

Chemical, Mineralogical and Textural Variations in Sediments from the Scotian Shelf

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Chemical, Mineralogical and Textural Variations in Sediments
from the Scotian Shelf*

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Introduction

In the analysis of the character of sediments most workers have concentrated on either the texture or the chemistry and mineralogy of the sediments while only a few have attempted to compare all three parameters (Leith and Mead, 1915; Clark, 1924; Grout, 1925). This study relates the chemical, mineralogical, and textural variations in a suite of sediments from the Scotian Shelf. A close relation between chemical composition and texture is shown by plotting the chemical data against the median diameter. Previous work (King, 1967a) indicates a genetic relationship between the glacial tills and younger sediments found on the shelf. This relationship is given further consideration in terms of the data of the present study.

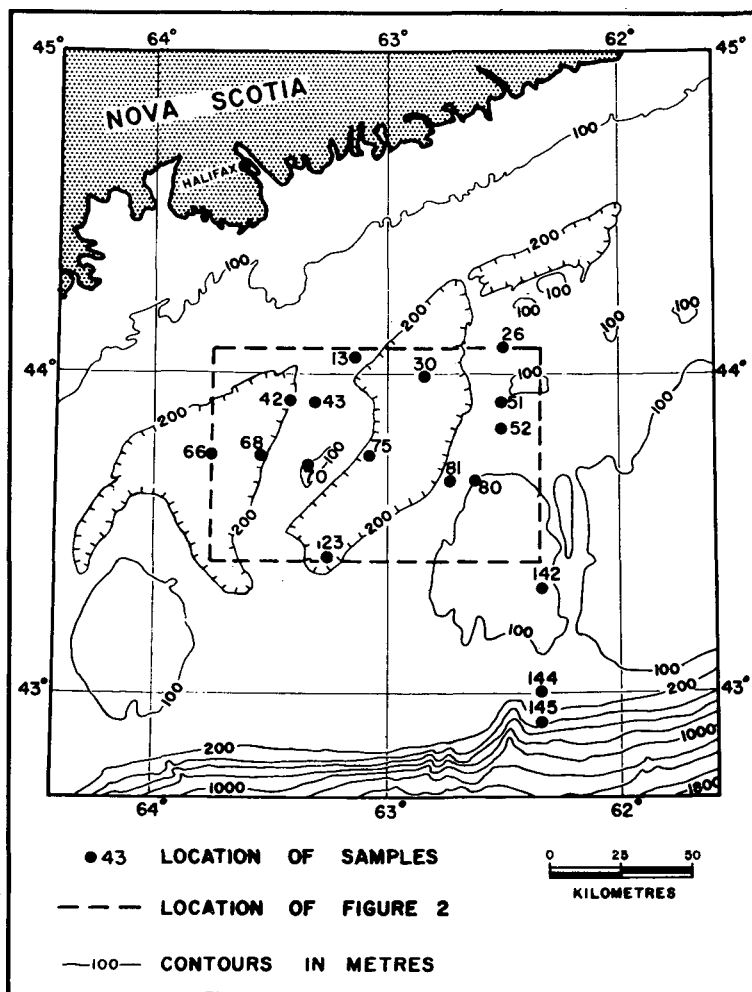


FIGURE 1 -

Index map of study area showing sample locations, as well as the area covered by the facies distribution map (Fig. 2).

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A suite of seventeen samples was selected from the larger number collected in the area and these represent the main sedimentary facies of the shelf. The sample locations are indicated in Figure 1. At least two samples were chosen from each facies, and in facies showing a large textural variation the samples were generally chosen to represent the average, as well as an extreme, variation. The coarse fractions of the samples, where present, were included in the analysis; however, the samples were originally selected in such a manner as to avoid large lithic fragments. The distribution of the sediments in the area was mapped by King (1967a) on the basis of a five-mile sampling grid together with the aid of data from echo-sounder records that defined facies boundaries (Fig. 2). The samples analyzed vary from glacial tills, through coarse sands from the sand and gravel facies on the banks, to silty clays from the bottom of the basins.

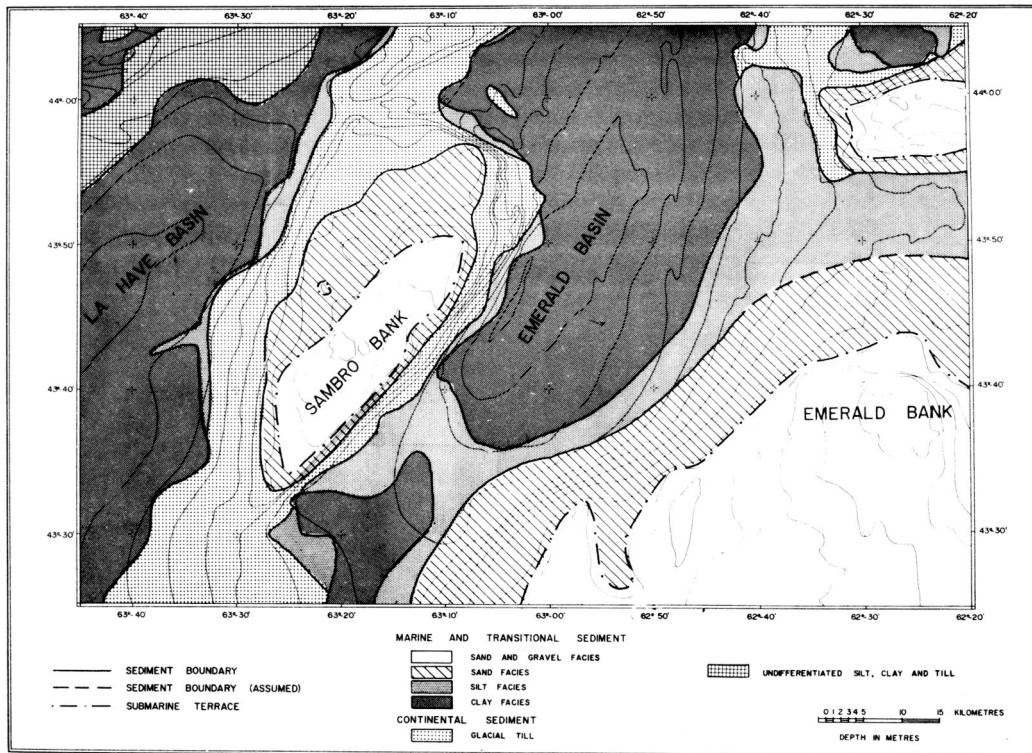


FIGURE 2 - Facies distribution map of study area (after King, 1967a).

All samples were chemically analyzed by the Geological Survey of Canada, Ottawa, and mineralogical studies were conducted at the Atlantic Oceanographic Laboratory, Bedford Institute, Dartmouth, Nova Scotia.

General Environmental History of the Area

It is important in this area of the continental shelf, to take into account the late Pleistocene environmental history of the area, because many of the sediments with which we are concerned are relict, originating in higher energy environments of shore and shallow-water conditions associated with lower eustatic levels that occurred during glaciation. King (1967a) mapped a well developed terrace throughout this part of the Scotian Shelf at a depth of 115-120 metres indicating that the tops of the banks were well above sea level when the glaciers receded from the shelf. An examination of the coarse fraction of the sediment on the isolated banks reveals a rock suite consisting of granite, quartzite, slate, and basalt similar to that of the glacial till, and also similar to the bedrock geology of much of western Nova Scotia. This indicates that the bank tops were also covered with glacial debris. Continuous seismic profiles (King, 1967b) also indicate a blanket of till over the banks underlying the sand, and sand and gravel facies. The ice cover on the shelf withdrew from at least this portion of the shelf during maximum

world-wide glaciation, thus enabling marine processes to produce the terrace. Beach sands associated with the feature were derived by the action of subaerial erosion, and from wave action adjacent to the shore. Finer materials were transported by marine currents to deeper portions of the basins.

With the melting of the ice and the resulting sea-level rise, subaerial erosion of the banks was replaced initially by vigorous wave erosion and then, as the depth of water increased over the banks, a gradual change was brought about to the present lower energy condition of current and storm-wave modification. Further winnowing of the sediments by currents and storm waves have added to the clay budget of the basin area.

Texture of the Sediments

The suite of sediments considered in this report vary in type from coarse sands containing gravel through finer sands and silts to silty clay. Three samples of glacial till are included to indicate the character of the probable material from which the other facies were derived. The distribution and textural character of each of the sedimentary facies is as follows:

Glacial Till:

Sediments classed as glacial till are found on the flanks of the bank areas in water depths ranging from 160 to 210 metres (Fig. 2). These are overlapped in deeper areas by silts and clays. The distribution of the till was mapped on the basis of interpretations of echograms and bottom samples.

The three samples of till examined show a considerable variation of median diameter and degree of sorting. Samples 13 and 43 show moderate sorting of 0.95 and 0.85 QD_{50} respectively which indicates modification of the surface by marine conditions after deposition. This may be explained by their location on a saddle at the northern end of Sambro Bank, which might have been an area of greater currents when sea level was 110-115 metres lower during the Pleistocene.

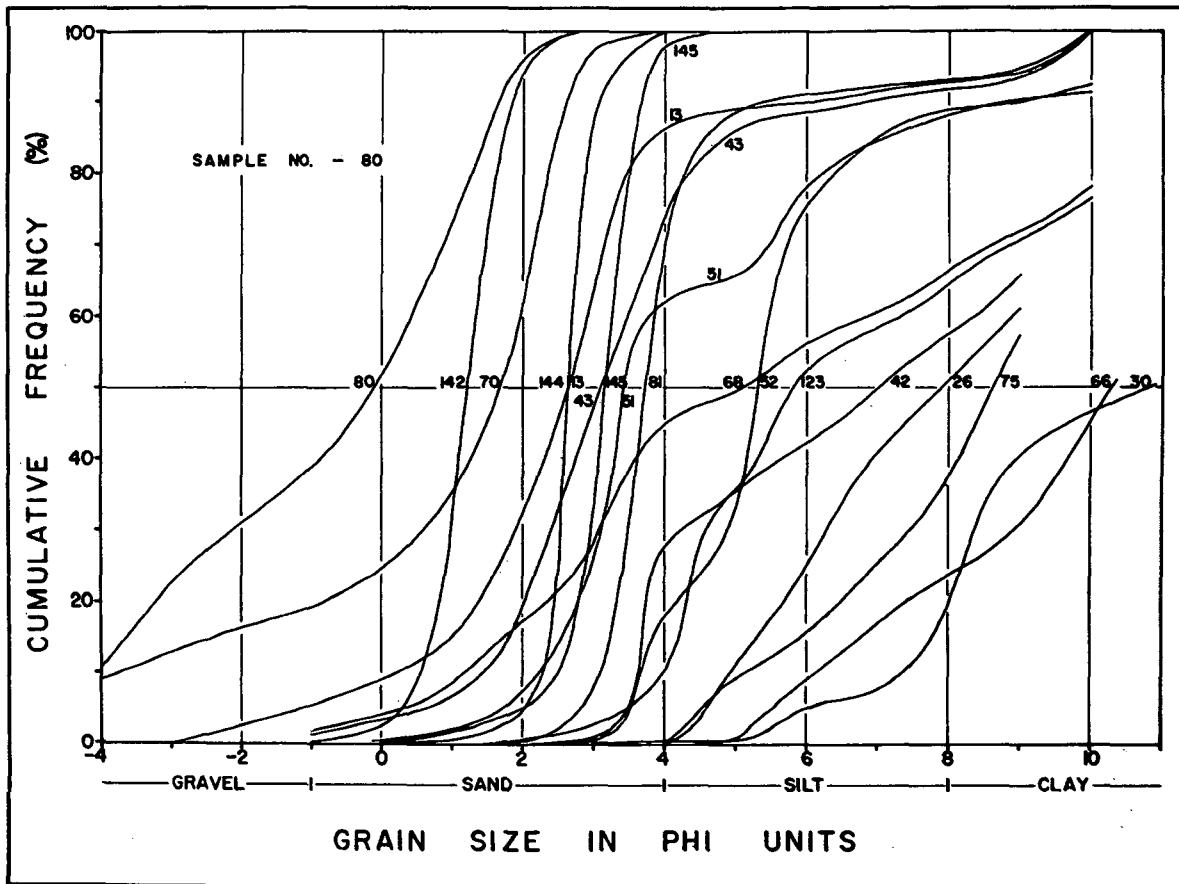


FIGURE 3 - Frequency distribution curves of sediment samples from the Scotian Shelf.

Sample 68 is distinct from samples 13 and 43. This sediment is poorly sorted ($QD\phi = 2.85$) with a tendency to bimodal size distribution in the silt fraction (Fig. 3). This is considered to be an unmodified till and bears more resemblance to the tills occurring on the mainland than either of the others. An examination of the echograms reveals that the surface is similar in all three cases; however, the depth of 210 metres for sample 68 would put this well below wave action at the 115-120 metre eustatic level. Also, its location on the western flank of Sambro Bank was probably not subjected to the same current action as the other two samples.

Sand and Gravel Facies:

The sediments belonging to this facies occur on the tops of the banks, sample 70 on Sambro Bank and samples 80 and 142 on Emerald Bank. They lie above the 110-115 metre Pleistocene terrace and, therefore, would have been subjected to subaerial weathering and strong wave action during lower eustatic levels. Within the area represented as sand and gravel, the distribution of individual sands and gravels is patch-like as shown by traverses using lateral acoustic equipment, therefore, these areas are grouped into one unit in Figure 2. These sediments represent the remains of glacial till from which essentially all of the silt and clay fractions have been winnowed by wave and current action.

Sand Facies:

Sediments of the sand facies separate the sand and gravel facies, which lie on the tops of the banks, from glacial till and silts lower down the slope. The sands have as their upper limit the submarine terrace. In this location sediments would be deposited in a shallow, high-energy environment immediately on and seaward of the Pleistocene beach. Such an environment explains the good sorting in samples 81, 144, and 145 from which the majority of the silt and clay fractions have been removed. The presence of many semi-rounded grains also reflects this higher energy environment. An exception to the other samples is sample 51 which lies on the flank of the small bank north of Emerald Bank. This sample has a bimodal size distribution curve.

Silt Facies:

The silts occur between the till and the clay facies around Sambro Bank and part of the small bank north of Emerald Bank, and around Emerald Bank down-slope from the sands. Two samples were examined which show marked differences, sample 123 from the southern end of Emerald Basin and more representative of this facies in the area, and sample 52 from the saddle north of Emerald Bank.

Sediment from sample 52 is well sorted ($QD\phi = 0.5$) compared with that of sample 123 ($QD\phi = 2.45$). These differences in sorting can be attributed to differences in the currents in the two areas. The area of sample 52 lies in a saddle between two banks through which tidal or other currents would be concentrated but in Emerald Basin, in the area of sample 123, current action would have been slight.

Clay Facies:

Sediments of this facies occur in the bottoms of the basin areas and overlap the silts occurring around the margin of the basin. The sorting is in general poor to moderate ($QD\phi = 1.25$ to 2.05).

The accuracy of median diameter of samples 30 and 66 is influenced by the bimodal character of these samples. From the chemical considerations, sample 66 shows features of a finer sediment than 30. Therefore, the form of the average chemical curves is slightly inaccurate at the finer end.

Chemical and Mineralogical Trends of the Sediments

In a suite of sediments such as those of this study, variations in grain size from pebbles to clay-sized particles present a problem in comparing the mineralogy throughout the suite.

Microscopic examination of sand-size grains in the samples has provided a general check of the methods described below. Comparisons on the basis of this type of examination can only be quantitative when the same size fraction from each of the samples is studied; however, these fractions are not necessarily representative of the whole parent sediment. Furthermore, in finer-grained samples and in tills where a high proportion of the sediment is fine grained, microscopic comparisons are difficult and inaccurate.

In searching the literature for data on other sediments for comparison it has been found that although a great number of sediments have been chemically analysed, few of these analyses are accompanied by the textural parameters of the sediment. It is evident that the chemical and mineralogical variations can be closely associated with textural variations of the sediments as indicated by Pettijohn (1957) and for comparative purposes data such as the median diameter are desirable. In this study the chemistry and mineralogy of the sediments has been related to the median diameter, thus, with the exception of the tills, the chemical analyses (Table 1) are arranged in order of decreasing median diameter.

Table 1 - Major element composition of sediments from the Scotian Shelf

	Glacial Tills			Sand and Gravel Facies			Sand Facies				Silt Facies		Clay Facies					
	13	43	68	80	142	70	144	145	51	81	52	123	Clayey Silt		Silty Clay			
													42	26	75	66	39	
SiO ₂	82.0	84.3	73.8	93.0	90.1	91.0	88.0	86.4	84.1	84.0	76.8	73.5	68.0	61.0	55.6	54.5	53.5	
TiO ₂	0.44	0.49	0.57	0.05	0.02	0.20	0.14	0.22	0.43	0.41	0.66	0.58	0.76	0.82	0.81	0.82	0.82	
Al ₂ O ₃	8.9	7.2	10.1	3.3	2.7	4.0	6.0	6.3	6.7	6.1	7.7	6.5	11.1	11.8	13.9	15.7	14.9	
Fe ₂ O ₃	2.3	2.1	4.1	0.7	0.8	1.0	1.8	1.8	1.3	1.5	2.5	3.2	4.2	5.6	6.1	6.7	6.4	
MnO	0.05	0.07	0.06	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.04	0.05	0.07	0.06	0.09	0.20	0.08	
MgO	1.4	0.5	3.1	2.2	2.3	2.9	0.5	1.0	1.2	1.6	2.4	1.2	3.1	2.4	4.1	3.9	2.6	
CaO	0.9	1.1	1.6	0.5	0.8	0.5	0.5	1.0	1.4	1.4	2.1	3.0	2.3	2.9	3.4	2.2	3.9	
Na ₂ O	1.0	1.0	1.2	0.4	0.4	0.7	0.6	1.1	0.9	1.1	1.4	1.4	1.4	1.4	1.3	1.4	1.2	
K ₂ O	1.4	1.5	2.0	0.4	0.5	1.1	1.3	1.6	1.4	1.7	1.7	2.1	2.3	2.6	3.0	3.3	3.1	
H ₂ O	1.9	1.4	4.1	0.7	0.4	0.5	0.7	1.0	1.8	1.8	1.7	4.2	5.7	7.0	9.1	9.0	9.0	
P ₂ O ₅	0.17	0.08	0.12	0.05	0.05	0.05	0.06	0.08	0.08	0.08	0.11	0.13	0.15	0.20	0.17	0.21	0.19	
CO ₂	0.5	0.6	1.0	0.1	0.2	0.2	0.1	0.5	1.0	0.8	1.3	2.2	1.3	1.8	2.2	1.2	2.4	
<u>Total</u>	101.0	100.	101.8	101.4	98.3	102.2	99.7	101.3	100.4	100.5	98.4	98.1	100.4	97.6	99.8	99.1	98.1	

Mineralogy:

As a means of determining the general mineralogy, a representative split of the samples was ground to minus 300 mesh and was mounted on a porous porcelain plate to produce a semi-oriented mount for X-ray diffraction study with copper radiation. The X-ray data not only indicate the principal minerals present in the samples, but also provide the opportunity for visual assessment of the variations in the major component minerals (Fig. 4). For example, the peak heights of the 4.26 Å quartz peaks follow similar trends to the calculated quartz content discussed later, and comparisons with other minerals show comparable trends, with some exceptions mentioned below.

To gain some understanding of what the chemical analysis of the sediments means in relation to the mineral components, ten minerals found to be most common in the samples were given simple empirical compositions and the chemical analyses were translated into percentages of these normative minerals in a manner similar to that used in the calculation of the "norm" of an igneous rock. Shales and sandstones have been similarly analyzed by Leith and Mead (1915), Clark (1924), Grout (1925), and Imbrie and Poldervaart (1959).

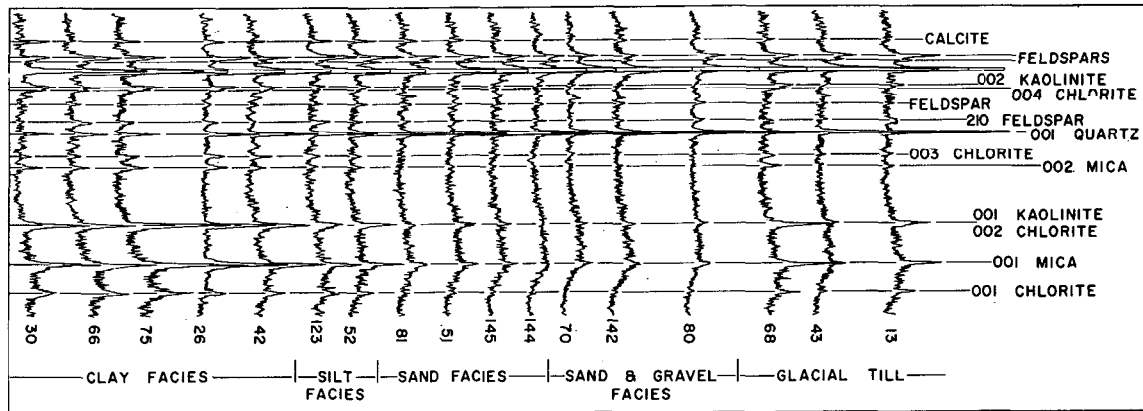


FIGURE 4 - X-ray diffractometer spectra for sediments from the Scotian Shelf.

In this study a somewhat simplified method of calculation to that of Imbrie and Poldervaart (1959) is employed, using as a basis those minerals that were observed in the sediment either by optical or X-ray techniques. The idealized compositions of the minerals considered are as follows:

Quartz	SiO_2
Mica	$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$
Anorthite	$\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$
Albite	$\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$
"Chlorite" (Mg)	$5\text{MgO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 10\text{H}_2\text{O}$
(Fe)	$5\text{FeO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 10\text{H}_2\text{O}$
Kaolinite	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$
Calcite	$\text{CaO} \cdot \text{CO}_2$
Apatite	$3\text{CaO} \cdot \text{P}_2\text{O}_5$ (No halogens were included in the analysis)
Ilmenite	$\text{FeO} \cdot \text{TiO}_2$

Although the sediment minerals vary in composition in many minor ways by cation replacement within their structure, such differences are assumed to be sufficiently small so that the above minerals can be used to represent the sediment for the comparative purposes of this study.

For simplicity, all magnesium and all iron in excess of that required for ilmenite is allocated to two divisions of a mineral named for convenience "chlorite". Little rutile was noted in heavy mineral preparations so TiO_2 is allocated to ilmenite which is abundant. Potassium is allocated to mica which is present in fact as muscovite in coarser fractions and as illite in finer sediments. These two minerals are given similar compositions. The ferromagnesium minerals present, with the exception of minor pyroxenes and amphiboles in the heavy mineral fractions of the sands, consists of chlorite and glauconite.

The method of calculating the normative mineral content is relatively simple. The weight per cents of the oxides shown in the analyses are converted to molecular proportions. In the first instance P_2O_5 , CO_2 and TiO_2 are allocated to apatite, calcite and ilmenite with the appropriate cations. The ratio of $\text{CaO}:\text{CO}_2$ in all the analyses is that of calcite (1.27), suggesting that little if any magnesium is present in the carbonate. Most of the carbonate, especially in the fine sands and silts, is in the form of foraminiferal tests. All the MgO is therefore allocated to "chlorite". Excess MgO in two sand samples, 70 and 142, was calculated as enstatite. This situation arises in these two sediments presumably because of the large amount of rock fragments containing such minerals as pyroxenes, amphiboles and biotite. Excess Al_2O_3 , after the calculation of the plagioclase, mica, and chlorite, is allocated to kaolinite which is present in the sediments. Calcium remaining after the calculation of calcite and apatite is allocated to anorthite. Soda is allocated to albite. Plagioclase is present both as grains in the sand fraction and in the rock fragments of the coarser sediments so that inclusion of this mineral as a constituent is justified. Excess SiO_2 is allocated to quartz. The calculated results are shown in Table 2.

Table 2 - Normative mineral content of sediments from the Scotian Shelf.

	Glacial Till			Sand and Gravel Facies			Sand Facies				Silt Facies		Clay Facies				
	13	43	68	80	142	70	144	145	51	81	52	123	Clayey Silt		Silty Clay		
													42	26	75	66	30
Quartz	64.0	68.8	51.1	83.0	83.5	77.8	76.1	70.6	69.5	69.5	56.3	58.7	45.6	37.3	29.3	24.9	26.9
Plagioclase	9.3	9.3	11.2	5.8	5.7	6.7	4.2	10.4	7.7	10.2	12.7	12.5	14.5	15.2	13.7	15.1	13.8
Mica	7.0	7.5	9.7	1.9	2.4	5.6	6.5	7.6	7.0	8.3	8.0	10.7	11.5	13.6	15.6	17.0	16.2
Kaolinite	8.9	6.2	6.7	1.6	--	--	7.5	3.1	6.9	2.3	3.1	1.0	7.1	10.0	10.7	13.7	13.7
"Chlorite"	8.6	5.6	17.6	7.7	4.0	7.2	4.9	6.4	5.6	6.8	15.3	10.5	16.5	18.0	23.7	24.7	21.8
"Enstatite"	--	--	--	--	3.9	2.2	--	--	--	--	--	--	--	--	--	--	--
Calcite	1.1	1.4	2.3	0.2	0.5	0.5	0.2	1.1	2.2	1.8	3.0	5.1	3.0	4.1	5.2	2.7	5.7
Apatite	0.3	0.3	0.3	--	--	--	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ilmenite	0.8	0.9	1.1	0.05	0.05	0.5	0.3	0.5	0.8	0.8	1.4	1.2	1.5	1.5	1.5	1.5	1.6

SiO₂ - quartz content of the sediments:

The variations of SiO₂ percentage plotted against median diameter are shown in Figure 5. The plot shows a systematic variation with a very close relation to the grain size and little scatter from the average curve. The suite varies from 93 per cent silica in the coarse material to 53 per cent in the fines.

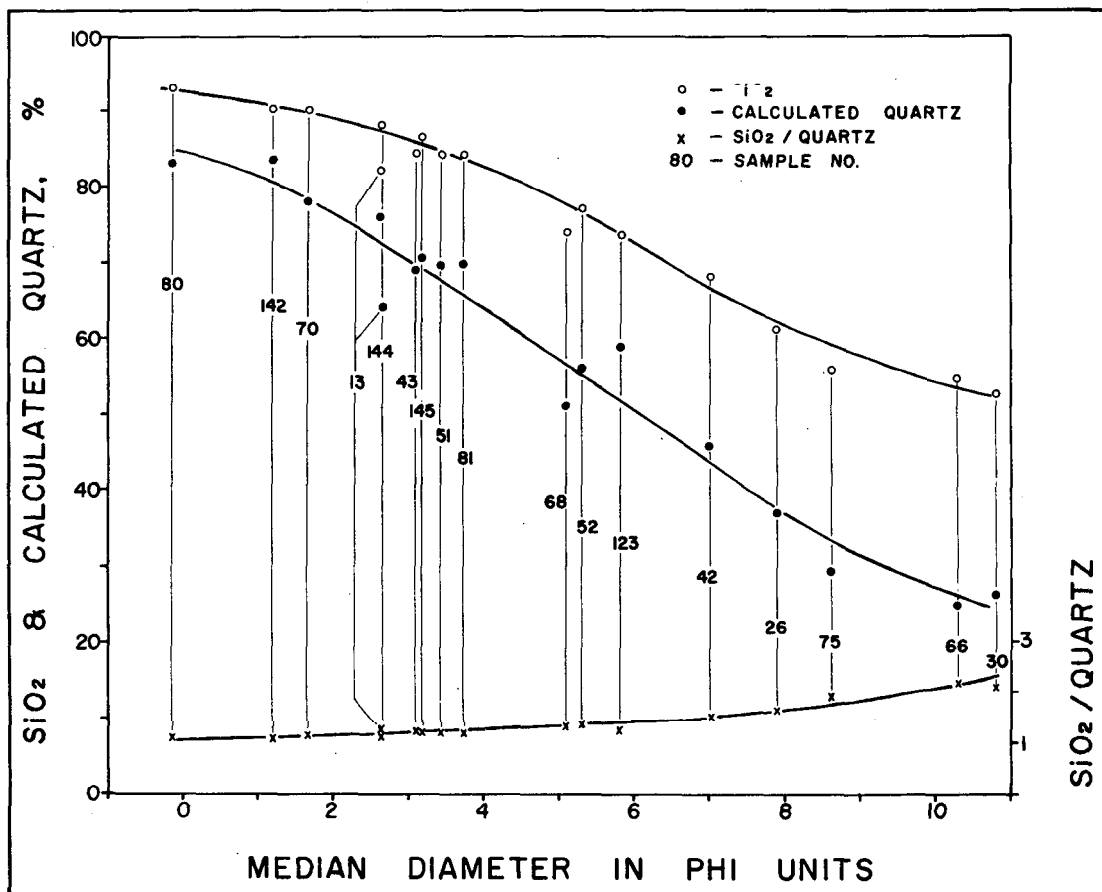


FIGURE 5 - Variation of SiO₂ quartz, and SiO₂/quartz with median diameter for sediment samples from the Scotian Shelf.

The glacial tills, from which the other samples were originally derived, vary in their silica content. Samples 13 and 43 show a higher silica content than sample 68 because of modification following deposition. They also lie slightly below the average curve possibly because of a higher percentage of unaltered silicates. Sample 52, a silt, which is located in the saddle north of Emerald Bank, shows some affinity with the tills in both its silica content and in relation to other oxides.

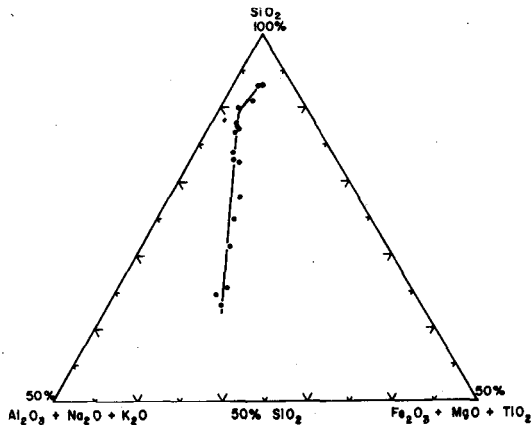


FIGURE 6 -
Triangular diagram for the major elements of the sediment samples from the Scotian Shelf.

The plot of silica to median size suggests that quartz is concentrated in the coarser sediments and the fines principally represent clays. This is emphasized by the triangular plot of SiO_2 ; $Al_2O_3 + Na_2O + K_2O$; $Fe_2O_3 + MgO + TiO_2$ (Fig. 6). The curve on this diagram represents the trend of the compositions and shows that although the compositions of the suite vary over a wide range they do so in a systematic manner. The deviation at the high-silica end is caused by an anomalous increase in MgO in the sand and gravel facies. The X-ray diffraction spectra of the sediments indicate a reduction in quartz content with reduction in median diameter; furthermore, this trend fits with the calculated quartz content of the sediments (Fig. 5).

A comparison of the silica and calculated quartz curves (Fig. 5) shows a divergence with decrease in particle size, indicating in addition a relative decrease in quartz with respect to the combined silica. This is also evident from the SiO_2 /quartz ratio which increases with decreasing particle size.

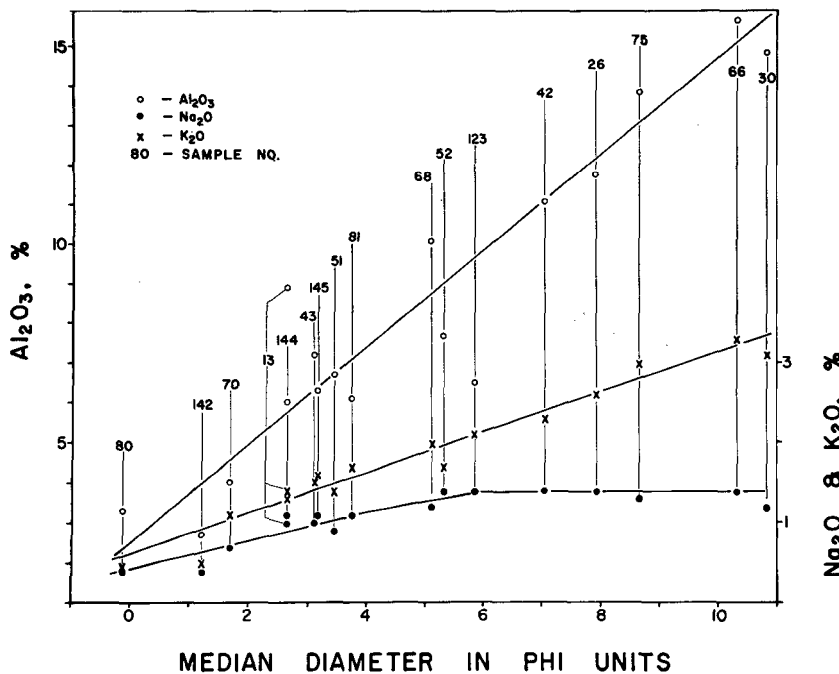


FIGURE 7-
Variation of Al_2O_3 , K_2O , and Na_2O with median diameter for sediment samples from the Scotian Shelf.

Variations in Al₂O₃ and K₂O with median diameter:

As might be expected from the discussion of the silica content, both the Al₂O₃ and K₂O contents of the sediments (Fig. 7) increase with a decrease in median diameter from 2.7 per cent to 15.7 per cent for Al₂O₃ and 0.4 per cent to 3.6 per cent for K₂O.

Because Al₂O₃ is associated with at least six common minerals in the suite, all of which are present in varying amounts and contain Al₂O₃ in varying proportions, it is difficult to gain a detailed understanding of the distribution of this constituent and its influence on the other oxides. The SiO₂/Al₂O₃ ratio (Fig. 8) decreases with decrease in particle size owing to the enrichment of clay, mica, chlorite and plagioclase, and depletion of quartz (Fig. 9 and Table 2); however, the rate of decrease is not constant.

The plot of the Al₂O₃/K₂O ratio (Fig. 8) is essentially constant for the suite of samples. It averages around 4.7 and the limits of variation become more confined towards the finer sediments. The relatively constant ratio indicates that there is little difference in the potassium-bearing minerals in the suite. The constancy in the mineralogy of the potassium-bearing minerals throughout the suite is also borne out by the X-ray diffraction patterns (Fig. 4). In addition, the sharp peaks developed by the micaceous minerals, considered as principally illite or muscovite, suggest that they are detrital rather than diagenetic. Nevertheless, some clay is produced by the breakdown of feldspars as is evident from microscopic examination.

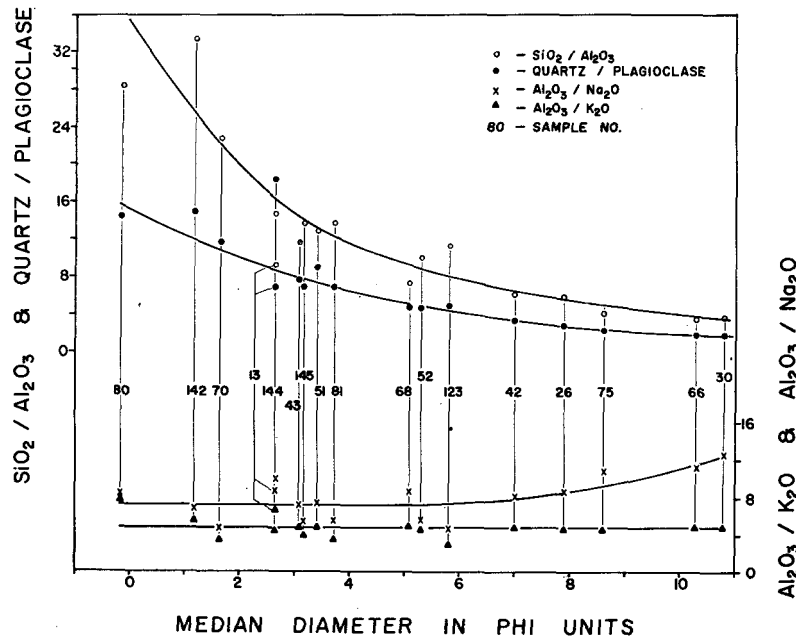


FIGURE 8 - Variation of SiO₂/Al₂O₃; Al₂O₃/K₂O; Al₂O₃/Na₂O, and quartz/feldspar ratios with median diameter for sediment samples from the Scotian Shelf.

Variations in Na₂O and calculated feldspar content with median diameter:

While K₂O shows a constant increase with decrease in particle size, Na₂O (Fig. 7) increases through the sand and gravel, as well as the sand facies, and becomes constant in the silt and clay facies. Over the range of increasing Na₂O the Al₂O₃/Na₂O ratio (Fig. 8) is constant at 7.1, but in the clay facies the ratio increases. This loss in Na₂O could represent slight weathering of feldspar in the finer-grained samples. The plagioclase (Fig. 9) increases at a declining rate with respect to particle size which could suggest a relative loss in the feldspar content. On the other hand, the quartz/feldspar ratio (Fig. 8) plots as a smooth curve increasing at a decreasing rate with respect to particle size, and shows nothing conclusive regarding a possible breakdown of feldspars in the finer particle range. Sample 144 is the only sample which varies appreciably from the average curve for the quartz/feldspar ratio possibly indicating a relative increase in the degree of maturity of this sample. This conclusion is substantiated by the fact that this sediment was laid down in the zone of wave action at the outer edge of the banks.

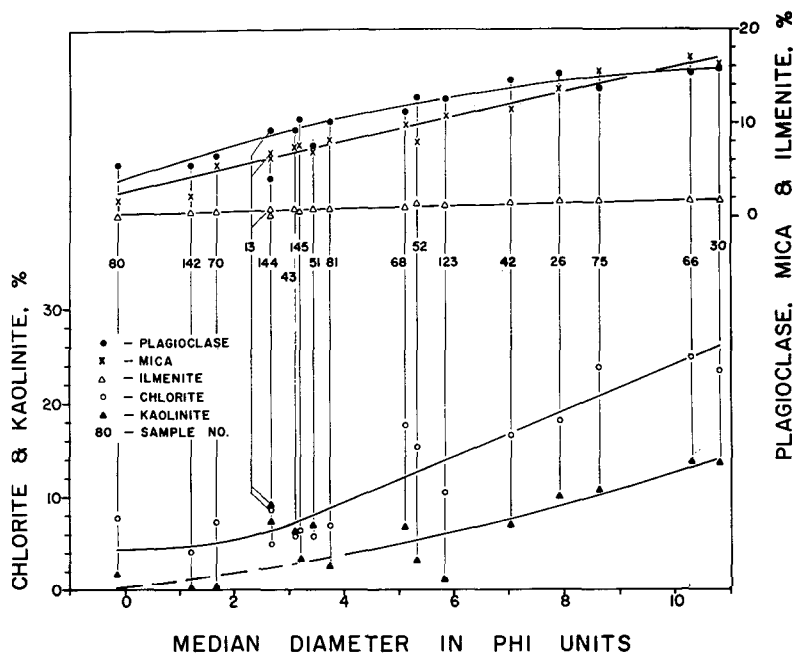


FIGURE 9 - Variation of ilmenite, kaolinite, plagioclase, mica, and chlorite with median diameter for sediment samples from the Scotian Shelf.

Trends in CaO, MgO, CO₂, TiO₂, and Fe₂O₃:

The variation of CaO and CO₂ with median diameter (Fig. 10) indicates a progressive increase in both constituents with decreasing size. Except for the four coarsest samples, the CaO/CO₂ ratio is constant, and a 1.6 average for the constant range is only slightly larger than

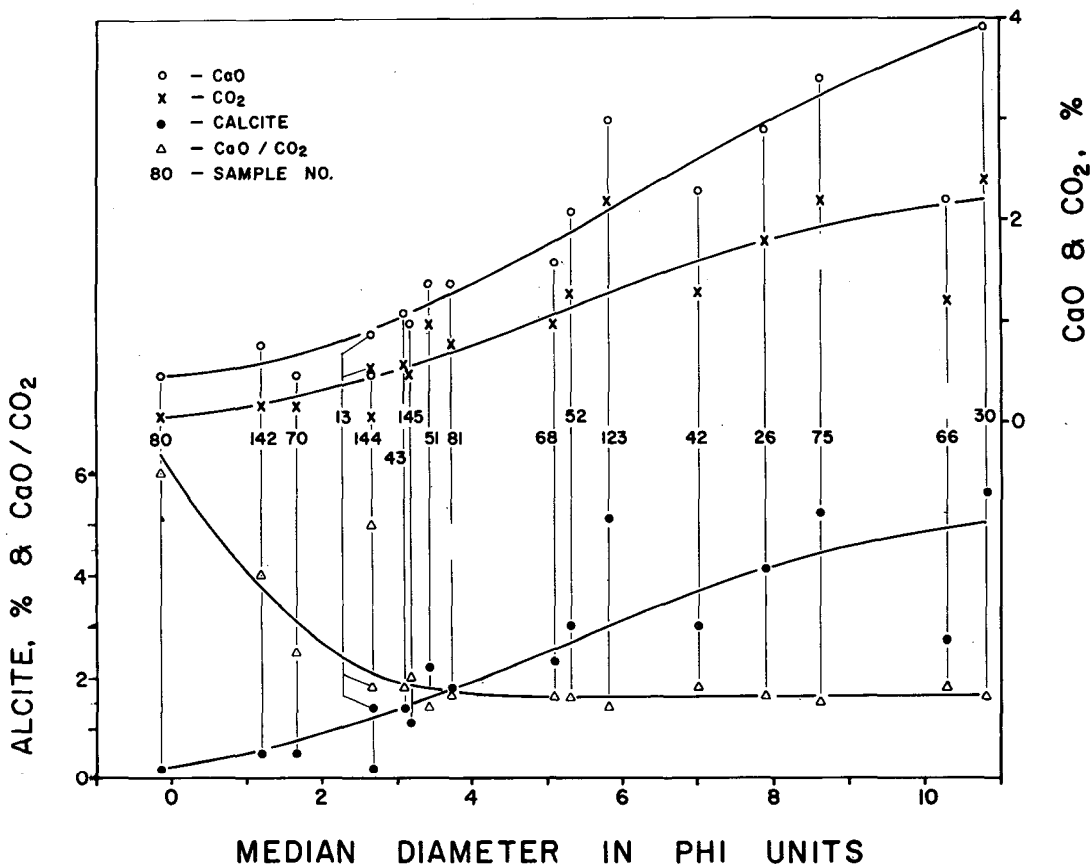


FIGURE 10 - Variation of CO₂, CaO, calcite, and CaO/CO₂ with median diameter for sediment samples from the Scotian Shelf.

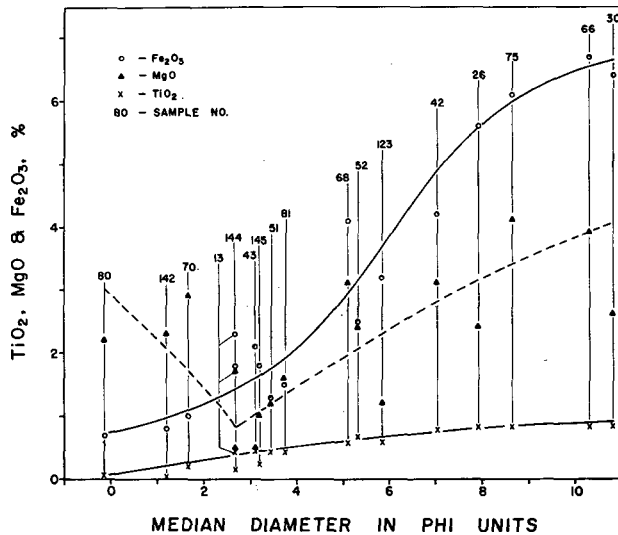


FIGURE 11 -
Variation of MgO, Fe₂O₃, and TiO₂ with median diameter for sediment samples from the Scotian Shelf.

the 1.27 ratio for calcium carbonate. The 1.6 ratio suggests that CaO is slightly in excess, the excess being combined in anorthite. The high ratio of the coarse samples is more difficult to explain but, it is assumed to be a result of a higher proportion of calcium-rich plagioclase in these samples.

Both the 1.6 ratio and the X-ray diffraction patterns suggest that most of the calcium is present as calcium carbonate, and microscopic evidence indicates that it is in the form of foraminiferal tests. It is doubtful whether the carbonate present contains much magnesium, particularly as magnesium (Fig. 11) is much more erratic showing higher values at the fine and coarse end of the scale. If the calcium carbonate is present principally as foraminiferal tests in the finer sediments and some shells other than forams in the sands, the amount of magnesium would be small. Analyses of foraminiferal tests given by Sverdrup (1942) shows a maximum MgO content of 0.16 per cent.

Table 3 - Composition of foraminiferal tests

	Maximum	Minimum	Average
SiO ₂	0.72	0.08	0.47
Al ₂ O ₃	1.35	0.22	0.78
Fe ₂ O + Fe ₂ O ₃	1.68	0.51	1.08
MgO	0.16	0.10	0.13
CaO	54.52	53.12	53.82
CO ₂	43.10	41.69	42.37
Loss on ignition	0.87	0.78	0.72

It may, therefore, be assumed that the magnesium is tied up with the iron in ferromagnesium minerals such as chlorite.

The TiO₂ is present as ilmenite which is one of the predominant minerals in the heavy mineral suite. Ilmenite content (Fig. 9) increases gradually with decreasing particle size until the silt range is reached at which point it becomes constant.

The Fe₂O₃ content (Fig. 11) increases quite sharply with decrease in particle size, and the Al₂O₃/Fe₂O₃ ratio decreases from values of 3-5 in the coarse-grained sediments to values of 2-2.5 in the clay. This indicates an enrichment of iron in the finer fractions, and might result from the surface adsorption of iron in the present environment.

Conclusions

A close relationship exists between the chemistry and the texture of a suite of samples from the Scotian Shelf, which is represented mainly by quartz. The other constituents are fairly constant when silica is excluded from the analyses. A similar degree of maturity between the various facies of the suite is illustrated by the constant Al_2O_3/K_2O and Al_2O_3/Na_2O ratios and it is significant that the tills, that were derived from the mainland rocks of Nova Scotia, are not anomalous. The similarity of the mineralogy of the samples with that of the glacial tills of the area indicates that the tills are probably the source material for the other sediments. Winnowing has mechanically fractionated the tills, and because of the physical and chemical character of the minerals has produced chemically different sediments. This is principally due to the fact that quartz in the tills is mostly sand size and consequently is concentrated in the sandy facies. The clay minerals such as kaolinite, mica-illite, and chlorite are concentrated in the silt and clay facies.

There is no evidence for any major change in the mineralogy or chemistry resulting from diagenetic processes. Minor exceptions are the formation of glauconite and the adsorption of iron on particle surfaces. Much of the glauconite might be recycled material from the underlying Coastal Plain sediments. The suite is also modified by a minor bioclastic contribution.

A quantitative comparison of the mineralogy of a suite of samples of wide textural variation presents a major analytical problem. The problem has been circumvented in this study by the use of the normative mineral composition. Provided that this type of calculation is linked with optical and X-ray data on the qualitative mineralogy of the sediments, this quantitative approach to a suite of related sediments can provide a useful method of comparison.

Application of the techniques used in this study to trace-element distribution studies in sediments would improve the significance of such studies. The variation of chemistry with texture shown in this study, the concentration of clay minerals in the finer sediments, and the known association of trace elements with the clay fraction of sediments, suggest that conclusions based simply on quantitative variations of elements without a quantitative consideration of particle size may not be significant.

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