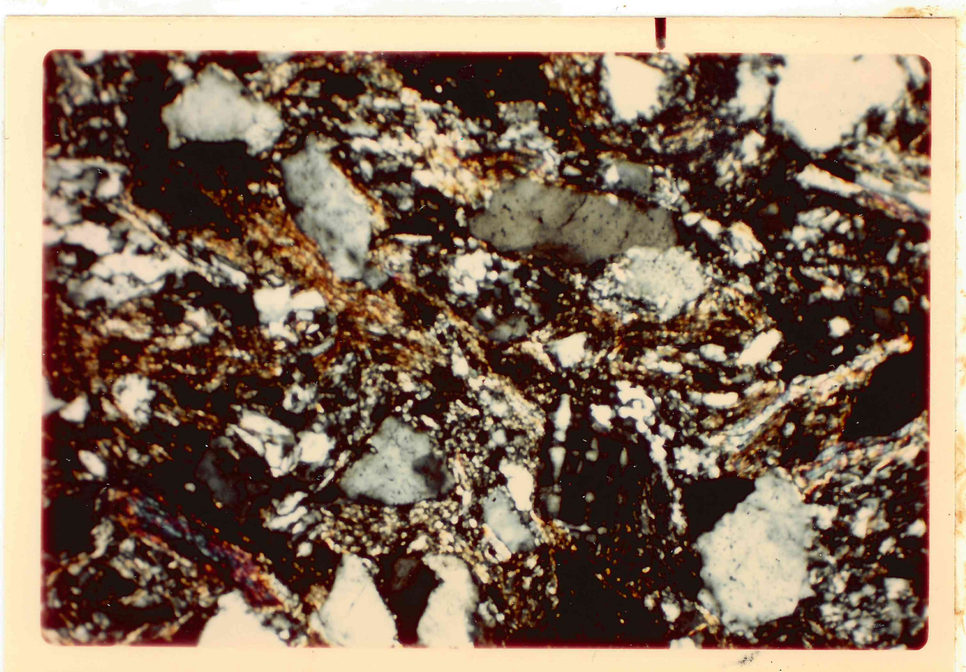


Same as above, crossed nicols.

Figure 22

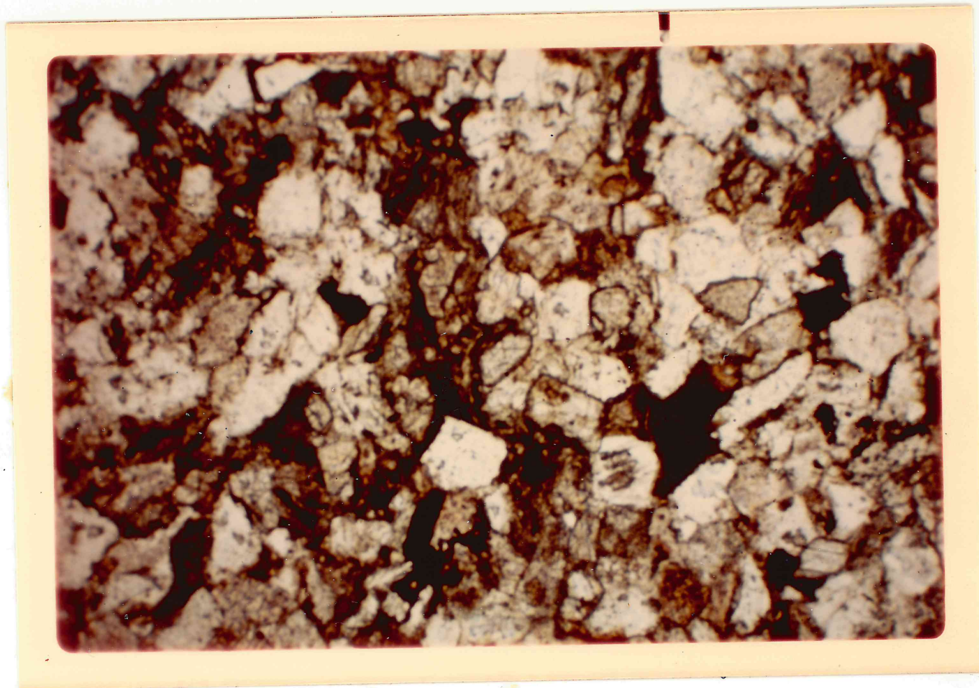


Ninuluk Formation, Umiat Area. RRR 669, field 1 mm wide, parallel nicols. Clasts of quartz, schist, phyllite, chert and microcline. Matrix iron-stained kaolinite, quartz silt and humus with authigenic chlorite starting to develop. Cement quartz overgrowths and carbonate.

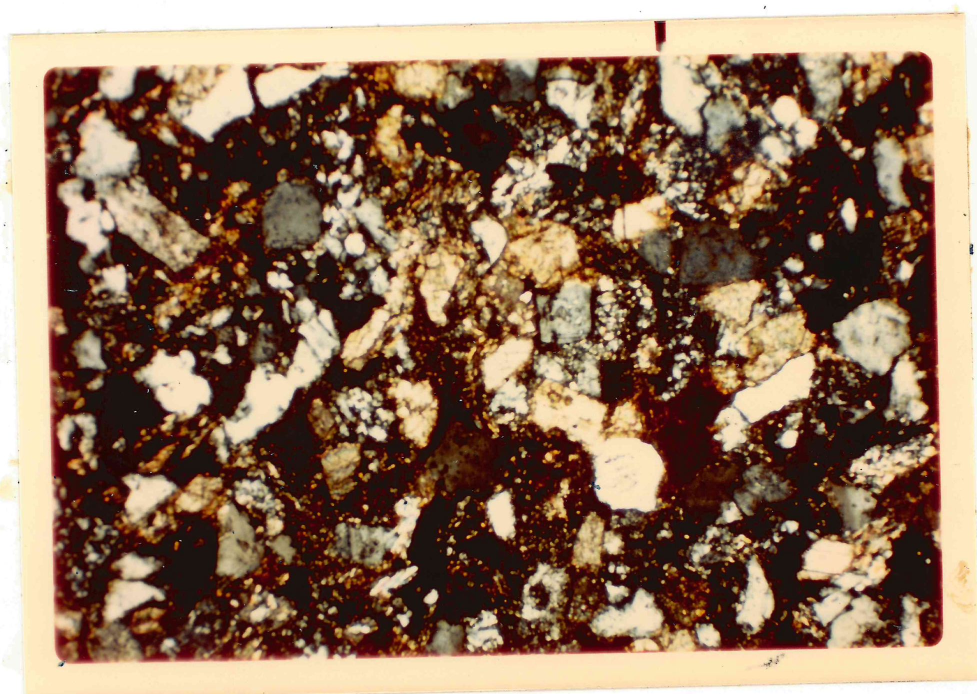


Same as above, crossed nicols.

Figure 23



Ninuluk Formation, Umiat Area, RRR 678, field 1 mm wide, parallel nicols. Clasts of carbonate (Inoceramus prisms?), quartz, phyllite, chert, feldspar and muscovite. Matrix of iron-stained kaolinite, organic matter and quartz silt. Cement of carbonate with minor quartz overgrowths.



Same as above, crossed nicols.

TURONIAN

SEABEE FORMATION

Thin Sections

RRR 848.

Age and Field Relations (Rose')

A marine formation of Turonian age containing bentonite and tuffaceous material with an apparent source to the south.

Texture

The Seabee is predominately fine grained, high in matrix (20%) with clasts modified by overgrowths but probably originally subrounded. Extensive cementation by both quartz and carbonate along with the high matrix result in a very low porosity.

Mineralogy

Clasts: Quartz is the most abundant clast forming 50% of the framework with feldspar a surprising second accounting for 21.4%. Chert at 17.7%, phyllite 9.0%, and mudstone with carbonate grains present but unimportant.

Matrix: An X-ray analysis of the matrix material revealed abundant smectite, mica and probably chlorite in addition to quartz. Organic matter is also present.

Cement: Carbonate cement is abundant with quartz overgrowths much less so. The smectite is probably authigenic and aids measurably in the lithification of the sandstone.

Distinctive Characteristics

The high feldspar content of the framework and the high smectite content in the matrix are unusual.

Provenance

Although much less prominent than in some other Cretaceous sandstones, metamorphic quartz and rock fragments are still abundant indicating an outcrop of low rank metamorphic rocks. Chert is abundant indicating a cherty limestone or mudstone. The presence of abundant plagioclase, an occasional andesite grain and abundant smectite in the matrix coupled with the lack of igneous quartz indicates a source of mafic volcanics.

Relief and Climate

Fresh feldspar along with phyllite and other fragile grains suggests rapid transport from a relatively nearby source and probably moderately high to high relief. A temperate to severe climate would assist in preserving the feldspar.

Transportation and Deposition

Transportation by running water and deposition in an organic rich but low energy environment of marine nature, such as lagoonal or shallow neritic is suggested.

Diagenetic History

The high smectite content suggests admixture and diagenetic alteration of volcanic ash in the matrix. The chlorite? in the matrix is also probably authigenic. The abundant carbonate cement is probably due to solution and reprecipitation of carbonate from shell debris. Quartz overgrowths indicate solution and reprecipitation from quartz or chert grains.

Classification

The unusually high feldspar content dictated classification as a Feldspathic Wacke.

Sample Number RRR 848

Formation Seabee

Locality Umiat Area

Number of points counted 636

Slide quality good

Texture

Wentworth Size Classes

Very Fine	77%
Fine	22
Medium	1

Framework: 51.3% of rock

Porosity - 1.9%

Median grain size - Very Fine

Sorting - Fair

Roundness - Angular to rounded

Matrix: 20.0%

Cement: 26.9%

Carbonate	93.6%
Quartz	6.4

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 25.8%

Types - (1) Contains inclusions of muscovite
(2) Polycrystalline with elongate grains
Could find no grains of unquestioned igneous origin

Feldspar - 11.0% Plagioclase (andesine?)

Micas - 0.3% Muscovite and biotite

Carbonate grains - Tr.

Rock Fragments:

Chert - 9.1%

Volcanic - Tr. (Andesite?)

Schist and phyllite - 4.6%

Mudstone - 0.5%

Compositional Maturity: Immature

Diagenesis

Rather coarse smectite and less important chlorite probably authigenic. The usual quartz and carbonate cement. Presence of andesite grains suggests the abundant smectite originated in volcanic glass in the matrix.

Matrix Minerals

X-ray analysis. A double peak at 14.2 and 12.7 A which changed to a single 17 A on glycolation and disappeared on heating to 550°C for one half hour indicated the smectite. A 3.53 A peak prior to treatment and a small 14 A peak after treatment suggested chlorite. An excellent 10 A peak is indicative of mica. The usual quartz peaks were also present.

Quartz silt and organic matter were apparent in the matrix.

Cement Minerals

Carbonate is the most prominent with minor quartz overgrowths. The matrix smectite and chlorite aided in lithifacation of the sandstone.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Largely low rank metamorphics. Some chert bearing mudstone or limestone and mafic volcanics.

Climate and relief - Modest to high relief and a nearby source were probably necessary to account for the relatively abundant feldspar and the fragile rock fragments. A temperate to severe climate would assist in retaining this material.

Transportation and Depositional Environment - Stream transportation of material to an organic rich, low energy marine environment.

Gilbert Classification

Percent matrix - 20.0% of rock

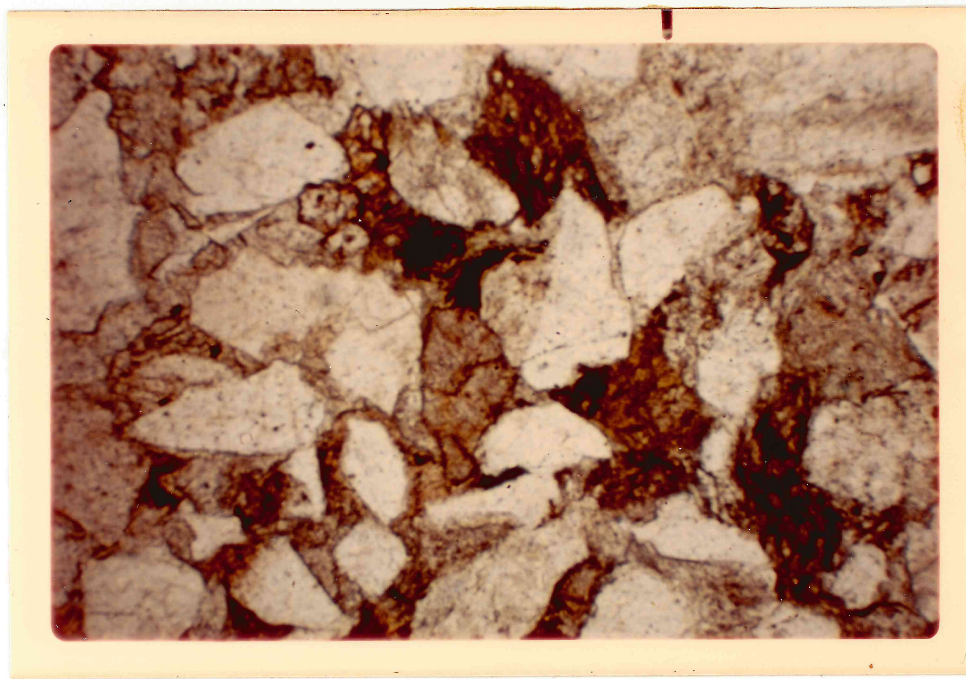
Quartz, quartzite and chert - 69.6% of framework

Feldspars and granitic rock fragments - 20.8%

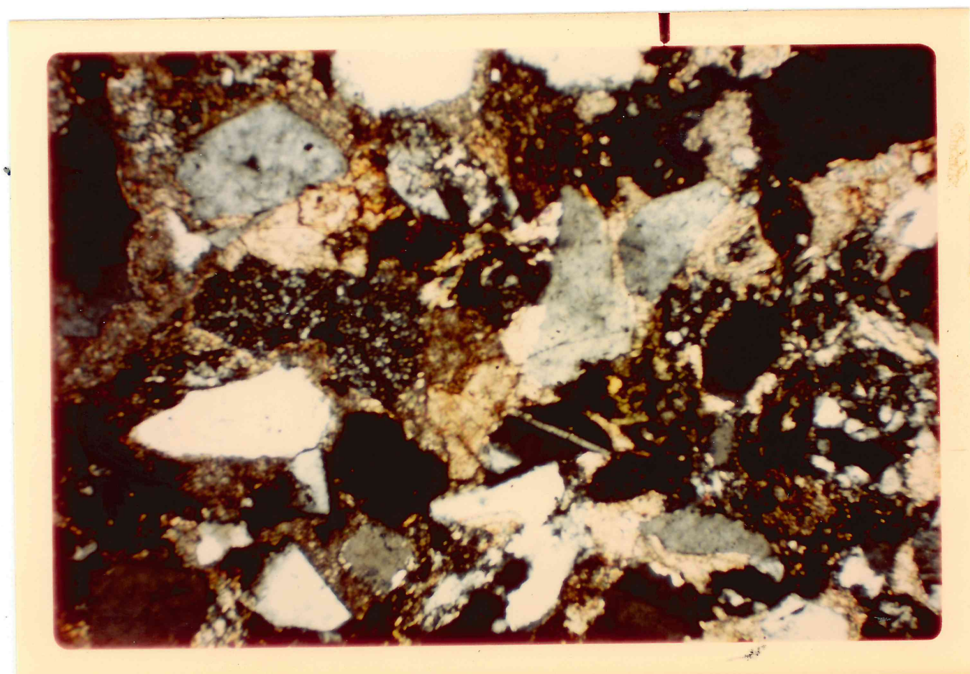
Unstable Lithics - 9.6%

Rock Name - Feldspathic Wacke

Figure 24



Seabee Formation, Umiat Area. RRR 848, field 1 mm wide, parallel nicols. Clasts of quartz, feldspar, phyllite, chert and carbonate grains. Matrix of smectite, some ironstained, organic matter, chlorite and quartz silt. Cement of carbonate and quartz overgrowths.



Same as above, nicols crossed.

LATE CRETACEOUS

LATE CRETACEOUS, SAGWON AREA

Thin Sections

RRR 529, 532, 555, 580 and 583

Age and Field Relations (Rose')

All the samples are of Late Cretaceous age collected in the Sagwon area. They have their source in the Brooks Range probably from rocks of Paleozoic and earlier Cretaceous age.

Samples RRR 580 and 583 are from a 35 foot thick sandstone with RRR 580 the lowest stratigraphically.

Texture

All samples were classified as lithic wacke or subfeldspathic lithic wacke; the framework forming 61% of the rock, matrix 25%, cement 11%, and pores 3%. Clasts range from rounded to angular but have been considerably modified by quartz overgrowths. They might have averaged at least subrounded in the original form. Sorting of the clasts is good despite the high matrix content. The great majority of the clasts (over 90%) were in the very fine grade size and only one sample (RRR 583) has grains as large as medium. Porosity is low due to abundant matrix and to extensive development of authicanic cement such as quartz and carbonate.

Mineralogy

Clasts: Quartz makes up 55% of the framework clasts. It is predominately metamorphic quartz, sparse igneous grains were found only in RRR 555, 580 and 583. Feldspar, forming 10% of the clasts, is largely plagioclase with minor microcline and untwinned feldspar. Phyllite 14%, chert 11%,, organic or phosphatic rich mudstone 4% , carbonate grains 4%, mica 2% and traces of glauconite, chlorite and tourmaline make up the rest of the clasts. Traces of volcanics are found only in RRR 580 and 583.

Matrix: X-ray analyses of the clay sized material of RRR 532 and 555 revealed, in addition to quartz, mica and chlorite while RRR 580 contained smectite in addition to the aforementioned three minerals. Organic matter and silt sized quartz particles were also abundant in the matrix.

Cement: Quartz, carbonate and minor albite are all found. The green chlorite (and in RRR 580 smectite) while counted in the matrix did much to lithify the rock.

Distinctive Characteristics

The presence of so much low rank metamorphic material, such as phyllite, mica and metamorphic quartz, the very fine grain size, abundant matrix rich in chlorite and good sorting are all distinctive. The Smectite in the matrix of RRR 580 and volcanic clasts in RRR 583 are interesting since the other samples did not contain evidence of volcanism.

Provenance

The abundant low rank metamorphic material suggests the Neruokpuk Formation. The chert might be from Lisburne or Shublik, as might the organic or phosphatic mudstone. The feldspar, largely plagioclase, along with the smectite and the volcanic debris suggests at least a minor igneous, probably mafic volcanic, source. The igneous quartz and silicic feldspar might be second cycle, probably from a sandstone such as the Sadlerochit.

Relief and Climate

The abundant feldspar and fragile phyllite would indicate fairly rapid transport hence reasonably high relief and a somewhat severe climate would aid in their preservation.

Transportation and Deposition

Stream transport from the provenance and rather rapid deposition in a low energy marine or paralic environment is suggested.

Diagenetic History

The presence of abundant authigenic chlorite, minor smectite and both quartz and albite cement indicates extensive diagenetic activity. Carbonate cement is also common probably originating in redistribution of the material from shell fragments, perhaps Inoceramus prisms.

Classification

All samples were classified as lithic wackes except RRR 555 which moved over the border into the subfeldspathic lithic wacke classification.

Sample Number RRR 529

Formation Late Cretaceous of the Sagwon Area

Locality Sagwon

Number of points counted 612

Slide quality poor, too thick

Texture

Wentworth Size Classes

Very Fine 96%
Fine 4

Framework: 52.0%

Porosity - 2%

Median grain size - Very Fine

Sorting - Good

Roundness - Grains altered by overgrowth. Angular to subrounded.

Matrix: 36.0%

Cement: 10.0%

Quartz 60%
Carbonate 40%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 41.0%

Types - (1) Contains aligned green crystals (muscovite?)
(2) Polycrystalline with elongate parallel grains
(3) Contain irregular inclusions
Suggest most of the quartz is metamorphic

Feldspar - 6.3%

Types - Plagioclase, andesine identified

Micas - 1.2%

Types - Muscovite

Carbonate grains - Tr.

Rock Fragments:

Chert - 2.2%

Schist or phyllite - 4.2%

Quartzite - Tr.

Mudstone - 2.8%

Compositional Maturity

Immature

Diagenesis

Quartz and carbonate cement, authigenic matrix chlorite.

Matrix Minerals

Quartz silt, mica, organic matter, chlorite and perhaps nontronite (green smectite).

Cement Minerals

Quartz chiefly as overgrowths and interstitial carbonate.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Low rank metamorphics, cherty limestones and silicified mudstones. The andesine might come from a weathering sandstone but it is thought most likely that some mafic volcanics, so well altered that the volcanic clasts have been destroyed, is a more likely source.

Climate and Relief - Modest to high relief and a temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a marine or paralic environment of low energy.

Gilbert Classification

Percent matrix - 36.0% of rock

Quartz, quartzite and chert - 76.0% of framework

Feldspar and granitic rock fragments - 11.4%

Unstable Lithics - 12.6%

Rock name - Lithic Wacke

Sample Number RRR 532

Formation Late Cretaceous of the Sagwon Area

Locality Sagwon

Number of points counted 616

Slide quality good

Texture

Wentworth Size Classes

Very Fine 99%
Fine 1

Framework: 50.3%

Porosity - 0%

Median grain size - Very fine

Sorting - Good

Roundness - Angular to subrounded. Some grains altered by overgrowths.

Matrix: 27.8%

Cement: 21.8%

Quartz 10%
Carbonate 90%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 36.0%

Types - (1) Contains muscovite as euhedral inclusions
(2) Polycrystalline with over 6 units each
All quartz of metamorphic origin

Feldspar - 5.2%

Types - Plagioclase, apparently andesine.

Micas - 0.8%

Types - Muscovite and biotite

Glauconite - 1.0%

Carbonate grains - 1.0%

Rock Fragments:

Chert - 1.0%

Schist or phyllite - 3.3%

Quartzite - Tr.

Mudstone - 2.0%

Compositional Maturity

Submature

Diagenesis

Minor chlorite in the matrix is probably authigenic, much carbonate and quartz cement probably due to solution and reprecipitation of quartz and carbonate from framework grains.

Matrix Minerals

Silt sized quartz grains, organic matter, muscovite and chlorite.

X-ray analysis. In addition to quartz peaks the clay sized fraction exhibited a strong 10 A mica peak and a 14 A peak which was unchanged when glycolated and heat treated and which was accompanied by 7.06 and 3.53 A peaks. This was taken to indicate chlorite.

Cement Minerals

Largely carbonate but minor quartz as overgrowths.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Abundant low rank metamorphics, cherty limestones with associated mudstone and perhaps some volcanics bearing andesine.

Climate and Relief - Modest to high relief and temperate climate.

Depositional Environment and Transport Mechanism - Stream transportation to a low energy marine or paralic environment.

Gilbert Classification

Percent matrix - 27.8% of rock

Quartz, quartzite and chert - 73.7% of framework

Feldspar and granitic fragments - 10.2%

Unstable lithics - 16.1%

Rock name - Lithic Wacke

Sample Number RRR 555

Formation Late Cretaceous of the Sagwon Area

Locality Sagwon

Number of points counted 695

Slide quality good

Texture

Wentworth Size Classes

Very Fine 98%
Fine 2

Framework: 66.0%

Porosity - 1.7%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to subrounded, some modification by overgrowths.

Matrix: 27.6%

Cement: 4.8%

Quartz 10%
Carbonate 90%
Very minor feldspar

Textural Maturity : Immature

Mineralogy

Framework Minerals:

Quartz - 34.8%

Types - (1) Euhedral muscovite inclusions and elongate polycrystalline grains predominate
(2) One grain with a liquid gas inclusion
Igneous grains present but metamorphic predominate.

Feldspar - 5.3%

Types - (1) Plagioclase
(2) Microcline?
(3) Untwinned?

Mica - 3.2%

Type - Muscovite only

Framework Minerals: (cont)

Carbonate grains - 4.8%

Tourmaline - Tr.

Rock Fragments:

Chert - 7.8%

Schist and phyllite - 8.1%

Quartzite - 1.7%

Mudstone (some very organic rich) - 4.6%

Compositional Maturity: Immature

Diagenesis

Quartz and minor feldspar overgrowths, carbonate cement and apparent authigenic matrix chlorite, some of the matrix mica may be authigenic.

Matrix Minerals

Quartz silt grains, chlorite, mica and much organic matter.

X-ray analysis. In addition to quartz and a very strong 10 A mica peak chlorite was indicated by a 14 A peak which did not expand on glycolation and was unaffected by heat treatment accompanied by a 7.01 A and a 3.53 A peak.

Cement Minerals

Carbonate predominates but quartz overgrowths and minor feldspar overgrowths are present.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Abundant low rank metamorphics, cherty limestone, dark resistant (perhaps silicified) mudstones and perhaps quartz and feldspar bearing sandstones.

Climate and Relief - Modest to high relief and temperate to severe climate.

Depositional Environment and Transport mechanism - Stream transportation to a low energy marine or paralic environment.

Gilbert Classification

Percent matrix - 27.6% of rock

Quartz, quartzite and chert - 76.0% of framework

Feldspar and granitic fragments - 9.1%

Unstable Lithics - 14.9%

Rock name - Subfeldspathic Lithic Wacke

Remarks

In this slide there are good examples of carbonate grains with dark hematitic borders and biotite bent around the grain by pressure. This indicates that these carbonate masses are indeed discrete grains and not masses of cement. The source is thought to be Inoceramus prisms or other shall material.

Sample Number RRR 580

Formation Late Cretaceous of the Sagwon Area
Stratigraphically lowest portion of a 35 foot sandstone

Locality Sagwon

Number of points counted 668

Slide quality poor, many grains plucked giving too high a porosity

Texture

Wentworth Size Classes

Very Fine	96%
Fine	3
Medium	1

Framework: 67.0%

Porosity - 9.7%

Median grain size - Very Fine

Sorting - Fair

Roundness - Angular to rounded, shapes modified by overgrowths

Matrix: 16.8%

Cement: 7.0%

Carbonate	85.7%
Quartz	14.3

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 29.8%

Types - (1) Contain euhedral crystals or consist of many polycrystalline grains, some elongate
(2) Rare grains with liquid-gas inclusions
Quartz largely metamorphic but minor igneous

Feldspar - 5.1%

Types - largely plagioclase, occasional untwinned

Carbonate grains - 6.6%

Mica - 1.5% Muscovite only

Rock Fragments:

Chert - 8.8%

Schist or phyllite - 13.0%

Mudstone (some so dark and organic as to be opaque) - 1.5%

Compositional Maturity

Immature

Diagenesis

Quartz and carbonate cement and in the matrix, chlorite, smectite, and mica. The mica is coarse and intergrown with the other material indicating a probable authigenic origin.

Matrix Minerals

Quartz silt, organic matter, smectite (green, probably nontronite), chlorite and mica.

X ray analysis. In addition to the ubiquitous quartz. A broad 14 A peak expanded on glycolation to 17 A and collapsed on heating. A small 14 A peak remained after glocolation and heating and was joined by a small 7.1 A and 3.53 A peak. This indicated to the technician that smectite and chlorite existed together. A strong 10 A peak indicated mica.

Cement Minerals

Quartz overgrowths and carbonate.

INFERENCE AND CONCLUSIONS

Provenance

Rock Types - Abundant low rank metamorphics, cherty limestones and organic rich mudstones. Although no volcanic fragments were observed, the rather abundant plagioclase and smectite in the matrix suggests some mafic volcanic material. Sandstones with igneous quartz grains are also suggested.

Climate and Relief - High relief to bring in the fragile metamorphic rocks and mudstone and perhaps a temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a low energy marine or paralic environment. Lagoonal?

Gilbert Classification

Percent matrix - 16.8%

Quartz, quartzite and chert - 65.5%

Feldspar and granitic rock fragments - 8.7%

Unstable lithics - 25.8%

Rock name - Subfeldspathic Lithic Wacke

Sample Number RRR 583

Formation Late Cretaceous of the Sagwon Area
Stratigraphically highest portion of a 35 foot sandstone

Locality Sagwon

Number of points counted 639

Slide quality good

Texture

Wentworth Size Classes

Very Fine 68%
Fine 30
Medium 2

Framework: 70.0%

Porosity - 3.3%

Median grain size - Very Fine

Sorting - Fair

Roundness - Angular to rounded with some shapes modified by quartz overgrowths

Textural Maturity: Immature

Matrix: 19.7%

Cement: 6.8%

Quartz 95.5%
Albite 4.5

Mineralogy

Framework Minerals:

Quartz - 30.7%

Types - (1) Polycrystalline grains, grains numerous and sometimes elongate
(2) Contains euhedral muscovite
(3) Rarely with liquid-gas inclusions
Igneous grains present but metamorphic predominate

Feldspar - 8.0%

Types - Plagioclase, probably andesine

Mica - 0.5%

Type - Muscovite and bleached biotite

Framework Minerals: (cont)

Chlorite grains - 0.3%

Tourmaline (olive green) - Tr.

Rock Fragments:

Chert - 12.7%

Volcanic - Tr.

Schist or phyllite - 15.6%

Mudstone (often organic rich and almost opaque) - 2.2%

Compositional Maturity: Immature

Diagenesis

Quartz and albite? cement and a green chloritic material in the matrix indicate considerable diagenesis.

Matrix Minerals

There is no X-ray data but the matrix seems identical to that of RRR 580 hence the matrix is probably a mixture of green smectite, chlorite, organic matter and quartz silt.

Cement Minerals

Quartz both as overgrowths and pore filling and albite? as overgrowths on certain feldspar grains.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - An analysis identical with that of RRR 580 (the lower part of this sandstone) except that in this sample actual volcanic fragments are present, although rare. Low rank metamorphics, cherty limestones, dark organic rich mudstones, mafic volcanics, and perhaps sandstones with igneous quartz grains.

Climate and Relief - High to moderate relief and a temperate to severe climate.

Depositional Environment and Transport Mechanism - Stream transportation to a low energy marine or paralic environment. Lagoonal?

Gilbert Classification

Percent matrix - 19.7% of rock

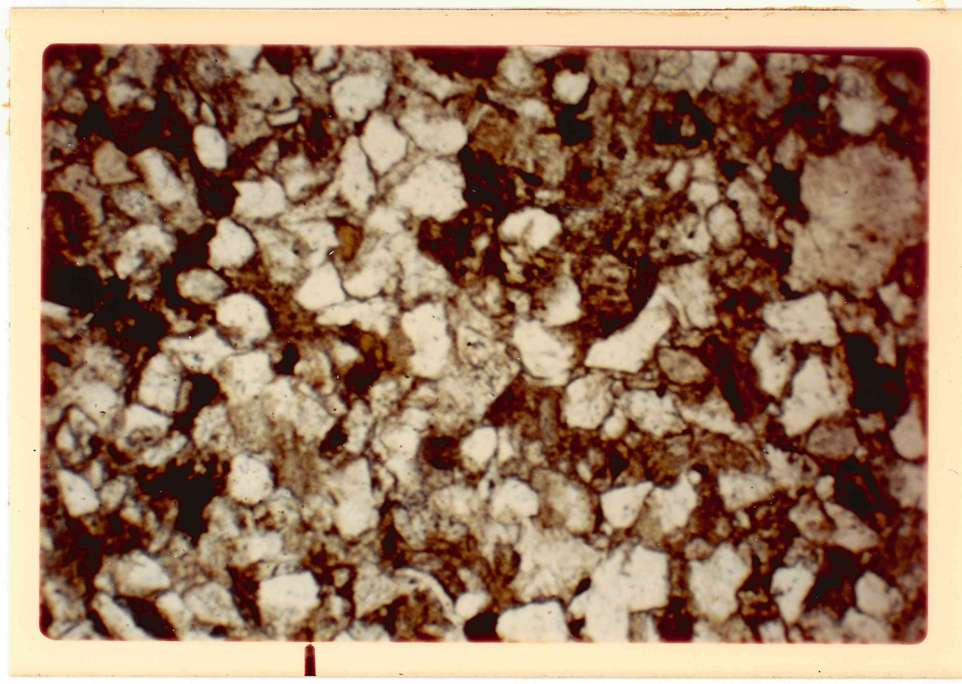
Quartz, quartzite and chert - 62.7% of framework

Feldspar and granitic rock fragments - 11.6%

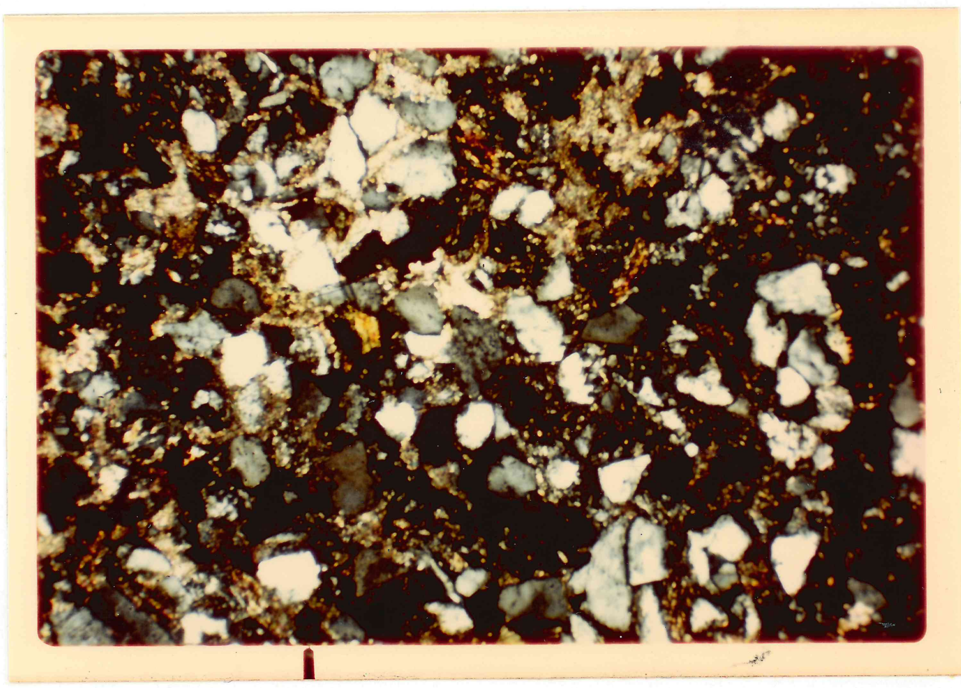
Unstable lithics - 25.7%

Rock Name - Lithic Wacke

Figure 25

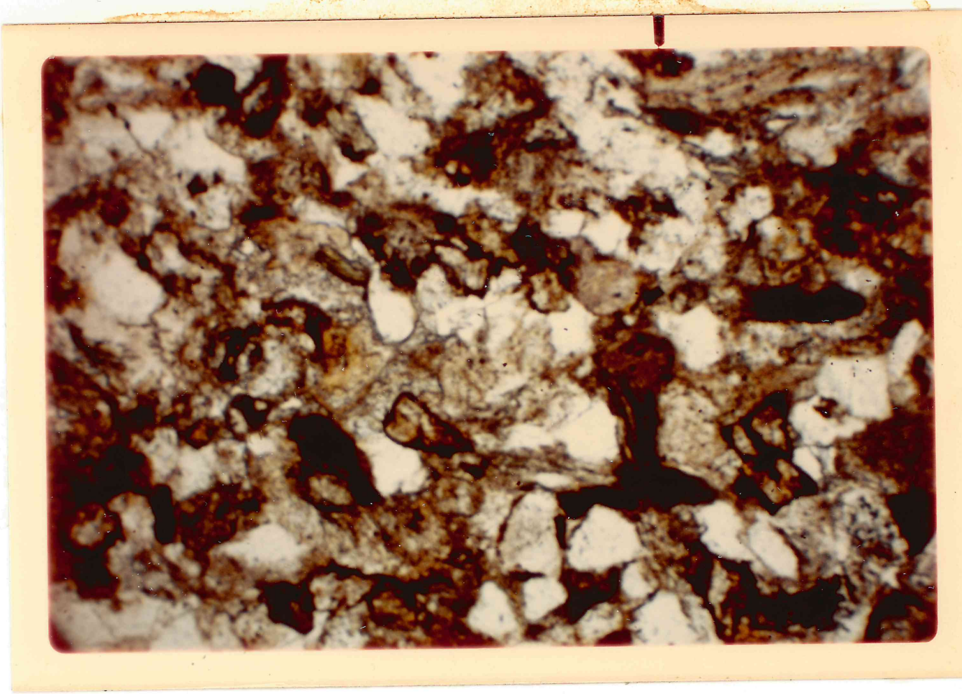


Late Cretaceous of the Sagwon Area. RRR 532, field 1 mm wide, parallel nicols. Clasts of quartz, chert, feldspar, phyllite, and chlorite. Matrix of quartz silt, ironstained clay (chloritic) and organic matter. Cement largely carbonate with minor quartz overgrowths.

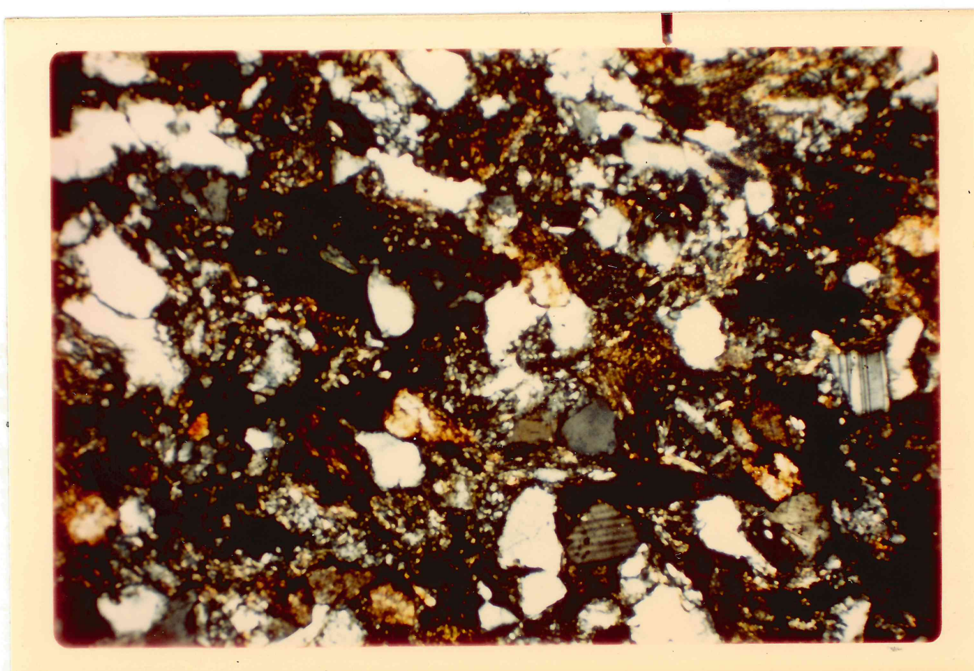


Same as above, crossed nicols.

Figure 26

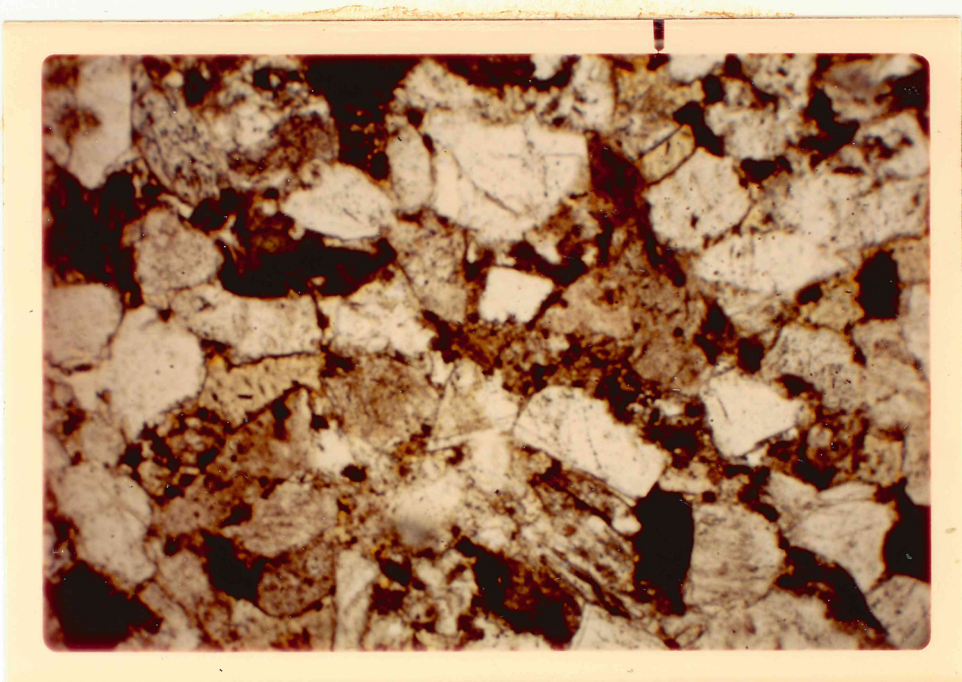


Late Cretaceous of the Sagwon Area. RRR 555, field 1 mm wide, parallel nicols. Clasts of quartz, chert, feldspar, carbonate grains, phyllite and chlorite. Matrix of iron stained chloritic material, quartz silt and organic matter. Cement of quartz and carbonate.

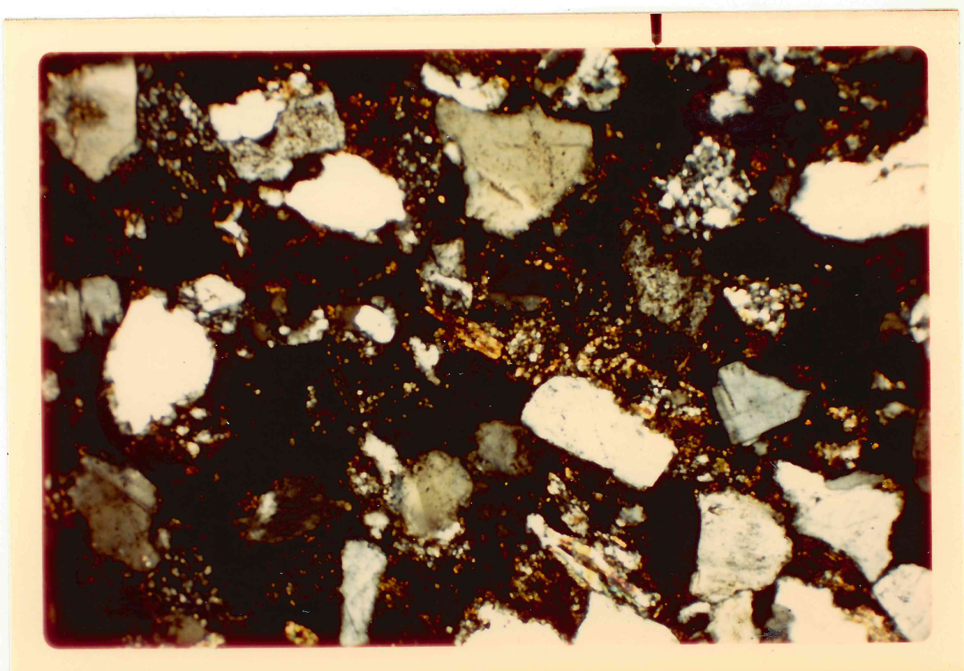


Same as above, crossed nicols.

Figure 27



Late Cretaceous of the Sagwon Area. RRR 583, field 1 mm wide, parallel nicols. Clasts of quartz, chert, feldspar, muscovite (or schist), biotite, dark organic or phosphatic mudstone. Matrix of quartz silt and chlorite. Cement of quartz overgrowths aided by authigenic matrix chlorite.



Same as above, nicols crossed.

SCHRADER BLUFF FORMATION

Thin Sections

RRR 648 and 894.

Age and Field Relations (Rose')

Of Late Cretaceous age the rock is marine and very tuffaceous and bentonitic. Possible zeolites.

Texture

The two slides have very different grades of sand. RRR 648 contains only very fine grade size sand. Slide RRR 894 while predominately very fine also contains fine, medium and even coarse grains. The matrix is high in both (23.8% and 34.7%) and the porosity low (below 3%). Grains are largely angular to subangular.

Mineralogy

Clasts: Due in part to the disparity in grade sizes, clast mineralogy varies between the two samples. The fine grained rock (RRR 648) contains 32.8% quartz and only traces of volcanic debris while the coarser one (RRR 894) contains 23.2% volcanic debris and only 15.4% quartz. Both contain about 8% feldspar, 4% phyllite rather large numbers of carbonate grains (2.6 and 13.7%) and minor mudstone and mica.

Matrix: X-ray analysis of RRR 648 reveals that in addition to quartz the matrix is rich in smectite with minor mica and chlorite. Organic matter is also present. Much of the quartz is present as silt grains.

Cement: Quartz overgrowths tend to be minor. Carbonate is abundant and in RRR 894 considerable pyrite is present. The matrix smectite and chlorite does much to lithify the rock.

Distinctive Characteristics

Both samples are rich in volcanic material but the coarser grained 894 is particularly distinctive in that it contains easily recognizable pumice lumps, shards and both fine grained mafic and silicic volcanic fragments. These samples are also unusually rich in carbonate grains, probably *Inoceramus* prisms, and sample RRR 894 contains abundant authigenic pyrite.

Provenance

The presence of low rank metamorphic clasts, metamorphic quartz and mica indicate a low rank metamorphic terrane, perhaps Neruokpuk. Abundant volcanics of both mafic and silicic type associated with matrix smectite is indicative of considerable volcanic activity in the provenance. Smaller amounts of mudstone and chert suggest dark cherty sedimentary rocks.

Relief and Climate

The presence of considerable feldspar and many fragile rock clasts indicate rapid transport from a nearby source and suggest moderate to high relief and probably a somewhat severe climate.

Transportation and Deposition

Original transportation by running water and deposition in an organic rich, perhaps stangant, low energy, marine environment is suggested. Presence of abundant *Inoceramus* prisms, organic matter and pyrite cement suggests high Eh and low pH in the environment.

Diagenetic History

Abundant smectite with minor pyrite quartz and carbonate cement indicate a very interesting environment and diagenetic activity.

Classification

RRR 894, rich in volcanic debris, may be classified as a Lithic Wacke or even a Volcanic Wacke. RRR 648 because of its high feldspar content must be termed a Feldspathic Wacke. The texture appears to dictate this difference. By the time much of the debris reaches the very fine grade size, which makes up all of RRR 648, all of the volcanic debris has been destroyed.

Sample Number RRR 648

Formation Schrader Bluff

Locality Umiat Area

Number of points counted 655

Slide quality good

Texture

Wentworth Size Classes

Very Fine 100%

Framework: 68.3% of rock

Porosity - 2.7%

Median grain size - Very Fine

Sorting - Excellent

Roundness - Angular to subrounded

Matrix: 23.8%

Cement: 5.8%

Carbonate	29%
Smectite	71%
Quartz	Tr.

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 32.8%

Types - (1) Contains euhedral inclusions, including muscovite
(2) Polycrystalline, elongate grains
Could find no unquestioned igneous quartz

Feldspar - 7.9% Plagioclase and myrmekite

Micas - 2.1% Muscovite and biotite

Carbonate grains - 13.7%

Tourmaline - Tr.

Rock Fragments:

Chert - 5.0%

Volcanic - 1.0% (Andesitic?)

Schist or phyllite - 3.8%

Mudstone - 1.7%

Collophane or very organic rich mudstone - 0.5%

Compositional Maturity: Immature

Diagenesis

Smectite probably from volcanic ash, chlorite from clay. Much carbonate from solution of abundant shell debris.

Matrix Minerals

X-ray analysis. A broad based smectite peak at 12.6 A expanded to 17.5 A upon glycolation and disappeared on heating to 550°C for one half hour. Chlorite is suggested by good 7.1 and 3.53 A peaks and a 14 A peak after heating. A good 10 A mica peak. The usual quartz peaks.

In addition to the above, organic material is present in the matrix.

Cement Minerals

In addition to the carbonate and traces of quartz overgrowth a relatively coarse light green material, identified as smectite, did so much to cement the rock that it was counted as cement.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Low rank metamorphics, cherty limestones or mudstones and mafic volcanics.

Climate and Relief - Moderate to high relief and a severe climate would aid in rapid transportation of the fragile grains and saving the feldspar.

Transportation and Depositional Environment - Stream transportation to a marine environment of low energy rich in organic matter.

Gilbert Classification

Percent matrix - 23.8% of rock

Quartz, quartzite and chert - 73.1% of framework

Feldspar and granitic fragments - 15.3%

Unstable lithics - (excluding carbonate grains) 11.6%

Rock Name - Feldspathic Wacke

Sample Number RRR 894

Formation Schrader Bluff

Locality Umiat Area

Number of points counted 726

Slide quality good

Texture

Wentworth Size Classes

Very Fine	66%
Fine	30
Medium	3
Coarse	1

Framework: 59.1% of rock

Porosity - 0.8%

Median grain size - Very Fine

Sorting - Poor

Roundness - Angular to rounded

Matrix: 34.7%

Cement: 5.4%

Pyrite	84.6%
Carbonate	12.8%
Quartz	5.1%

Textural Maturity: Immature

Mineralogy

Framework Minerals:

Quartz - 15.4%

Types - (1) Euhedral inclusions, some with muscovite. Common
(2) Polycrystalline grains
(3) Liquid gas bubbles. Not uncommon
Both igneous and metamorphic quartz but mostly metamorphic.

Feldspar - 7.6%

Types - Plagioclase, microcline, myrmekite, untwinned.

Carbonate Grains - 2.6%

Micas - 1.1% Muscovite and biotite

Chlorite grains - 0.4%

Rock Fragments:

Chert - 4.1%

Volcanics - 23.2%

Schist or phyllite - 4.4%

Mudstone, often organic rich - 0.7%

Siltstone - 0.3%

Remarks. The volcanics consist of:
(1) Pumice lumps - 2.5%
(2) Shards - 19.5%
(3) Fine grained mafics - 0.5%
(4) Fine grained acidics - 0.7%
To complete the 23.2% of total volcanics

(see remarks at end of description)

Compositional Maturity: Immature

Diagenesis

Smectite is developed from the abundant volcanic debris, both volcanic grains and the matrix are altered. Authigenic pyrite is particularly noteworthy. Minor carbonate and quartz overgrowths are also present.

Matrix Minerals

Large shapeless masses of green fine grained material of low birefringence, probably smectite perhaps some chlorite, organic material, quartz silt and the intermixed carbonate cement.

Cement Minerals

Pyrite, carbonate and minor quartz overgrowths. The smectite? in the matrix is also a great aid in lithification. Some veinlets with clear, colorless, low birefrengent material may contain zeolites.

Remarks

The unusual content of rock fragments in this sample deserves special attention. Some of the following are notable.
(1) Chert containing veinlets of quartz and parallel arrangement of grains.
(2) Muscovite and chlorite schists and phyllites.
(3) Andesites with pilotaxitic textures.
(4) Glass shards, some devitrified some still vitreous.
(5) Pumice lumps still fresh and vitreous.
(6) Very fine grained greenish rock, argillite? greenstone?
(7) Siltstone
(8) Dark almost opaque clay lumps, organic or phosphatic.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Extensive volcanics, both mafic and silicic. Active volcanism represented by the still vitreous pumice and shards. Low rank metamorphics and sedimentary rocks, probably dark cherty mudstones and minor sandstones.

Climate and Relief - Moderate to high relief insuring short but rapid transport, temperate to severe climate.

Transportation and Depositional Environment - Running water transport to a low energy organic rich marine environment, probably stagnant.

Gilbert Classification

Percent matrix - 34.7% of rock

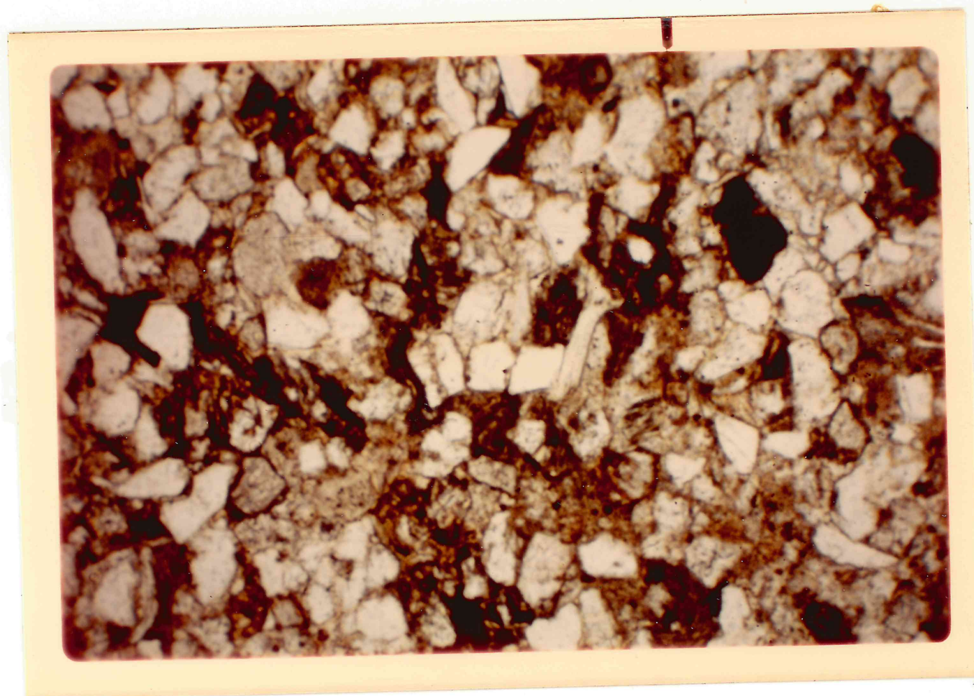
Quartz, quartzite and chert - 34.1% of framework

Feldspars and granitic rock fragments - 13.2%

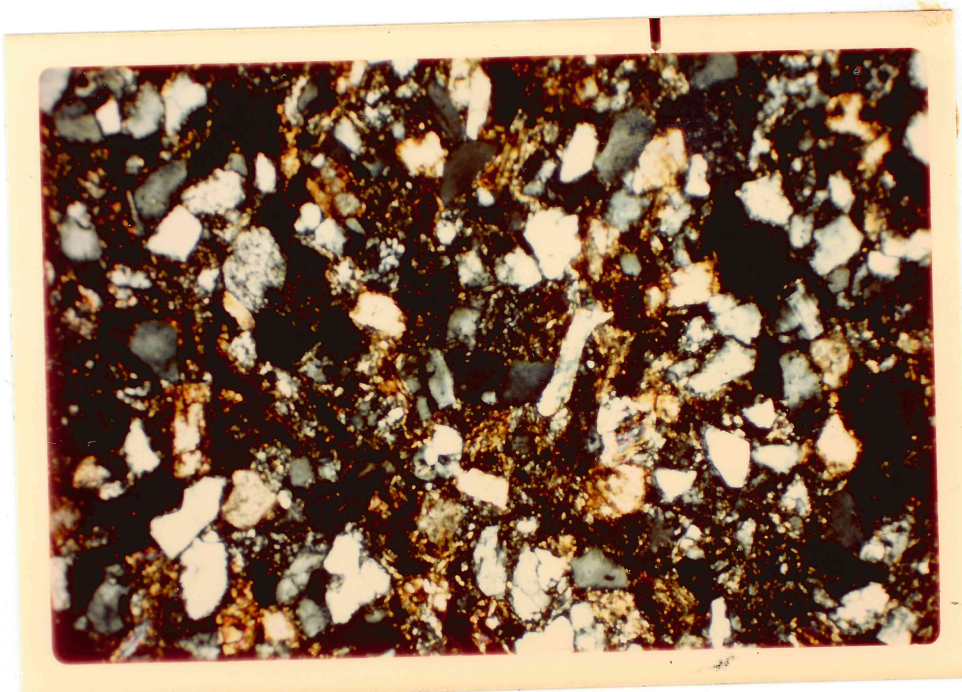
Unstable Lithics - 52.6%

Rock Name - Volcanic Wacke

Figure 28

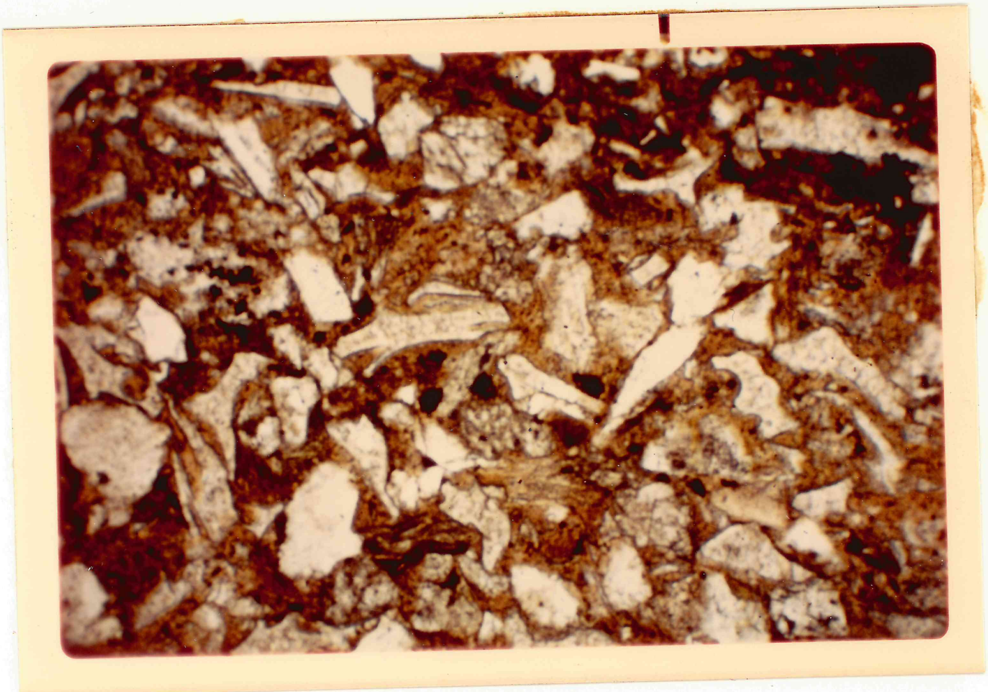


Schrader Bluff Formation, Umiat Area. RRR 648, field 1 mm wide, parallel nicols. Clasts of quartz, feldspar, carbonate grains, muscovite, biotite, chert and black opaque mudstone. Matrix of iron-stained smectite, mica and quartz silt. Cement of carbonate and minor quartz overgrowths.

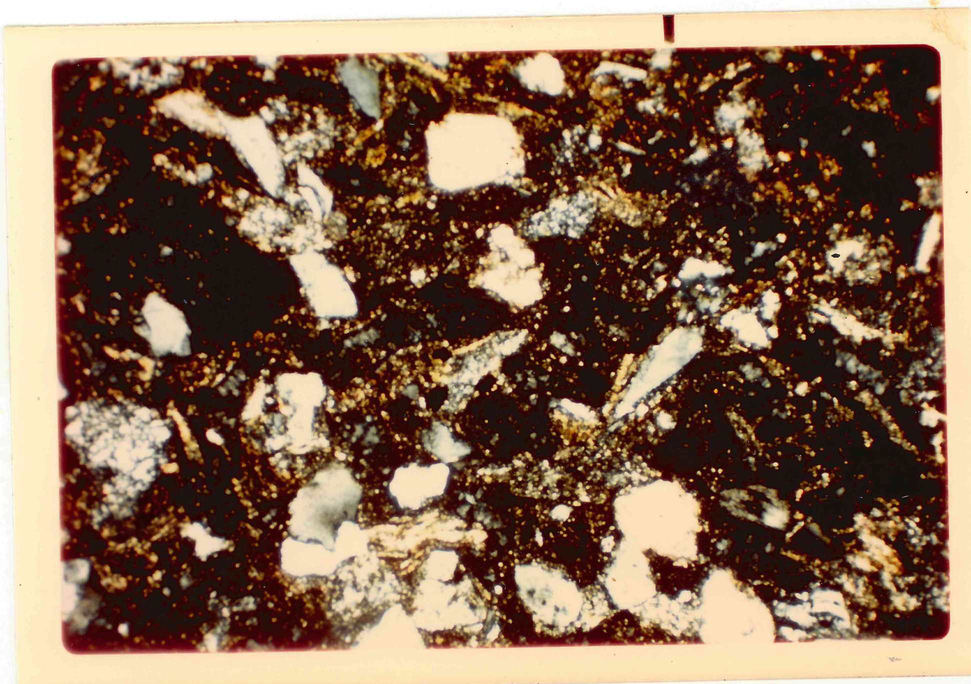


Same as above, crossed nicols.

Figure 29

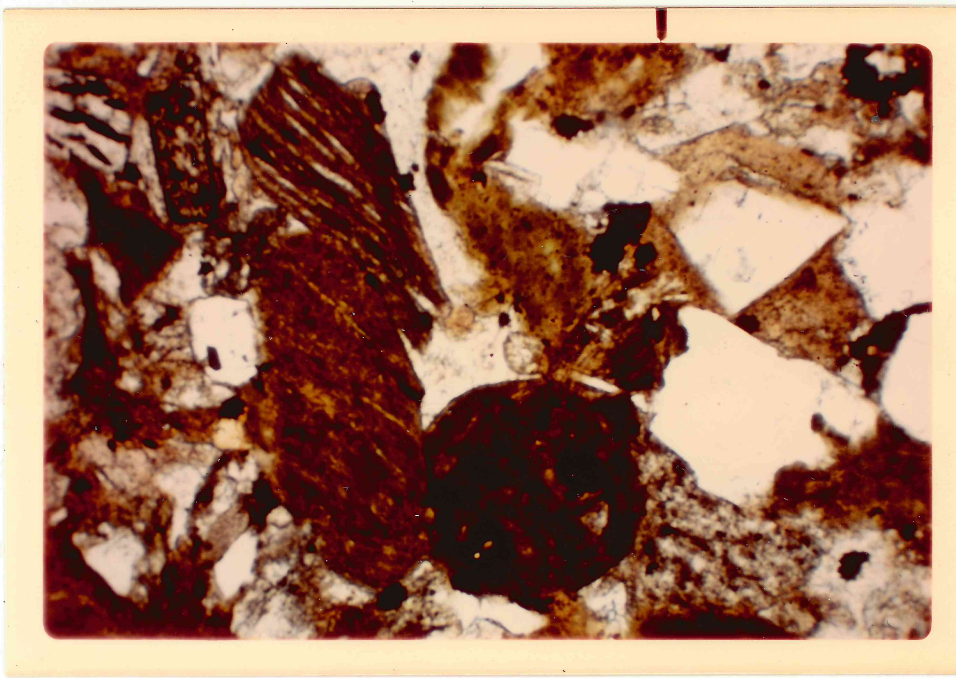


Schrader Bluff Formation, Umiat Area. RRR 894, field 3.5 mm wide, parallel nicols. Clasts of quartz, chert, feldspar, glass shards, pumice lumps, and carbonate grains. Matrix of smectite, pyrite and clay. Cement of coarse smectite and carbonate.

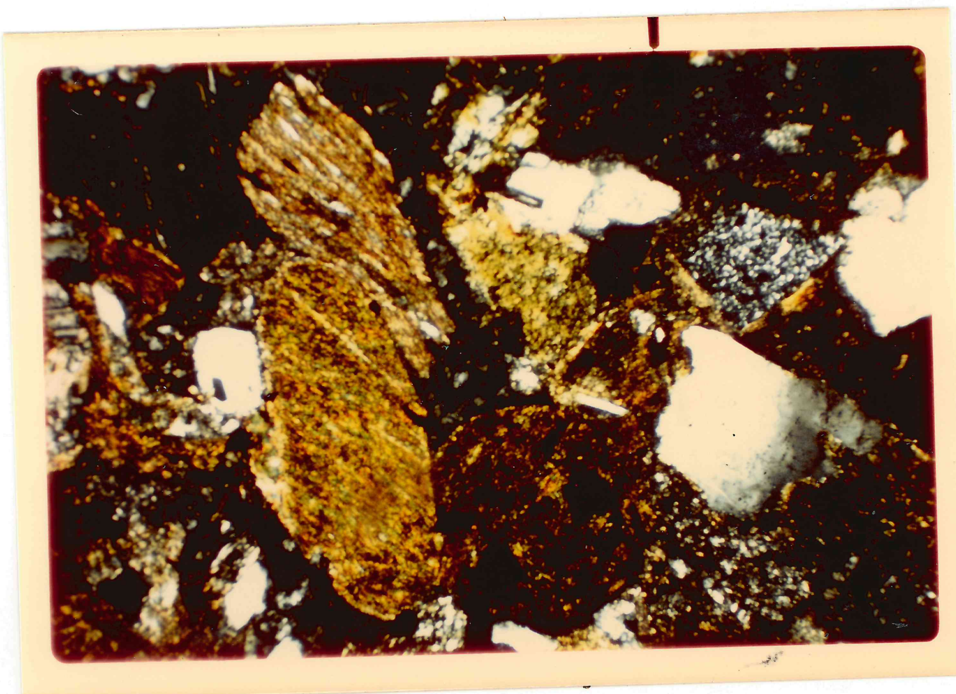


Same as above, crossed nicols.

Figure 30



Schrader Bluff Formation, Umiat Area. RRR 894, field 1 mm wide, nicols parallel. Clasts of phyllite, greenstone?, feldspar, quartz and chert. Matrix and cement of pyrite, quartz silt, smectite and zeolite?



Same as above, nicols crossed.

PALEOCENE

PALEOCENE

Thin Sections

RRR 451b, 600 and 605

Age and Field Relations (Rose')

These samples are Paleocene in age, non-marine and come from the south with a source in the Brooks Range and its foothills.

Texture

The three samples have such widely varying textures that it was thought best to contrast them in the table given below.

Sample	Framework	Matrix	Cement	Porosity	Median grade size	Number of Grade sizes Represented
RRR 451B	71.1%	0.5%	2.0%	29.4%	Medium	4
RRR 600	66.6	22.3	3.0	8.0	Fine	3
RRR 605	60.1	36.4	1.4	2.1	Very Fine	2

The coarser grained RRR 451b exhibited clasts varying from subangular to rounded while the clasts of the finer grained samples RRR 600 and 605 ranged from angular to subrounded. Quartz grains were but moderately modified by overgrowths. Pores are characteristically filled by matrix rather then cement.

Mineralogy

Again it is thought best to illustrate and contrast the mineralogy of these three somewhat unlike rocks by the use of a table. (see next page)

Sample	RRR 451b	RRR 600	RRR 605
Framework Clasts	67.9% of rock	66.6	60.1
Quartz	10.4	34.4	44.0
Feldspar	-	Tr.	0.5
Mica	Tr.	-	3.1
Chlorite	-	Tr.	0.5
Garnet or Spinel	-	Tr.	0.2
Zircon	-	-	Tr.
Tourmaline	-	-	Tr.
Chert	43.8	25.0	4.4
Schist or Phyllite	-	3.1	4.3
Siliceous Mudstone	13.4	4.1	0.8
Organic Mudstone	-	-	2.3
Wacke	0.3	-	-
Matrix	0.7% of rock	22.3	36.4
	Fine green "clay" perhaps authigenic.	Quartz silt, clay organic matter. Some green chloritic material, perhaps authigenic.	Much cloudy, opaque iron oxide stained and organic rich clay. Rather coarse highly birefringent mica and quartz silt. Green chloritic material, perhaps authigenic
Cement	2.0% of rock	3.0	1.4
	Quartz overgrowths	Quartz overgrowths	Quartz as overgrowths and as interstitial grains.
Porosity	29.4% of rock	8.0	2.1

Distinctive Characteristics

RRR 451b. The high content of chert and siliceous mudstone, high porosity, almost non existent matrix, and lack of metamorphic debris (except for metamorphic quartz) and the coarser than usual texture make this sample distinctive.

RRR 600. This rock is similar to many of the Cretaceous sandstones except for somewhat higher porosity and much less intense diagenesis.

RRR 605. Similar to Cretaceous sandstones. Perhaps finer grained than most with a higher matrix content, many dark unsilicified masses of organic rich clay as clasts and much less intense diagenesis.

Provenance

The source seems similar to that suggested for many of the Cretaceous rocks that owe their origin to debris coming from the Brooks Range.

RRR 451b. This rock might well have a source from sedimentary rocks only. Siliceous mudstone or shale, cherty limestone and a sandstone yielding both igneous and metamorphic quartz and some grains of very fined grained wacke. (Lisburne, Siksikpuk and Sadlerochit?)

RRR 600. This rock requires cherty limestone and siliceous mudstone along with a sandstone to furnish igneous quartz and low rank metamorphics for phyllite, garnet, chlorite and metamorphic quartz. (add Neruokpik to the list for RRR 451b)

RRR 605. Requires chiefly an extensive low rank metamorphic source with a minor source for igneous quartz and some mudstone. (Chiefly Neruokpuk)

Relief and Climate

It is difficult to generalize conditions for these unlike rocks. However, the phyllite and mudstone in two samples suggest rapid transport from a nearby source, hence moderate to high relief. Climatic conditions are obscure but a temperate to severe climate might help.

Transportation and Deposition

Stream transportation for all and deposition in a high energy environment, perhaps a stream channel, for 451b and a low energy environment, perhaps a floodplain, for 600 and 605.

Diagenetic History

Diagenesis has been mild. Modest amounts of quartz overgrowths and perhaps some authigenic chlorite appear to be the only results.

Classification

Three such unlike rocks have unlike classifications, as see below.

RRR 461b Quartz Arenite

RRR 600 Quartz Wacke

RRR 605 Subfeldspathic Lithic Wacke

Sample Number RRR 451b

Formation Paleocene

Locality ?

Number of points counted 603

Slide quality fair

Texture

Wentworth Size Classes

Very Fine	1%
Fine	17
Medium	79
Coarse	3

Framework: 67.9%

Porosity - 29.4%

Median grain size - Medium

Sorting - Poor

Roundness - Subangular to rounded

Textural Maturity: Submature

Matrix: 0.7%

Cement: 2.0%

Quartz 100%

Mineralogy

Framework Minerals:

Quartz - 10.4%

Types - (1) Polycrystalline, many units of widely different sizes
(2) Cloudy parallel lines of inclusions
(3) Euhedral green muscovite inclusions, common
(4) Liquid-gas bubbles, common
Both igneous and metamorphic quartz common

Mica - Tr. Muscovite only

Rock Fragments:

Chert - 43.8%

Quartzite - Tr.

Siliceous mudstone - 13.4%

Very fine grained quartz wacke - 0.3%

Compositional Maturity: Mature

Diagenesis

Modest quartz overgrowths and perhaps a little authigenic chlorite from the scant matrix.

Matrix Minerals

Some quartz silt and green "clay" which might be authigenic.

Cement Minerals

Some quartz as overgrowths and in interstices. Very fine grained.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Largely chert or cherty limestone and silicified mud or shale. The quartz comes from both metamorphic and igneous sources and is thought to be second cycle from a sandstone.

Climate and Relief - There are few climatic indicators but the coarse grain plus the mudstone suggests reasonably rapid movement, hence at least moderate relief.

Depositional Environment and Transport Mechanism - Transport by running water and deposition in a high energy continental environment, perhaps a stream channel.

Remarks

The mudstone clasts are strongly silicified with veinlets of fine grained quartz and pockets of the same very common. It is not far removed from chert and might easily be termed impure chert. It is difficult to think of this material as an "unstable fine grained rock fragment" so it was included with the chert when it came to classification of the rock. Only the quartz wacke was counted as unstable rock fragments.

Gilbert Classification

Percent matrix - 0.7% of rock

Quartz, quartzite and chert - 99.5%

Feldspar - 0%

Unstable Lithics - 0.5%

Rock name - Quartz Arenite

Sample Number RRR 600

Formation Paleocene

Locality ?

Number of points counted 652

Slide Quality good

Texture

Wentworth Size Classes

Very Fine 14%
Fine 74
Medium 12

Framework: 66.6%

Porosity - 8.0%

Median grain size - Fine

Sorting - Fair

Roundness - Angular to subrounded, some interference by overgrowths

Textural Maturity: Immature

Matrix: 22.3%

Cement: 3.0%

Quartz 100%

Mineralogy

Framework Minerals:

Quartz - 34.4%

Types - (1) Polycrystalline with muscovite inclusions, not uncommon
(2) Polycrystalline with elongate parallel grains
(3) Liquid-gas inclusions, common
(4) With acicular inclusions, common
Both igneous and metamorphic quartz, igneous most common

Feldspar - Tr. Plagioclase only

Chlorite - Tr.

Unknown, isotropic, colorless, high relief: garnet or spinel? - Tr.

Rock Fragments:

Chert - 25.0%

Schist or phyllite - 3.1%

Siliceous mudstone - 4.1%

Remarks. Siliceous mudstone, phyllite, argillite? seem similar and almost gradational. The mudstone has fine-grained quartz veinlets. As aggregate polarization develops it moves into argillite or phyllite.

Compositional Maturity:

If the very siliceous mudstone were counted as chert, as well it might, the rock would have to be termed mature compositionally. (framework only)

Diagenesis

Mild. Minor quartz cement and a little authigenic chlorite in the matrix.

Matrix Minerals

Quartz silt, organic matter, clay and some pale green chloritic material.

Cement Minerals

Quartz as overgrowths.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Cherty limestone and siliceous mudstone must predominate but some low rank metamorphics must also be present.

Climate and Relief - Little of climatic significance and the relief need be little more than moderate.

Depositional Environment and Transport Mechanism - Stream transportation and deposition in a low energy environment, perhaps a floodplain.

Gilbert Classification

Percent matrix - 22.3% of rock

Quartz, quartzite and chert - 95.4%

Feldspar and granitic rock fragments - 0%

Unstable Lithics - 4.6%

Rock name - Quartz Wacke

Sample Number RRR 605

Formation Paleocene

Locality ?

Number of points counted 655

Slide quality poor, too thick in places, too many grains plucked out

Texture

Wentworth Size Classes

Very Fine 98%
Fine 2

Framework: 60.1%

Porosity - 2.1%

Median grain size - Very Fine

Sorting - Good

Roundness - Angular to subrounded, some interference by overgrowths

Matrix: 36.4%

Cement: 1.4%

Quartz 100%

Mineralogy

Framework Minerals:

Quartz - 44.0%

Types - (1) Contains euhedral inclusions of muscovite, common
(2) Irregular inclusions, gas-fluid bubbles or other igneous textures, uncommon
(3) Very extraordinary with parallel lines of inclusions making brownish streaks
Majority seem to be of metamorphic origin, but igneous present

Feldspar - 0.5% Plagioclase

Mica - 3.1%

Type - Both muscovite and biotite

Chlorite - 0.5%

Garnet or spinel - 0.2%

Zircon - Tr.

Tourmaline - Tr.

Rock Fragments:

Chert - 4.4%

Schist or phyllite - 4.3%

Mudstone - 3.1%

Remarks. Some of the mudstone fragments were very dark organic rich masses of clay, looking almost like rip-ups.

Compositional Maturity: Immature to submature

Diagenesis

Mild. Minor quartz cement as overgrowths and pore filling and a little green chloritic material in the matrix taken as authigenic.

Matrix Minerals

Much clay stained with iron oxide or dark with organic matter, rather coarse highly birefringent mica (considered detrital), quartz silt and some green chloritic material taken as authigenic.

Cement Minerals

Quartz as overgrowths and pore filling.

INFERENCE AND CONCLUSIONS

Provenance

Rock types - Sandstones to supply the igneous quartz and minor feldspar, dark mudstone or argillite and much low rank metamorphics to supply metamorphic quartz, phyllite and mica.

Climate and relief - Moderate to high relief to quickly carry the fragile metamorphics and mudstones. This rock not to climate diagnostic but a temperate to severe climate might help.

Depositional Environment and Transport Mechanism - Stream transportation to a low energy continental environment such as a floodplain.

Gilbert Classification

Percent matrix - 36.4% of rock

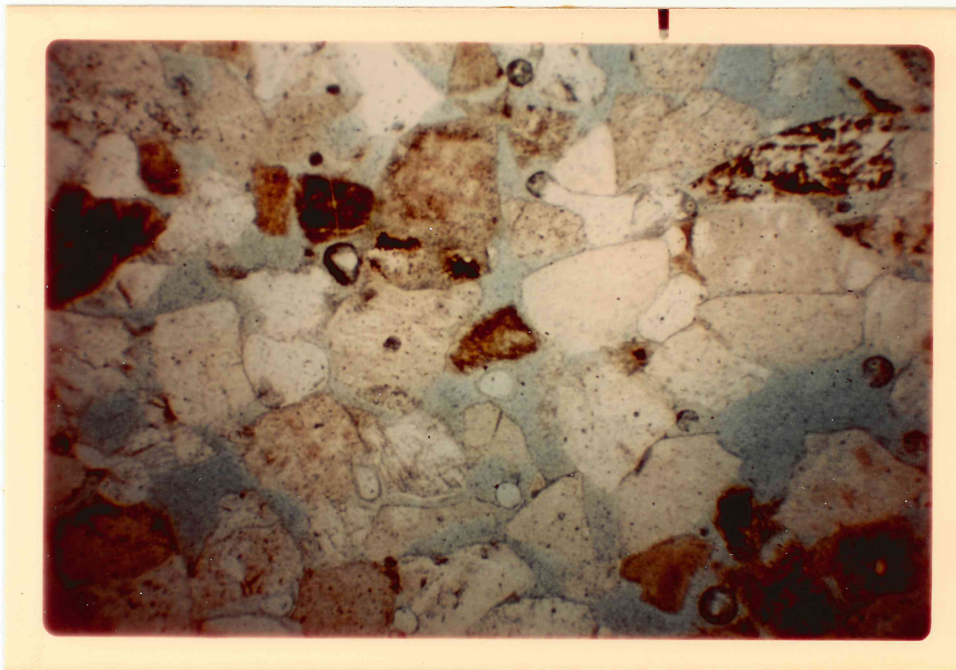
Quartz, quartzite and chert - 81.5% of framework

Feldspar and granitic rock fragments - 0.8%

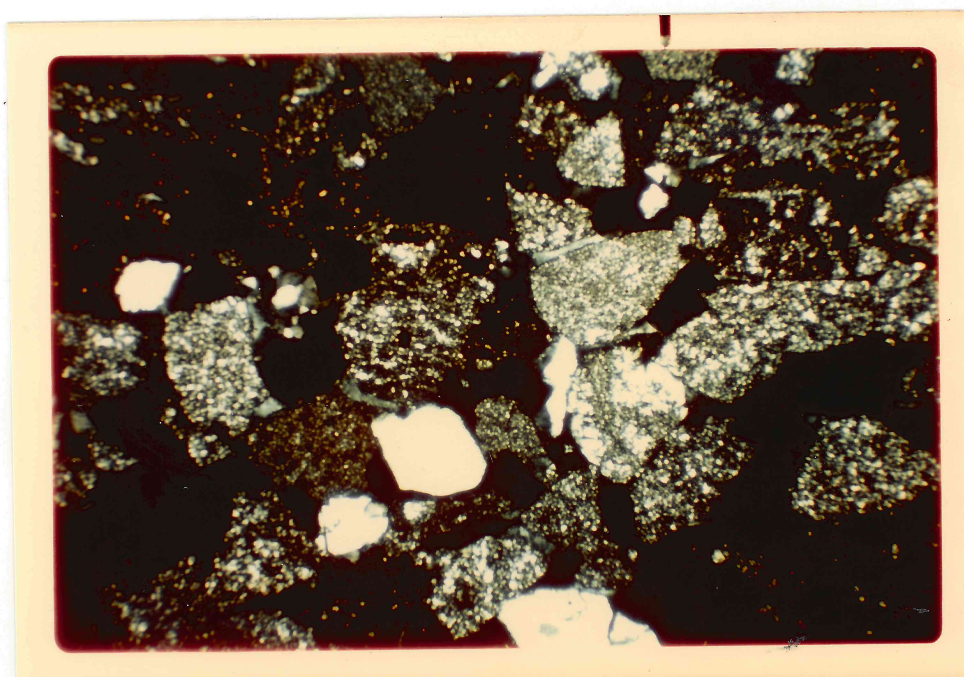
Unstable Lithics - 17.7%

Rock name - Subfeldspathic Lithic Wacke

Figure 31

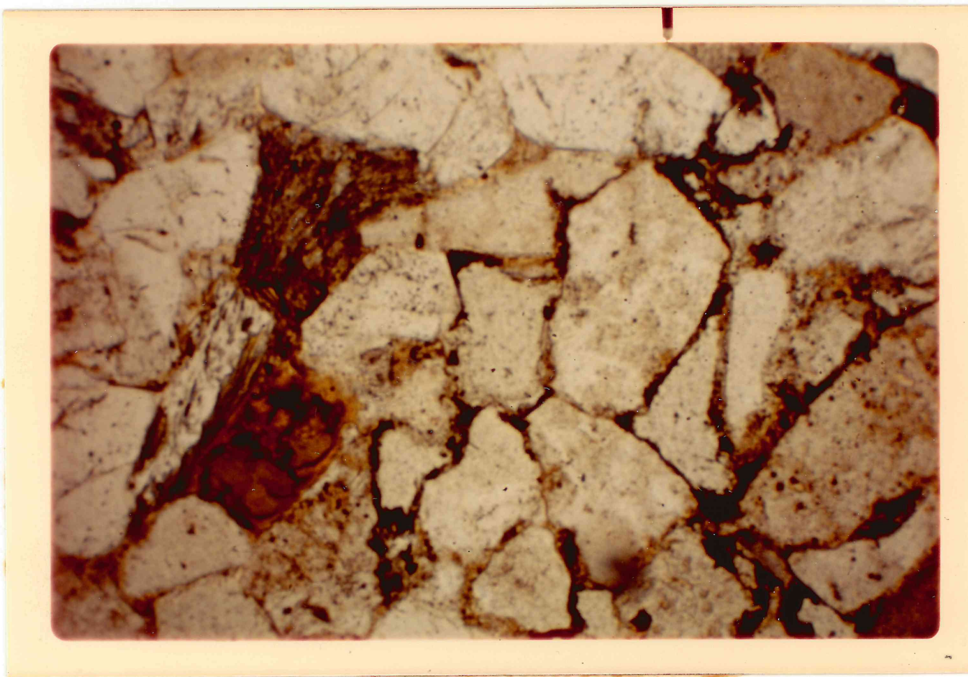


Non-Marine Paleocene north of the Brooks Range. RRR 451b, field 1 mm wide, parallel nicols. Clasts are chiefly various types of chert and quartz. Practically no matrix, sparse quartz overgrowths as cement. Pores filled with blue stained mounting material.

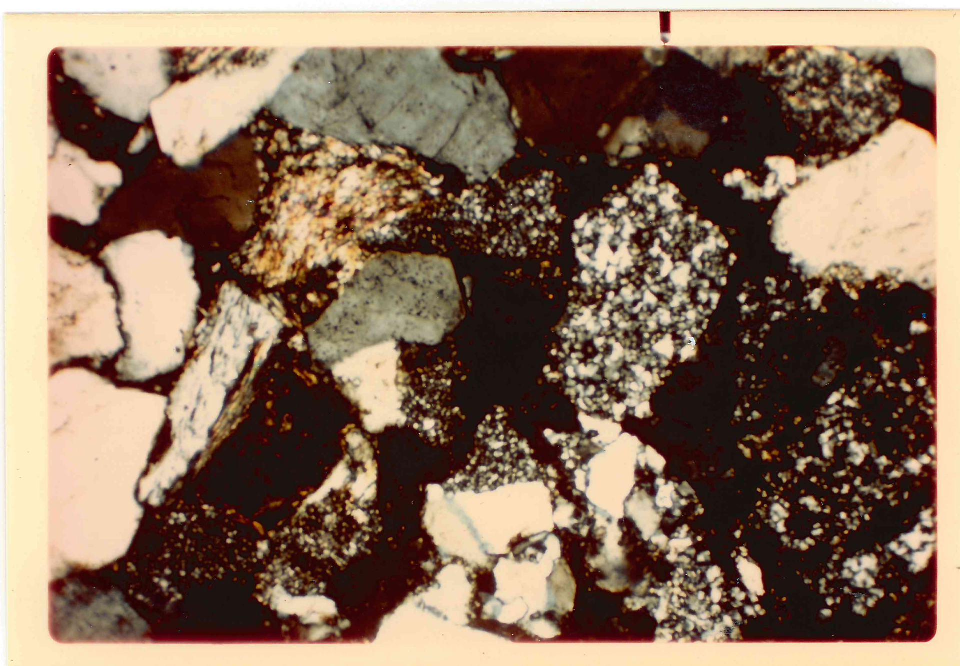


Same as above, nicols crossed.

Figure 32



Non-Marine Paleocene north of the Brooks Range. RRR 600, field 1 mm wide, parallel nicols. Clasts are various varieties of chert, phyllite, quartz, quartzite and chlorite. Cement is chlorite from the matrix and quartz. In addition to the chlorite, iron stained clay can be seen in the matrix. Several pores are observed.



Same as above, crossed nicols.