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GRAVELS FROM THE ALASKA CONTINENTAL SHELF, BEAUFORT SEA, ARCTIC OCEAN: PETROLOGIC CHARACTER AND IMPLICATIONS FOR SEDIMENT SOURCE AND TRANSPOET

By

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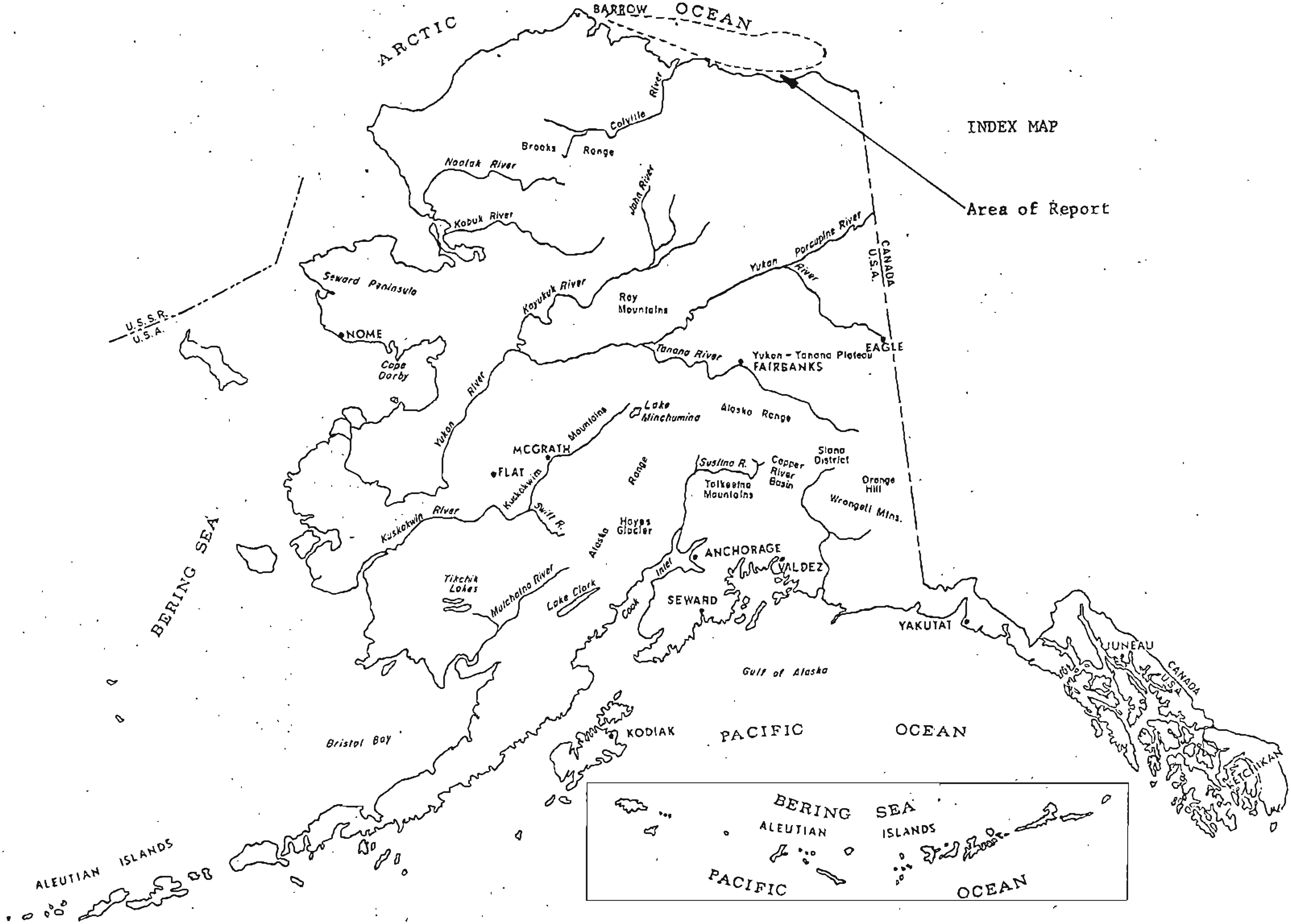
ABSTRACT

A suite of several hundred gravel-sized particles was collected from the floor of the Beaufort Sea, Arctic Ocean, on the continental shelf adjacent to northern Alaska. Fifty-four samples representative of this suite were selected for petrographic study, supplemented by X-ray diffraction analysis. A variety of lithologic types was characterized, including diabasic, granitic, volcanic, carbonate, clastic sedimentary, and high-grade metamorphic rocks. Presumably gravel fragments such as these were carried to their collection site off northern Alaska by some mechanism involving ice-transport. However, study of the bedrock geology of potential source areas within the circum-Arctic region indicates that the analyzed samples are not uniquely definitive of any particular area. A source in the Canadian Arctic Archipelago (in particular, Ellesmere Island) seems most likely for at least some of the gravels studied, however, some of the gravels might equally well have been derived from other areas in the northern portions of the North American Continent (Canada and/or Alaska), or elsewhere within the Arctic.

INDEX MAP



Area of Report
ARCTIC
OCEAN
BARROW
Colville River
Brooks Range
Noatak River
Kobuk River
John River
Seward Peninsula
NOME
Cape Darby
U.S.S.R.
U.S.A.
Kayukuk River
Ray Mountains
Yukon River
Porcupine River
CANADA
U.S.A.
EAGLE
Tanana River
Yukon - Tanana Plateau
FAIRBANKS
Lake Minchumina
Alaska Range
MCGRATH
FLAT
Kuskokwim Mountains
Kuskokwim River
Swift R.
Susitna R.
Talkeetna Mountains
Copper River Basin
Slana District
Orange Hill
Wrangell Mtns.
Hayes Glacier
ANCHORAGE
VALDEZ
SEWARD
Cook Inlet
Lake Clark
Tikchik Lakes
Mulchatna River
BERING SEA
YAKUTAT
JUNEAU
CANADA
USA
KETCHIKAN
Gulf of Alaska
KODIAK
PACIFIC
OCEAN
Bristol Bay
ALEUTIAN ISLANDS
BERING SEA
ALEUTIAN
ISLANDS
PACIFIC
OCEAN

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Samples were collected with the assistance of the crew of the U.S. Coast Guard icebreaker "Glacier" (WAGB-4), and we thank them for their many other courtesies as well.

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However, the interpretations herein are solely those of the authors, who readily admit the desirability of more data and further study in attempting to elucidate the relationships of interest.

INTRODUCTION

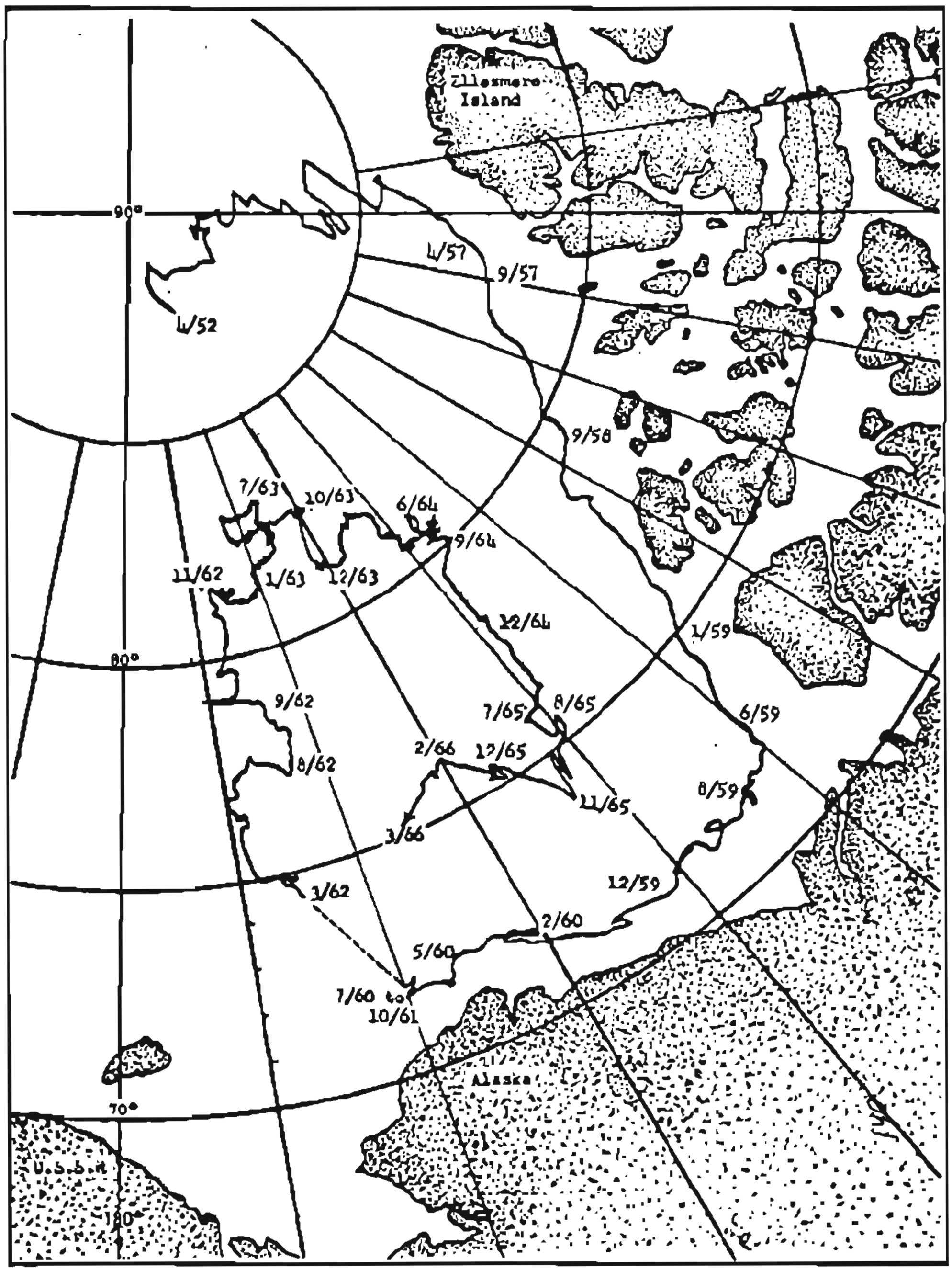
This paper describes the results of petrographic examination of gravel-sized materials collected from the sea floor of the continental shelf area of the Beaufort Sea, Arctic Ocean, in the region adjacent to northern Alaska. The area under consideration is shown on Figure 1, together with an overview of adjoining portions of the Arctic basin.

The samples reported on herein were collected during the "Websec-71," 1971, cruise of the U.S. Coast Guard icebreaker "Glacier" (WAGB-4) in the Beaufort Sea. The sample station localities are shown on Figure 2.

Samples were collected with Van Veen and Smith - McIntyre grab samplers. It should be stressed that our samples represent hand-picked gravel particles and, as such, thus do not represent a truly quantitatively representative suite. However, it is felt that, at least in a somewhat less rigorous manner, they should be useful in this preliminary assessment of the petrologic nature of Beaufort Sea floor gravels.

NATURE OF THE GRAVEL MATERIAL

In order to elucidate the character of the gravel fragments, fifty-four representative specimens were selected for detailed study from the total suite



Drift track — Fletcher's Ice Island, T-3, from April 1962 to March 1966, Arctic Ocean. From Schindler, 1968.

Figure 1.

Figure - 2

of some several hundred specimens collected. This selection was made on the basis of hand specimen and binocular microscope examination of the entire suite. These selected specimens have been studied in thin-section with the petrographic microscope, supplemented by X-ray diffraction analysis as appropriate. The results are listed in Table 1 (appendix).

Petrologically, the specimens studied may be grouped into several categories as follows:

1. Diabasic rocks
2. Volcanic rocks
3. Rocks of granitic aspect
4. Clastic sedimentary rocks
5. Carbonate rocks
6. Metamorphic (intermediate to high-grade) rocks

Generalizing somewhat, each of these categories is comprised of a relatively restricted range of rock types in our suite. The groupings are summarized below.

1. Diabasic rocks - (seventeen specimens).

   Predominantly medium-grained, with typically diabasic textures; plagioclase of sodic-labradoritic composition, intersertal to intergranular augitic clinopyroxene ($\pm$ pigeonite), some interstitial micropegmatitic intergrowths, less common granular olivine in small amount, occasional interstitial quartz, infrequent orthopyroxene, and ubiquitous opaque magnetite/ilmenite. The rocks range from strikingly fresh and essentially unaltered, through moderately altered (plagioclase somewhat sericitized, and mafics altering to chlorite-amphibole-biotite + opaques), to rocks in which the degree of alteration has been fairly intense. In the latter cases, the plagioclase is pervasively sericitized (albeit remaining recognizably labradoritic microscopically), the original primary mafic minerals have been changed to a melange of the afore-mentioned alteration products, and there has been associated development of secondary carbonate-zeolitic-silica phases. On balance, the majority of the diabases studied showed moderate amounts of alteration, although the relative freshness of many was noteworthy. There is little or no evidence of physical/mechanical alteration of these specimens.

2. Volcanic rocks - (three specimens).

Fine grained rocks of basaltic aspect, moderately to intensely altered. The plagioclase, where identifiable, is albitic, presumably representing secondary alteration, in association with intergranular clinopyroxene, which is moderately to strongly altered to chloritic-ferruginous-carbonatic material.

Magnetite/ilmenite is ubiquitous, and generally moderately altered to hematite $\pm$ leucoxene. Chlorite-silica $\pm$ zeolite-filled amygdules were noted in one specimen. Another specimen appears to be an intensely altered equivalent of an original glassy volcanic and/or pyroclastic rock, but this is difficult to assess due to the degree of alteration.

3. Rocks of granitic aspect (ten specimens).

Fundamentally these specimens show the usual hypidiomorphic granular texture commonly associated with medium-coarse grained granitic rocks, with several examples of aplitic and protoclastic/flaser variants. Most of these specimens fall within the composition field of "granite" (one is a "granodiorite") as defined by Streckeisen, 1967, with modes of 20 to 30 + percent quartz, 20 to 40 percent alkali feldspar, and 20 to 40 percent plagioclase. The next most abundant primary mineral is biotite, which is present in every specimen, but never in excess of 20 modal percent. Primary hornblendic amphibole occurs in only one specimen (10 modal percent). The alkali feldspars are predominantly of microcline aspect, microscopically. The two exceptions noted optically showed microcline characteristics (poorly defined) in bulk-rock X-ray diffraction patterns. Some are slightly-strongly perthitic, optically. The plagioclase shows moderate to weak zoning, is generally somewhat altered (sericitized, mainly), twinned, with bulk composition generally in the oligoclase range, and texturally early with regard to the other phases. The biotite commonly exhibits a moderate degree of alteration to chlorite-opaques ± secondary amphibole, although there are some specimens in which the primary biotite apparently has been strongly altered/bleached to a phase difficult to distinguish optically from muscovitic mica.

These specimens also all exhibit the tendency toward varying degrees of proto-cataclastic strain effects which is common in granitic rocks. The quartz ranges from slightly undulose extinction in some rocks, through degrees of crenulation/pulverizing to a relatively thoroughly comminuted "matrix" in other specimens. The latter rocks are sub-foliated, with obvious effects of deformational stresses also manifested by the other mineral phases present. The development of appreciable epidote is also noted in such rocks. It is perhaps noteworthy that most of these rocks possess feldspars of pink-reddish color in hand specimen.

4. Clastic sedimentary rocks - (fifteen specimens)

Most of these specimens consist of medium-coarse grained rocks of greywacke-subgreywacke-subarkose character, as defined by Pettijohn, 1957. They consist of angular-subangular-subrounded clastic grains of quartz, chert, rock fragments, alkali and plagioclase feldspars, associated with a somewhat finer-grained matrix of chloritic-sericitic material, which latter often includes (or has been altered to) hematitic-ankeritic material. In one specimen, the amount of modal hematite (40 + percent) suggests that the apellation "iron-formation" might not be inappropriate for this rock. Other carbonate (calcite) material is infrequently present as intergranular cement. Secondary silica overgrowths are common on the clastic quartz grains, some of which were apparently fairly well-rounded originally. One occurrence of tourmaline in minor (<5 modal percent) amount was noted in a subgreywacke. Included in this category of clastic sedimentary rocks are two fine-grained specimens, one a siltstone with apparent greywacke affinities, the other a calcareous-phosphatic argillite.

5. Carbonate rocks - (eight specimens).

The specimens include three quartzose limestones - one pelletoidal and oolitic, another pelletoidal and burrowed, the third an intraclastic variety. Cherty rocks are represented by a calcareous penecontemporaneous conglomeratic chert and by a dolomitic chert. A burrowed(?) pelletoidal dolomite and two essentially holocrystalline dolomites complete the carbonate suite examined to date. All of these rocks are fine-very fine grained and, although none exhibit recognizable fossils, some traces of the activity of burrowing organisms contemporaneous with the sedimentation seem to be discernible. The specimens thus are recrystallized (to varying degrees) sedimentary rocks, but not marbles in the usual sense.

6. Metamorphic rocks - (one specimen).

This rock is a garnet-sillimanite quartzo-feldspathic gneiss. The alkali feldspar is faintly microclinic optically, and perthitic. The mineral phases exhibit a tendency toward segregation into discreet bands of quartz (granulated), garnet-sillimanite-biotite (small amount), and alkali feldspar. Poorly characterized muscovitic(?) material is found in minor amount, possibly representing retrograde material, and/or a metastable phase in the sillimanite-muscovite zone of the amphibolite facies. Staurolite also appears in minor amount associated with the garnet and muscovite in this rock, which would further tend to indicate metastability within the afore-mentioned metamorphic grade. Certainly the assemblage seems to be representative of regional metamorphism in the upper amphibolite range (cf. Turner, 1968; Winkler, 1967).

POSSIBLE SOURCE AREAS

Given the preceding petrologic information, it was hoped that further insight might be gained regarding possible source area(s) for these gravel materials, as well as the mode of transport to their collection sites on the Beaufort Sea floor off northern Alaska. Obviously, the initial phase of such work entails a knowledge of the lithologic character of rocks exposed presently, or in the recent geologic past, in geographically reasonable potential source areas. With this in view, we have carried out a review of the available literature (cf. the Selected Bibliography, this paper) pertaining to the bedrock geology of northern Alaska and Canada, with consideration also being given to other areas peripheral to the Arctic Ocean basin as well. The analogous study of Stoiber, et al, 1956, regarding the source of gravels on ice island T-3 served as a very useful point of departure in our work and, interestingly enough, our studies result in conclusions similar to those of Stoiber, et al. Additionally, consultations and discussions with the parties cited in the acknowledgments section of this paper helped considerably.

Presumably, with due regard for the sampling bias mentioned earlier, the lithologies encountered during the present work represent the combined effects of lithologic nature of source areas, the likelihood for formation and preservation of gravel-sized fragments of the various lithologies, geomorphic processes relative to erosion, coarse sediment transport and dispersal, as well as physical conditions of climate, wind, ocean currents, etc. Given these complexities, together with the likelihood of any given analyzed lithology being somewhat less than rigorously definitive with respect to possible source area, it was appreciated that unambiguous resolution of the questions of source and transport mode might not be anticipated, at least from this initial study. However, it was hoped that collective consideration of the spectrum of lithologies would provide a useful framework and point of departure for further work, as well as permitting more speculative attempts at interpretation such as the discussion which follows.

If this suite of samples represents an assemblage of materials derived from a single general source region, subsequently transported together to the present site of occurrence on the Beaufort Sea floor, then the most likely source area for the suite, <u>in toto</u>, would seem to be somewhere in the Canadian Arctic Archipelago.

If, however, more than one source area furnished materials to this suite, the problem of ascertaining such source areas becomes considerably more difficult. Since each of the rock-types represented might well have been derived from any one of several possible sources, the most useful information regarding any of these sources will be provided by those lithologies which occur in the fewest possible source sites. In this regard, the gneiss is perhaps the most definitive lithology in our suite, the diabases (with or without the volcanics as possible consanguinous associates) next, with the granitoids , the clastic sedimentary rocks, and the carbonate rocks being somewhat less useful in endeavoring to specifically elucidate source areas.

As an example of the less-than-definitive nature of the suite in toto, the south shore of Coronation Gulf, Northwest Territories, Canada, has the diabase-volcanics-granitoid-high-grade gneiss ± the sedimentary rocks possibly analogous to our Beaufort Sea gravel suite. However, it is difficult to envision a feasible mechanism for transporting such gravel-sized materials from this particular potential source area to the northern Alaska shelf, given the current and climatic regimen presently active in the region. Of course it is possible that at some previous stage these factors might have been more favorable for a westerly transport of ice, and that the gravels represent an earlier depositional cycle on the Beaufort Sea shelf, but there is not sufficient information available at present to permit anything but tentative speculation in this regard.

Thus, in order to further consider the matter of possible source localities for the gravels, we have merely attempted to summarize the observations from our work, and to make such comparisons as seemed appropriate with information from other sources.

Certainly, the high-grade sillimanite-garnet quartzo-feldspathic gneiss has no analog in northern Alaska, as regional metamorphic terrains of this grade are not known in the region. It is possible that this rock represents a contact aureole/roof pendant occurrence associated with granitic rocks from

A Brooks Range-Romanzof uplift source, but this is considered unlikely in view of the apparent "regional-metamorphic" aspect of the sample studied. Admittedly this is a difficult problem to resolve rigorously on the basis of the study of a single gravel fragment, but it appears more likely that this material represents a sample of a high-grade metamorphic terrane elsewhere. The possible areas for such include the Aphebian and Helikian of Northwest Territories, Canada, (south shore of Coronation Gulf, south shore of Queen Maude Gulf, Baffin Island, or Ellesmere Island). Another possible source would be the Hadrynian of Ellesmere Island.

The diabasic rocks studied are somewhat less definitive, in that their possible source areas are more numerous than the gneiss discussed above. These basic rocks may have been derived from nothern Alaska either from areas in the De Long Mountains or from the Southern Foothills of the North Slope sequence, particularly in the Etivluk River area. Although the petrologic character of the gravels studied does not preclude a derivation from this region, the Alaskan diabasic rocks generally seem to be considerably more altered than the gravels studied. An alternative source would be the Hadrynian of the Coronation Gulf area (south shore), and/or Victoria Island, Northwest Territories, Canada. Perhaps more likely are origins in the Ellesmere Island or Ellef Ringnes Island mafic intrusive bodies, which apparently are not too extensively altered.

The volcanic rocks represented in the gravels studied seem to have few known analogs at present in feasible source areas in northern Alaska. However, they might have been derived from the De Long Mountains or the Southern Foothills of the North Slope sequence, as per the diabases discussed above, particularly if the basaltic rocks were either consanguinous with, or represent marginal facies of the diabases. Perhaps more likely is a source in the Neohelikian and/or Aphebian volcanics along the south shore of Coronation Gulf, the Helikian volcanics of Victoria Island and/or Baffin Island, or the Ellesmere Island Ordovician or Devonian sequences.

The granitic rocks represented in the Beaufort Sea gravels are fairly typical of most such lithologies. The subequal amounts of quartz, potassium feldspar, and plagioclase are similar to Brooks Range plutonic rocks we have studied, but such characteristics are hardly uniquely definitive in terms of the present study. Furthermore, the associated minerals such as the micas, amyphibole, etc. do not seem to be particularly promising indicators either. Other possible granitic source terranes in the proximal Arctic Basin region include northern portions of the U.S.S.R., as well as areas of northern Canada. Of the latter, the Archean granitoids of the south shore of Coronation Gulf, and the Devonian granitoids of Ellesmere Island are perhaps the most likely. The Romanzof Uplift granitic rocks of northeast Alaska are another possibility, although the petrology again is not definitive.

The clastic sedimentary rocks of the gravel suite do not seem to be as amenable to as clear-cut an assignment regarding their source areas as might be anticipated. Thus, it appears that the predominantly subgreywacke (with subarkosic affinities in a few cases) aspect of these rocks might suggest a source in the contiguous regions of northern Alaska and Canada, as well as from more distant areas of the Canadian Arctic. Part of the problem is the considerable extent of such rocks areally and stratigraphically, in this entire region. The finer-grained clastic sedimentary rocks represented in the Beaufort Sea gravels seem to be equally non-definitive.

The carbonate rocks in the suite studied could well have been derived from adjacent northern Alaska as they are rather similar to Devonian and Carboniferous rocks which presently outcrop in this region. However, they might equally well have come from various source areas in the Canadian Arctic and, thus, are not apparently definitive in this regard either. Once again, rocks of this aspect are quite abundant throughout the entire region.

SUMMARY

It would appear, based on the foregoing discussion, that although a northern Alaska source for the Beaufort Sea gravels is a possibility, there is a greater likelihood that at least some of the gravel fragments have come from other regions. The Ellesmere Island area seems to represent the most favorable situation, in terms of lithologies and terrains, in conjunction with the present current patterns in the Arctic Basin. Certainly the work of Stoiber, et al with regard to some of the materials on ice island T-3 is suggestive of this, and the petrologic character of the Beaufort Sea gravels seems to indicate that this is a very likely source area. The only other general region which seems to have the requisite bedrock geology at present is the south shore of Coronation Gulf, but there are problems in demonstrating the feasibility of gravel transport from this area to the Beaufort Sea shelf of northern Alaska. The crucial presence of the high-grade sillimanite-garnet gneiss and the relatively moderately altered diabasic rocks seems to suggest an Ellesmere Island source for at least these materials, and, by implication, perhaps a considerable portion of the other lithologies noted in the gravels.

In conclusion, we wish to stress the preliminary nature of the present investigation. It is hoped that further studies will aid in clarifying the situation and the additional work we are currently undertaking will be a contribution to this end.

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APPENDIX

Table 1. Petrographic Analyses

PETROGRAPHIC ANALYSIS

Specimen Number: ______________ Location: GLA 71-1

Texture: ______________ Structure: ______________

Misc.: Quartzose pelletoidal - oolitic limestone

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	sub-angular	< 0.1	15		floating freely in carbonate matrix.
Calcite	oolites;	< 1.0	35		
	irregular pellets;	< 0.8	30		
	crystalline mosaic	0.2-0.05	20		

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-1

Texture: Clastic **Structure:** ______

Misc.: Siltstone

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz (± feldspars?)	angular	< 0.05	70		
Muscovite	laths	< 0.06	5		
Carbonate	irregular	variable	5		cement
Biotite/ Chlorite	irregular/ semi-hedral	< 0.05	10		intergranular
Opaques	irregular	< 0.04	10	leucoxene (complete)	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ Location: GLA 71-1

Texture: Clastic Structure: ______________________

Misc.: Medium-grained hematitic greywacke

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	ang./subang.	< 0.3	20		
Chert	ang./subang.	< 0.3	10		
M.R.F.	ang./sub-ang.	< 0.3	10		
Plagioclase	ang./sub-ang.	< 0.3	5		
Microcline	ang./sub-ang.	< 0.3	5		
Carbonate	ireg.	< 0.5	5		cement
Hematite	ireg.		40		pervasive as matrix, and on detrital grains
Magnetite/ Ilmenite	ireg.	< 0.5	5	hematite/leucoxene	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-3

Texture: Protoclastic granitoid **Structure:** ______

Misc.: Biotite-hornblende granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	irregular	< 2.3	25	strongly crushed	
Plagioclase	subhedral/ irregular	2.0; < 0.2	25	moderately sericitized; fresh	zoned; AN_{20}
K-feldspar	subhedral	< 2.0	20		perthitic
Biotite	subhedral	< 2.0	15	moderately to chlorite	
Hornblende	irregular/ sub-hedral	< 2.0	10		green-blue
Epidote	euhedral/ subhedral	< 0.3	< 5		assoc. with biotite, etc.
Zircon	subhedral	< 0.3	trace		
Sphene	subhedral	< 0.3	trace		
Magnetite/ Ilmenite	subhedral	< 0.2	< 5	moderately to leucoxene	

Commentary: A protoclastic foliated granitoid

PETROGRAPHIC ANALYSIS

Specimen Number: ____________ Location: GLA 71-4

Texture: ____________ Structure: ____________

Misc.: Dolomite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Dolomite	anhedral/ irregular	0.7-0.06 and <	100		interlocking mosaic, and with burrows(?) filled coarser crystals, and with pellet/fossil relict throughout the rock.

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-4

Texture: Hypidiomorphic granular

Structure:

Misc.: Granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	$<$ 3.0	35		
Microcline	anhedral	$<$ 4.0	36		
Plagioclase	subhedral/ anhedral	$<$ 3.0	25	moderately sericitized	zoned; oligoclase
Biotite	anhedral	variable	$<$ 5	moderately to chlorite	
Magnetite/ Ilmenite	subhedral	very fine	$<$ 5	hematite + leucoxene	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-4

Texture: Clastic **Structure:** ______

Misc.: Coarse-medium-grained feldspathic sandstone

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	sub-rounded/ sub-elongated	<0.9	80		with secondary overgrowths
Chert	sub-rounded	<0.9	10		
K-feldspar	sub-rounded/ subhedral	<0.9	5		
Chlorite	irregular	very fine	trace		intergranular coatings
Magnetite/ Ilmenite	anhedral	very fine	5	hematite	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ Location: GLA 71-4

Texture: ______________________ Structure: ______________________

Misc.: Calcareous-phosphatic shale/argillite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	sub-rounded	< 0.1	major		with secondary overgrowths on some grains
Chlorite/Mica	irregular	very fine	major		
Phosphatic	sub-rounded nodules	irregular	major		
Carbonate	irregular	variable	major		
K-feldspar	sub-hedral	< 0.3	minor		

Commentary: Specimen difficult to decipher petrographically, due to small grain sizes and complex intergrowth of constituents.

PETROGRAPHIC ANALYSIS

Specimen Number: ______

Location: GLA 71-4-I

Texture: Diabasic-subophitic/intergranular

Structure: ______

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 2.0	40	weakly-moderately saussuritized	zoned, AN_{55}
Clinopyroxene	irregular/ subhedral	< 2.0	30	moderately	mostly intersertal-subophitic
Orthopyroxene	subhedral/ subrounded	variable	10	moderately	mafic minerals alter to chlorite + biotite + amphibole + talc+
Olivine	subhedral	< 1.0	10	some fresh, some obliterated	carbonate-serpentine
Magnetite/Ilmenite	subhedral/ euhedral	< 2.0	10	slightly to hematite	from alteration of mafic minerals, as well as primary

Commentary: Moderately altered rock.

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ **Location:** GLA 71-4-II

Texture: ______________________ **Structure:** ______________________

Misc.: Quartz diabase/gabbro

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	subhedral	< 3.0	30	moderately to sericite, etc.	zoned, AN_{63-50}, some with albite rims
Amphibole/ chlorite ± carbonate	irregular	variable	30	after mafics	some amphibole may be primary.
Micrographic material	irregular	variable	10		interstitial
Quartz	anhedral	variable	10		interstitial
Calcite	anhedral	variable	5		veins
Apatite	laths	variable	trace		
Magnetite/Ilmenite	subhedral	variable	15	hermatite/leucoxene	

Commentary: Strongly altered rock. Texture uncertain.

PETROGRAPHIC ANALYSIS

Specimen Number: ______ Location: GLA 71-4-III

Texture: ______ Structure: ______

Misc.: Diabase (?)

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Clinopyroxene	euhedral	4.0-2.0	20	moderately to chlorite/amphibole/biotite/epidote	phenocrysts
Chlorite/biotite amphibole/epidote	irregular	variable	35	after matrix and/or mafics	
Plagioclase	irregular	indistinct	35	moderately albitized and/or sericitized-saussuritized	
Magnetite/ Ilmenite	subhedral/ euhedral	$<$1.0	10		

Commentary: Strongly altered rock. Texture obscure.

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-9

Texture: Clastic **Structure:** ______

Misc.: Medium-grained greywacke

Description of Minerals:

Name	Shape	Size(mm)	Modal %	Alteration	Remarks
Quartz	sub-rounded	< 0.5	60		with secondary overgrowths; semi-elongated and semi-parallel aligned.
Plagioclase	sub-rounded	<0.5	5		
K-feldspar	sub-rounded	<0.5	5		
Chlorite/ sericite	laths	<0.03	20		intergranular matrix
Chert + M.R.F.	irregular	<0.5	10		

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-9

Texture: ______ **Structure:** ______

Misc.: Dolomitic chert

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Dolomite	euhedral/ subhedral	< 0.5	40		"floating" in chert
Chert	irregular	< 0.02	55		matrix
Quartz	subangular	< 0.05	5		detrital grains

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______________ **Location:** GLA 71-9

Texture: Protoclastic granitoid **Structure:** ______________

Misc.: Granodiorite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 1.2	32	highly crushed	
Plagioclase	sub-anhedral	< 2.3	35	moderately to sericite	AN_{15-20}
K-Feldspar	sub-hedral	< 2.3	16	moderately to sericite, etc.	
Biotite	sub-hedral	< 0.6	16	moderately to chlorite + hematite + opaques	sub-parallel elongation and layers; smeared out
Magnetite/ Ilmenite	anhedral	very fine	1		

Commentary: A protoclastic (flaser) granitoid, with larger feldspars, granulated quartz, and interleaved biotite.

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-13

Texture: Diabasic - subophitic **Structure:** ______

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 1.5	40	moderately sericitized	AN_{60}; Zoned somewhat
Micrographic material	irregular	variable	5		interstitial
Clinopyroxene	irregular	<1.0	30	moderately to horn-blende + biotite, etc.	interstitial to plagioclase, mainly
Biotite/ Hornblende	subhedral/ euhedral	< 1.0	15	after olivine and/or orthopyroxene	
Magnetite/Ilmenite	euhedral/ subhedral	< 0.5	10		

Commentary: Moderately altered.

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-18

Texture: Diabasic-intergranular/subophitic **Structure:** ______

Misc.: Olivine diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 2.0	30	moderately to sericite/ saussurite	AN_{52} moderately zoned
Micrographic material	irregular	variable	5		interstitial
Clinopyroxene	subhedral/ irregular	< 1.0	30	moderately	mafic minerals alter to talc + biotite + amphibole + opaques (Clinopyroxene, Orthopyroxene, Olivine)
Orthopyroxene	irregular/ subhedral	< 1.0	20	moderately strong	
Olivine	subhedral	< 1.0	10	moderately	
Magnetite/Ilmenite	euhedral/ subhedral	< 1.0	5		

Commentary: Moderately altered rock.

PETROGRAPHIC ANALYSIS

Specimen Number: ____________ Location: GLA 71-23

Texture: ____________ Structure: ____________

Misc.: Quartzose intraclastic limestone

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	angular	< 0.13	40		
Plagioclase	angular	< 0.13	10		
K-feldspar	angular	< 0.13	5		
Calcite	subhedral	< 0.13	45		as layers and intraclasts of interlocking mosaics of crystals.

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-27-I

Texture: Diabasic

Structure:

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	<1.2	40		AN_{52}
Clinopyroxene	subhedral/ irregular	<2.3	40	weakly to biotite + chlorite, etc.	generally intersertal; some pigeonite
Orthopyroxene	subhedral/ irregular	variable	trace		
Micrographic material	irregular	variable	5		interstitial
Magnetite/ Ilmenite	subhedral/ euhedral	<2.0	15		

Commentary: Very weakly altered.

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ **Location:** GLA 71-27-II

Texture: Diabasic **Structure:** ______________________

Misc.: Olivine diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 3.0	30^{+}		AN_{60}
Clinopyroxene	irregular/ subrounded	< 4.0	30^{+}		largely intersertal-poikilitic
Orthopyroxene	irregular	< 1.0	5		
Chlorite/ amphibole/ biotite	irregular	patchy, variable	15^{+}	after olivine	
Olivine	sub-rounded	< 0.5	10	moderately to biotite + chlorite + opaques ± talc, serpentine, etc.	
Magnetite/Ilmenite	subhedral/ euhedral	~ 0.5	~ 5		

Commentary: Moderately altered.

PETROGRAPHIC ANALYSIS

Specimen Number: ________ **Location:** GLA 71-28

Texture: Diabasic - subophitic **Structure:** ________

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 2.0	25	weakly-moderately to sericite/saussurite	AN_{55}; moderately zoned
Clinopyroxene	irregular	< 3.0	20	moderately to biotite + opaques + chlorite + amphibole	mainly intersertal
Orthopyroxene	irregular	variable	5	moderately-strongly to biotite + opaques + amphibole + chlorite	poikilitic
Olivine	rounded/ ovoid	< 0.3	5		
Micrographic material	irregular	patchy	10		late and interstitial
Chlorite/amphibole/ biotite	irregular	variable	15		alteration products
Magnetite/Ilmenite pyrite	subhedral/ euhedral	< 1.0	20		often assoc. with alteration products

Commentary: Moderately altered.

PETROGRAPHIC ANALYSIS

Specimen Number: 　　　　　　**Location:** GLA 71-28

Texture: Gneissic; Protoclastic　　　　**Structure:**

Misc.: Garnet-sillimanite quartzo- feldspathic gneiss

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	$\angle$ 2.0	30		protoclastic
Garnet	subhedral/ sub-elongated	$\angle$ 4.0	20	opaques + biotite ± chlorite	almandine
K-feldspar	irregular	$\angle$ 3.0	20		slightly microclinic, and perthitic
Sillimanite	euhedral	$\angle$ 1.0	20		
Biotite	subhedral	$\angle$ 0.5	$<$ 10		assoc. with garnet (retrograde?); red-brown
Chlorite	irregular	variable	trace		assoc. with garnet and muscovite.
Staurolite	irregular	variable	trace		assoc. with garnet and muscovite.
Magnetite/ Ilmenite	irregular	variable	$<$ 5		assoc. with biotite

Commentary: Bands of granulated quartz; garnet-sillimanite-biotite; and K-feldspar.

PETROGRAPHIC ANALYSIS

Specimen Number: ______________ Location: GLA 71-31

Texture: ______________ Structure: ______________

Misc.: Limestone

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Calcite	irregular/ anhedral	∠0.8	95		interlocking mosaic, with relict pellets(?)
Quartz	sub-angular	∠0.07	5		detrital grains

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-31

Texture: Clastic

Structure:

Misc.: Fine-grained meta-subgreywacke

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz (± Plag.?)	angular/ sub-angular	$<$ 0.25	40		
Chert/M.R.F.	sub-rounded	$<$ 0.25	20		
Muscovite	laths	$<$ 0.4	5		discreet flakes
Biotite/ Chlorite	irregular	$<$ 0.13	10		flakes, and some with M.R.F.
Mica	irregular, laths	very fine	10		matrix
Carbonate	irregular	$<$ 0.3	5		intergranular cement
Magnetite/ Ilmenite	irregular	variable	10	hemátite/leucoxene	

Commentary: Rock is moderately metamorphised (thermal?) to biotite grade.

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-31

Texture: ______ **Structure:** ______

Misc.: Calcareous chert

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Chert	irregular	< 0.1	60		matrix, pervasive
Calcite	irregular, and rounded	< 0.2	10		replacing some clasts
Rock fragments	rounded/ irregular	< 3.0	30	moderately to calcite	some as clasts, others as soft clasts and/or interstitial sediment with chert.
Phosphate (?)	irregular	< 0.1	trace		

Commentary: An intimate melange of chert-clasts/sedimentary matrix of clays-sedimentary rock clasts; ie. a "calcareous penecontemporaneous micro-conglomeratic chert".

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-31b

Texture: ______ **Structure:** ______

Misc.: Highly altered basaltic rock

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Clinopyroxene	subhedral	< 0.5	40	strongly to chlorite	highly altered and rather nondescript (Clinopyroxene and Plagioclase)
Plagioclase	irregular	< 0.5	30	strongly saussuritized, etc.	
Magnetite/Ilmenite	irregular	< 0.5	30	leucoxene	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-38

Texture: Clastic

Structure:

Misc.: Coarse-grained quartzose subgreywacke

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	sub-angular/ rounded	$\angle$ 2.0	60		with secondary overgrowths
Chert	sub-rounded	$\angle$ 2.5	10		
M.R.F.	sub-rounded	$\angle$ 1.0	10		one recognizable rhyolite fragment.
Muscovite	subhedral	$\angle$ 0.5	10		matrix
Magnetite/ Ilmenite	irregular	variable	10	hematite/leucoxene	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-38

Texture: Diabasic; inequigranular **Structure:** ______

Misc.: Olivine diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	euhedral laths; laths	1.5 + $<$; $<$ 0.3	30	moderately sericitized	AN_{52}, weakly zoned; AN_{40}
Orthopyroxene	irregular	$<$ 3.0	10		subpoikilitic, enstatitic
Clinopyroxene	irregular	$<$ 4.0	30	moderately to biotite, etc.	augitic
Olivine	subhedral/ indistinct	$<$ 3.0	10	strongly to talc + opaques + hornblende + chlorite + serpentine	
Opaques	subhedral/ euhedral	$<$ 2.0	20		

Commentary: Moderately altered.

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ **Location:** GLA 71-40

Texture: ______________________ **Structure:** ______________________

Misc.: Dolomite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Dolomite	anhedral/ irregular	< 0.3	100		interlocking mosaic, with suggestions of relict organic structures.

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______________

Location: GLA 71-41

Texture: Aplitic

Structure: ______________

Misc.: Aplitic granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	irregular	< 2.3	23		strained and bent
Plagioclase	subhedral/ anhedral	< 1.2	24	slight	oligoclase
Microcline	irregular	< 1.0	18	slight	bent and deformed
Myrmekite	irregular	variable	11		
Biotite/ amphibole	irregular/ subhedral	variable	19	strongly to chlorite + opaques + mica	
Magnetite/ Ilmenite	subhedral/ anhedral	< 0.2	5		assoc. with altered mafic minerals.

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-44

Texture: Protoclastic granitoid

Structure:

Misc.: Biotite granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	irregular	< 3.0	27	moderately crushed	
Plagioclase	subhedral/ anhedral	< 3.0	24	weakly sericitized	oligoclase
Muscovitic mica	subhedral	< 1.0	12	after biotite ??	
Microcline	subhedral/ anhedral	< 3.0	25		
Biotite	irregular	variable	8	strongly to chlorite + opaques	
Magnetite/ Ilmenite	irregular	fine	4	leucoxene	assoc. with biotite

Commentary: Protoclastic granitoid.

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ **Location:** GLA 71-45

Texture: Diabasic **Structure:** ______________________

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths/ subhedral	< 4.0	30	moderately saus- suritized	AN_{50}; zoned
Amphibole	subhedral/	6.0+ <; < 2.0	20 10	weakly-moderately to chlorite	primary or secondary ?
Clinopyroxene	irregular	< 6.0	25	moderately to hornblende to actinolite to chlorite	mostly intersertal
Biotite	irregular	variable	5		assoc. with opaques and altered phases.
Magnetite/Ilmenite	subhedral/ euhedral	< 4.0	10		
Pyrite	anhedral	very fine	trace		

Commentary: Moderately-strongly altered rock.

PETROGRAPHIC ANALYSIS

Specimen Number: ______

Location: GLA 71-68-1

Texture: Aplitic and hypidiomorphic

Structure: ______

Misc.: Aplitic granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	2.0; <1.0	35		
Microcline	anhedral	2.0; <1.0	30		slightly perthitic
Plagioclase	subhedral	4.0; <1.0	26	very strong to sericite, etc.	oligoclase
Muscovite	subhedral	1.5; <1.0	8	after biotite ??	
Biotite	subhedral	<0.5	1		

Commentary: Layered/banded by grain size.

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ **Location:** GLA 71-68-2

Texture: Hypidiomorphic granular **Structure:** ______________________

Misc.: Biotite granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	irregular	< 2.3	25		
Plagioclase	subhedral/ anhedral	< 2.3	30	weakly sericitized	zoned, AN_{28-25}
K-feldspar	irregular	< 3.4	20	weakly sericitized	
Biotite	subhedral	< 2.5	15	somewhat bleached (to "muscovite"?)	
Carbonate	irregular	< 0.5	trace		
Sphene	subhedral	< 0.5	trace		
Epidote	subhedral	< 0.5	5		
Magnetite/ Ilmenite	irregular	variable	5	slightly to hematite	pseudomorphs after some biotite

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ Location: GLA 71-68-3

Texture: Clastic Structure: ______________________

Misc.: Coarse-medium-grained arkose/subgreywacke

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	angular/ sub-angular	<1.0	30		
Microcline	subhedral/ angular	<1.0	20		
Chert	sub-rounded	<1.0	20		
Plagioclase	sub-angular	<1.0	10		
M.R.F.	irregular	<1.0	10		
Chlorite/ muscovite	irregular	very fine	10		intergranular matrix
Biotite	subhedral	<1.0	trace		

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-68-4

Texture: Clastic **Structure:** ______

Misc.: Fine-grained lithic greywacke

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	angular	< 0.2	25^{+}		
K-feldspar	sub-angular	< 0.2	5		
Muscovite	subhedral	< 0.2	5		
Plagioclase	sub-angular	< 0.2	5		
Chlorite/mica	subhedral	< 0.02	25^{+}		matrix
M.R.F.	irregular	< 0.2	20		
Carbonate	anhedral	variable	< 5		cement
Magnetite/ Ilmenite	subhedral/ sub-angular	< 0.2	10	strongly to hematite/leucoxene	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-68-6

Texture: Diabasic **Structure:** ______

Misc.: Fine-grained diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	subhedral	< 1.0	40		AN_{62}
Clinopyroxene	subhedral/ irregular	< 1.0	25	moderately to amphibole/chlorite	Interstitial to plagioclase
Micrographic material	irregular	variable	10		Interstitial
Orthopyroxene	subhedral/ irregular	variable	20	strongly to chlorite + biotite and opaques	
Magnetite/Ilmenite	euhedral/ subhedral	< 1.0	5		

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-68-7

Texture: Diabasic

Structure:

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 1.5	40	very strongly saussuritized, etc.	
Clinopyroxene	subhedral/ euhedral	< 2.0	30	moderately strongly to chlorite, etc.	
Orthopyroxene	subhedral	< 1.0	10	moderately strongly to chlorite, etc.	
Micrographic material	irregular	variable	10		interstitial
Magnetite/Ilmenite	subhedral/ euhedral	< 4.0	10	moderately to leucoxene	some after mafics, and some primary.

Commentary: Very strongly altered rock. Contains secondary veins of albite/oligoclase.

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-68-8

Texture:

Structure:

Misc.: Altered basalt

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	subhedral/ laths	< 0.3	30	albitized	AN_{0-10}
Clinopyroxene	irregular/ sub-rounded	< 0.13	30		crystallized with or later than plagioclase
Chlorite	irregular	variable	20		after groundmass
Magnetite/ Ilmenite	subhedral	< 0.3	20	moderately to hermatite	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number:

Location: GLA 71-68-9

Texture: Clastic

Structure:

Misc.: Medium-grained lithic greywacke

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	rounded;	1.0-0.5	10		crudely bedded
	sub-angular/ sub-rounded	<0.3	40		
Chert	sub-rounded	<0.3	5		
M.R.F.	sub-rounded	<0.3	5		
Muscovite	irregular	<0.3	30		matrix
Magnetite/ Ilmenite	irregular	<0.3	10	hematite	especially as cement

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ________ **Location:** GLA 71-68-10

Texture: Clastic **Structure:** ________

Misc.: Very fine-grained hematitic arkose

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	angular	< 0.1	40		
Muscovite	subhedral	< 0.1	20		
Plagioclase	sub-angular/ sub-rounded	< 0.1	10		
Hematite	irregular	-	20		cement
Magnetite/ Ilmenite	irregular	< 0.1	10	hematite	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-68-11

Texture: Subophitic **Structure:** ______

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	subhedral	< 2.0	50	moderately to sericite + carbonate	AN_{50}
Clinopyroxene (+ Orthopyroxene?)	irregular	< 4.0	40	moderately to biotite + amphibole + chlorite + opaques	mainly interstitial
Magnetite/Ilmenite	subhedral	<1.3	10		mostly assoc. with altered mafics
Pyrite	subhedral/ anhedral	variable, small	trace		
Calcite	irregular	variable	?		interstitial, and replacing all phases

Commentary: Moderately-strongly altered rock.

PETROGRAPHIC ANALYSIS

Specimen Number: ____________________ Location: GLA 71-68-12

Texture: ____________________ Structure: ____________________

Misc.: Strongly altered amygdaloidal basalt

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Orthopyroxene	euhedral	< 0.8	10	moderately to chlorite	phenocrysts
Plagioclase	laths/ subhedral	< 0.2	30	strongly to saussurite/ carbonate/iron-stain	matrix
Clinopyroxene	subhedral; irregular	< 0.3 < 0.2	10 30	moderately to chlorite	phenocrysts; matrix
Magnetite/Ilmenite	subhedral	< 0.07	20		

Commentary: Specimen displays amygdules (~0.5 mm diameter) filled with chlorite, quartz ± zeolitic material.

PETROGRAPHIC ANALYSIS

Specimen Number: ________ **Location:** GLA 71-68-13

Texture: Clastic **Structure:** ________

Misc.: Coarse-medium-grained subgreywacke

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Chert	sub-angular;	~ 3.0	5		
	sub-angular/ sub-rounded	< 0.7	10		
Quartz	sub-angular;	~ 2.0	5		
	sub-angular	< 0.7	40		with secondary overgrowths
Chlorite/ Mica	irregular/ subhedral	variable	10		matrix
Plagioclase	sub-angular	< 0.7	10		
Microcline	sub-angular	< 0.7	10		
M.R.F.	sub-angular	< 0.7	< 10		
Magnetite/ Ilmenite	irregular	< 0.7	< 5	hematite/leucoxene	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-68-14

Texture: Granitoid **Structure:** ______

Misc.: Biotite granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	irregular	< 3.0	22		
Microcline	subhedral	< 6.0	37		microperthitic
Plagioclase	subhedral	< 3.0	29	strongly to sericite + hematite	
Biotite	subhedral	< 0.6	10	moderately to chlorite + opaques + hematite	
Magnetite/ Ilmenite	subhedral/ irregular	very fine	2	leucoxene + hematite	

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-68-15

Texture: Intergranular **Structure:** ______

Misc.: Olivine diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	subhedral	< 2.0	30	moderately to sericite/saussurite	AN_{55}
Clinopyroxene	irregular	< 1.0	20	moderately to strongly	mostly interstitial
Orthopyroxene	irregular/ subhedral	< 0.6	10	moderately	mafics alter to biotite/ chlorite/ $\pm$ amphibole
Olivine	ovoid/ irregular	< 1.0	20	moderately, some rather fresh	
Micrographic material	irregular	variable	10		interstitial
Apatite	needles	< 0.4	trace		
Magnetite/ Ilmenite	subhedral/ euhedral	variable	10		much assoc. with altered mafics

Commentary: Moderately-strongly altered (weathered, also?) rock.

PETROGRAPHIC ANALYSIS

Specimen Number: ______

Location: GLA 71-68-16

Texture: Granitoid

Structure: ______

Misc.: Biotite granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	irregular	< 3.0	35	strongly crushed	
Plagioclase	subhedral	< 6.0	24	strongly to sericite + hematite, etc.	oligoclase
Microcline	anhedral	< 3.0	26		
Biotite	subhedral/ anhedral	< 0.5	10		
Muscovite	subhedral/ anhedral	< 0.5	5	bleached biotite??	
Magnetite/ Ilmenite	irregular	variable	trace	leucoxene	

Commentary: Early plagioclase, later quartz + mica.

PETROGRAPHIC ANALYSIS

Specimen Number: ______ **Location:** GLA 71-68-18

Texture: Clastic **Structure:** ______

Misc.: Coarse-grained subgreywacke

Description of Minerals:

Name	Shape	Size	Modal %	Alteration	Remarks
Quartz	sub-rounded; sub-angular	$\angle$ 1.0; $\angle$ 0.03	40		with secondary overgrowths; broken-up fragments.
Chert	sub-rounded/ sub-angular	1.0-0.03	25		some as recrystallized siliceous matrix
M.R.F.	sub-rounded/ sub-angular	1.0-0.03	20		
Mica/ Chlorite	irregular	$\angle$ 0.03	10		matrix
Magnetite/ Ilmenite	irregular	very fine	5	hematite/leucoxene	

Commentary: Coarse fragments of quartz, chert, and M.R.F. in a matrix of fine quartz, chert, and mica/chlorite. This is a heterogeneous sedimentary assemblage which has undergone physical deformation subsequent to lithification.

PETROGRAPHIC ANALYSIS

Specimen Number: ________ Location: GLA 71-68-19

Texture: Granitoid Structure: ________

Misc.: Biotite granite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Quartz	anhedral	< 2.2	26		
Plagioclase	sub-hedral	< 1.4	38	strongly to sericite and hematite	zoned, AN $_{20\rightarrow 13}$
Microcline	irregular	< 2.3	25	moderately to sericite	some after, and on plagioclase; most in matrix with quartz, and in veins.
Biotite	irregular	variable	6	moderately to chlorite	
Hematite	irregular	very fine			pervasive, especially on altered feldspars
Magnetite/ Ilmenite	sub-anhedral	< 0.4	5	weakly to hematite + leucoxene	especially assoc. with a mafic(?)inclusion

Commentary: Rock contains an inclusion of a mafic(?)rock, of ~4.0 mm diameter now composed of chlorite/biotite + magnetite/ilmenite.

PETROGRAPHIC ANALYSIS

Specimen Number: ____________

Location: GLA 71-68-20

Texture: ____________

Structure: ____________

Misc.: Dolomite

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Dolomite	euhedral/ subhedral	< 1.0	100		interlocking mosaic of subhedral crystals; considerable euhedral material as well.

Commentary:

PETROGRAPHIC ANALYSIS

Specimen Number: ______

Location: GLA 71-68-21

Texture: Intergranular

Structure: ______

Misc.: Quartz diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	euhedral/ subhedral	< 6.0	30		AN_{55}
Micrographic material	irregular	variable	5		Interstitial
Clinopyroxene	subhedral	< 6.0	25	moderate	crystalline grains
Quartz	irregular	variable	5		
Biotite	subhedral	variable	10		
Orthopyroxene	subhedral/ euhedral	< 1.0	15	moderately to biotite/ hornblende/chlorite/opaques	crystalline grains
Apatite	acicular	< 0.6	< 2		
Magnetite/Ilmenite	subhedral/ euhedral	< 1.0	< 10		

Commentary: Slightly-moderately altered.

PETROGRAPHIC ANALYSIS

Specimen Number: ______________________ Location: GLA 71-68-23

Texture: Diabasic - subophitic Structure: ______________________

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 1.3	40	moderately sericitized (esp. larger grains)	AN_{54}; weakly zoned
Clinopyroxene	irregular; subhedral	4.0; < 1.0	30		intersertal, poikilitic (after plagioclase); with and after plagioclase
Biotite/chlorite/ ± amphibole	irregular	variable; < 1.0	10 10	after orthopyroxene and/or olivine(?)	some interstitial, perhaps after matrix?
Pyrite	subhedral/ euhedral	< 1.0	5		
Magnetite/ Ilmenite	subhedral/ euhedral	< 1.0	5		

Commentary: Moderately altered.

PETROGRAPHIC ANALYSIS

Specimen Number: ____________ **Location:** GLA 71-87

Texture: Diabasic - subophitic **Structure:** ____________

Misc.: Diabase

Description of Minerals:

Name	Shape	Size (mm)	Modal %	Alteration	Remarks
Plagioclase	laths	< 1.5	45	very slight	AN_{60}
Micrographic material	irregular	variable	trace		intergranular
Clinopyroxene	irregular	< 4.5	35	slight to biotite + talc/chlorite	intersertal; augite $\pm$ pigeonite(?) interstitial
Hornblende/biotite/ chlorite	irregular	< 2.5	5	after olivine(?)	
Olivine	irregular	variable	trace	strongly to talc and/or biotite + opaques	
Orthopyroxene	irregular	variable	5	some with subsequent clinopyroxene	
Magnetite/ ilmenite	euhedral subhedral	< 2.0	10		

Commentary: Very fresh rock.