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TRACE-ELEMENT GEOCHEMISTRY OF DETRITAL SEDIMENTS FROM NEWFOUNDLAND INLETS AND THE ADJACENT CONTINENTAL MARGIN: APPLICATION TO PROVENANCE STUDIES, MINERAL EXPLORATION, AND QUATERNARY MARINE STRATIGRAPHY

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ABSTRACT

Textural, mineralogical, and total chemical analyses of 109 marine sands and muds from four Newfoundland inlets, the adjacent continental shelf, and the Nova Scotia outer continental margin indicate that the chemical composition of detrital sediments is regulated by their texture, depositional environment, proportions of silicate and non-silicate components present, and source. Trace-element chemistry is a first-order reflection of the composition of parent lithologies because the major concentrations of elements occur in mineral structural sites. As well, the chemistry reflects the proportions of lithologies contributing to the sediment. For these reasons, trace-element chemistry can be used for provenance studies, mineral exploration, and Quaternary marine stratigraphy provided the effect of sediment texture on chemistry is accounted for.

Examples of each application are presented on the basis of plots of ppm trace element/% clay, vs. % clay for six trace elements. Cu in Halls Bay and Cu, Pb, and Cr in Conception Bay are enriched in sediments that are locally derived from nearby onshore mineralized bedrock. Surficial sediments on the Newfoundland shelf can be divided into a Cu-rich inner facies and a Cu-poor outer facies, each of which is derived from a different underlying bedrock source. For surface sediments in four Newfoundland inlets and on the inner shelf, differentiation by trace element/clay vs. clay plots suggests that the inlet sediments are of local origin. On the Nova Scotia outer margin, late-Wisconsin slope and rise facies in widely-spaced piston cores are correlated by trace-element chemistry and differentiated from Holocene facies, suggesting a different provenance for the two.

None of the areas studied has been affected by industrialization, so the natural concentration levels of trace elements and other components in the sediments can be utilized either for comparative studies in similar industrialized coastal environments, or in these same areas in the event of future industrialization/urbanization.

RÉSUMÉ

Des analyses texturale, minéralogique et chimique totale de 109 sables marins et boues provenant de quatre petits bras de mer terre-neuviens, du plateau continental adjacent et de la marge continentale extérieure de la Nouvelle-Ecosse indiquent que la composition chimique de sédiments détritiques est règlementée par leur texture, l'environnement des dépôts, les proportions des composants de silice et de non-silice présents et de leur source. La chimie d'élément de trace est une indication de premier ordre, dans la composition de lithologies primaires, du fait que les plus grandes concentrations d'éléments apparaissent dans des emplacements minéraux et structuraux. La chimie démontre, aussi, les proportions de lithologies contribuant au dépôt. C'est pour ces raisons que la chimie d'élément de trace peut être utilisée pour des études de provenance, d'exploration minérale et de stratigraphie marine du Quaternaire dans la mesure où l'effet de la texture du dépôt sur la chimie est prise en considération.

Des exemples de chaque application de six éléments de trace sont présentés sous forme de tracés en ppm/% argile vs. % argile. Le Cu de Halls Bay et le Cu, le Pb et le Cr de Conception Bay se sont enrichis des sédiments provenant d'un fond rocheux minéralisé situé tout près, sur la côte. Les sédiments superficiels du plateau de Terre-Neuve peuvent être divisés en un faciès intérieur riche en Cu et un faciès extérieur pauvre en Cu, chacun provenant d'un différent fond rocheux sous-jacent. La différenciation, par élément de trace/argile vs. des tracés d'argile, des sédiments superficiels de quatre bras de mer terre-neuviens et d'un plateau intérieur suggère que les dépôts des bras de mer sont d'origine locale. Sur la marge extérieure de la Nouvelle-Ecosse, les faciès montant et descendant de l'ancien Wisconsin dans des carottes en forme de piston très espacées sont reliées par la chimie d'élement de trace et sont différentes du faciès Holocène, en suggérant une origine différente pour les deux.

Aucune des régions étudiées n'a été affectée par l'industrialisation; ainsi les niveaux naturels de concentrations d'éléments de trace et les autres composants dans les sédiments peuvent être utilisés soit pour des études comparatives en de semblables milieux côtiers industrialisés, ou soit dans ces mêmes régions dans le cas d'une éventuelle industrialisation/urbanisation.

(Traduit par le journal)

INTRODUCTION

Although post-depositional diagenetic reactions alter the composition of marine sediments (Mackenzie & Garrels 1965; Sharma 1970; Bonatti *et al.* 1971; Turekian 1971; Buckley 1972; Hatcher & Segar 1974), the specific source input of elements exerts a first-order controlling influence on their final chemical composition. This is because the majority of trace, as well as major, element concentrations in detrital sediments occur in mineral structural sites rather than adsorbed onto minerals, organic matter and oxide coatings (Hirst 1962a,b). The purpose of this investigation is to demonstrate that, because trace-element composition of marine sediments is a primary reflection of the composition of parent lithologies, trace-element chemistry can be utilized for provenance studies, mineral exploration, and correlation and differentiation of marine sedimentary facies. Geochemical studies of marine-sediment provenance have been done by Jones (1972) using Fe, Mn, Ti, and P, by Bostrom *et al.* (1973) using relationships between Fe, Ti, Al and Mn, and by Wright (1974a, b) using major and some trace elements. Hirst (1962b) discusses the use of trace-element chemistry for stratigraphic correlation.

We have obtained 95 surficial sediment samples from four Newfoundland inlets and the Newfoundland continental shelf and 14 samples from two widely-spaced piston cores from the Nova Scotia continental slope and rise (Fig. 1). Shelf samples were collected in water depths ranging from about 80 to 350 metres. Only shallow-water samples were collected in Bonavista Bay; water depths in the other inlets

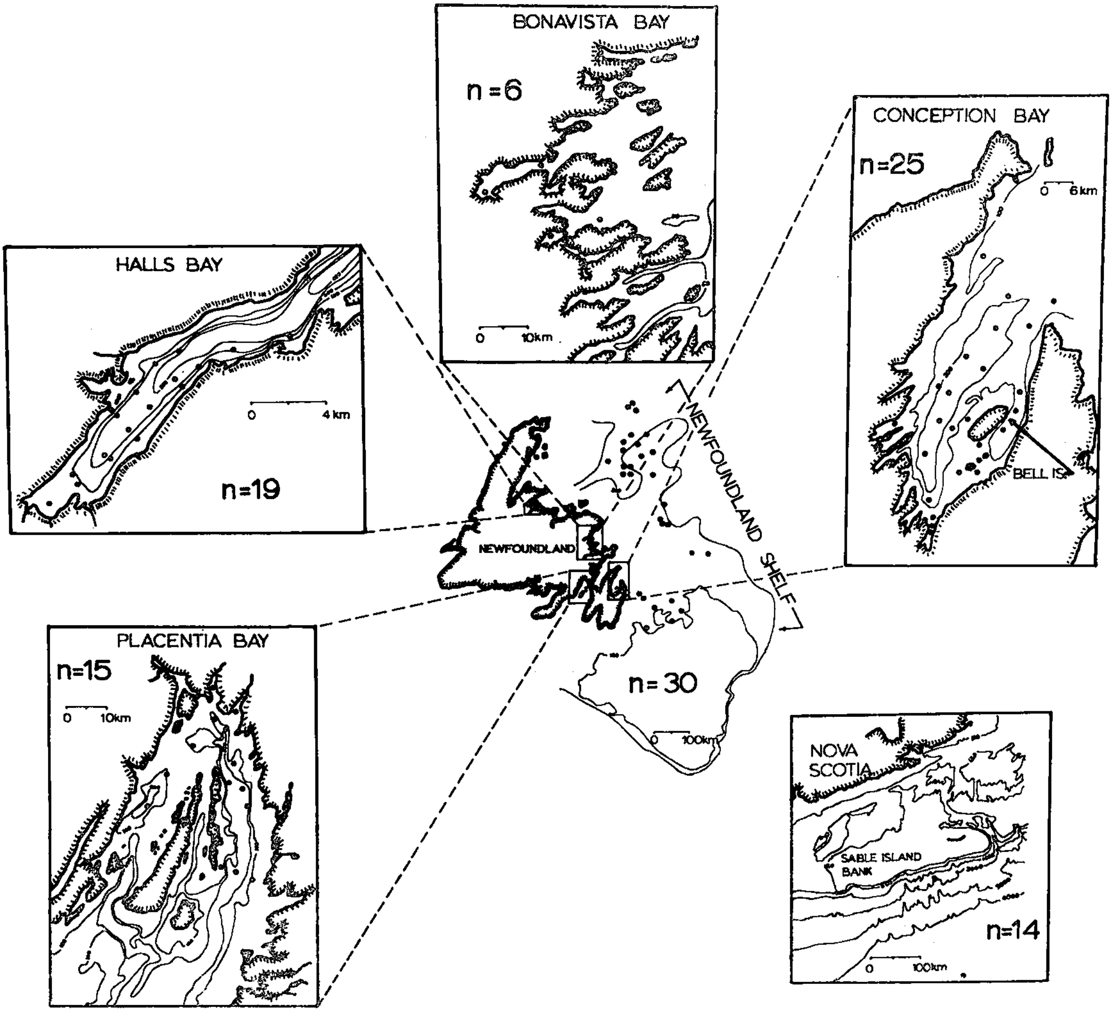


FIG. 1. Sample locations.

ranged from about 40 to 300 metres. More detailed discussions on the sedimentology and/or geochemistry of these sediments is presented by Slatt (1974a,b) for Conception Bay, Slatt (1975) for Halls Bay, Willey (in prep.) and Stehman (in prep.) for Placentia Bay, Slatt (1974c) for the Newfoundland continental shelf, and Piper (1975) for the Nova Scotia outer margin.

None of the areas has been heavily affected by industrialization, although a part of the Placentia Bay coast has become industrialized since sample collection. Therefore, a secondary objective is to establish natural concentration levels of chemical constituents in the sediments which can be utilized either for comparative studies in similar industrialized coastal environments or in these same areas in the event of future industrialization/urbanization.

Although trace-element chemistry is emphasized in this paper, we have completed textural, mineralogical, and total chemical analyses of the sediments. In subsequent sections we first use these data to explain the general factors that regulate marine-sediment chemistry. We then

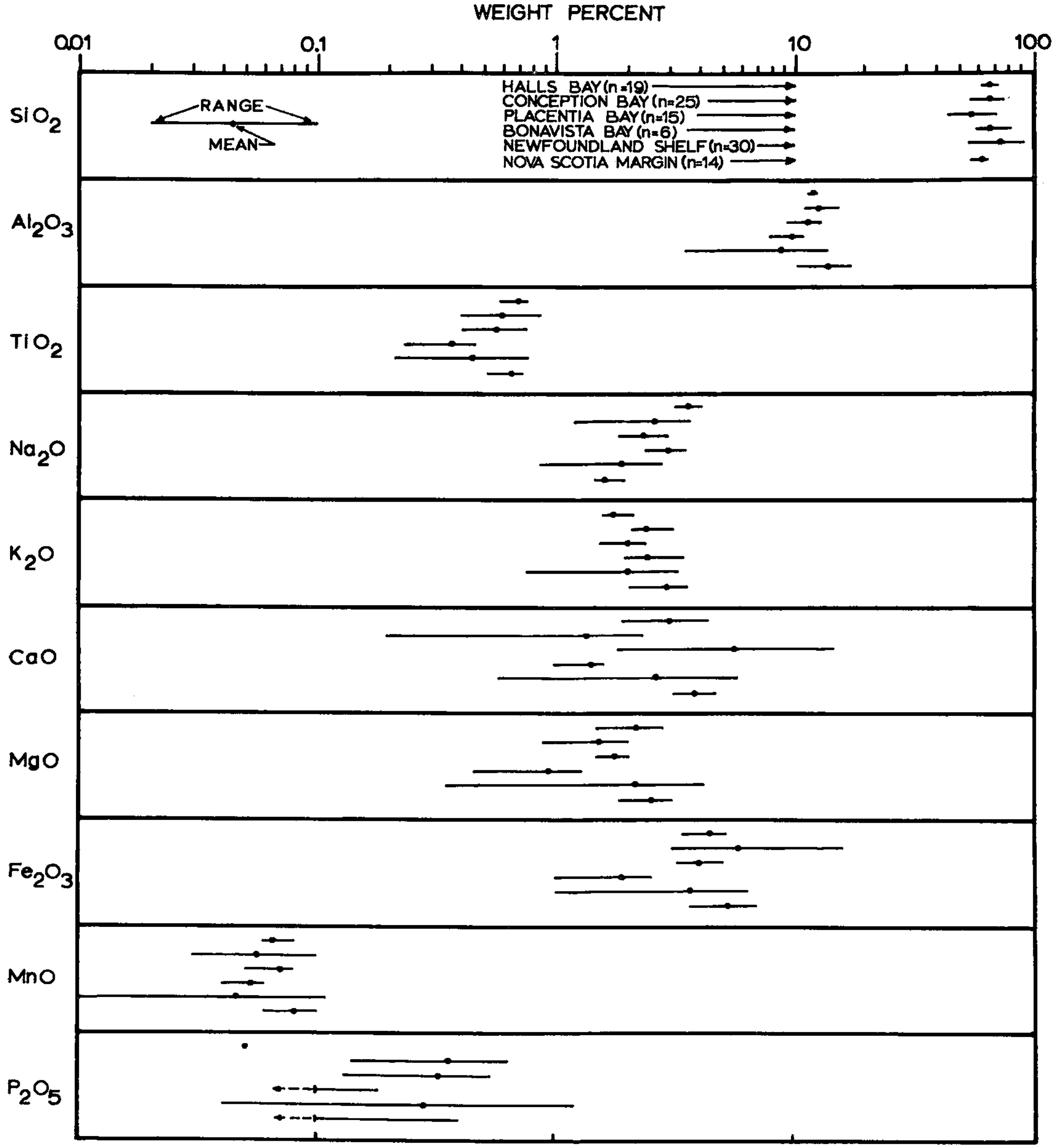


FIG. 2. Concentrations of major and minor elements in sediments.

demonstrate the influence of source lithologies on sediment chemistry by presenting examples of anomalous concentrations of trace elements in sediments from Halls Bay and Conception Bay which can be traced to nearby onshore bedrock mineralization. These examples demonstrate the applicability of marine-sediment geochemistry to mineral exploration. Next, we differentiate surficial sediments and their provenance in the four inlets and on the Newfoundland shelf on the basis of trace-element chemistry. Finally, we provide an example of correlation and differentiation of late-Quaternary sedimentary facies in the deeper marine cores by trace-element chemistry.

METHODS AND RESULTS

The sediments are varying admixtures of sand, silt, and clay. Analytical methods are discussed by Slatt (1974b, 1975). Sample pre-treatment consists of removing interstitial salt with de-ionized water, oven-drying the sample, then grinding it to a fine powder. Chemical analyses are performed by atomic absorption spectrophotometry after total digestion (HF for major and minor elements and HF-aqua regia for trace elements). Organic-C, S, and $CaCO_3$ contents are also determined.

Mineralogical analysis of the powdered samples is performed by *x*-ray diffraction using random powder mounts. Proportions of sand (2mm to 0.063mm), silt (0.063mm to 0.004mm), and clay (finer than 0.004mm) are determined on separate untreated splits of samples by standard methods (Folk 1968). Clay mineralogy of the <0.002mm fraction of these splits is performed using Biscaye's (1965) method.

Results of chemical and textural analyses are summarized in Figures 2 and 3. There is considerable variability both within each suite of samples and among the suites from different

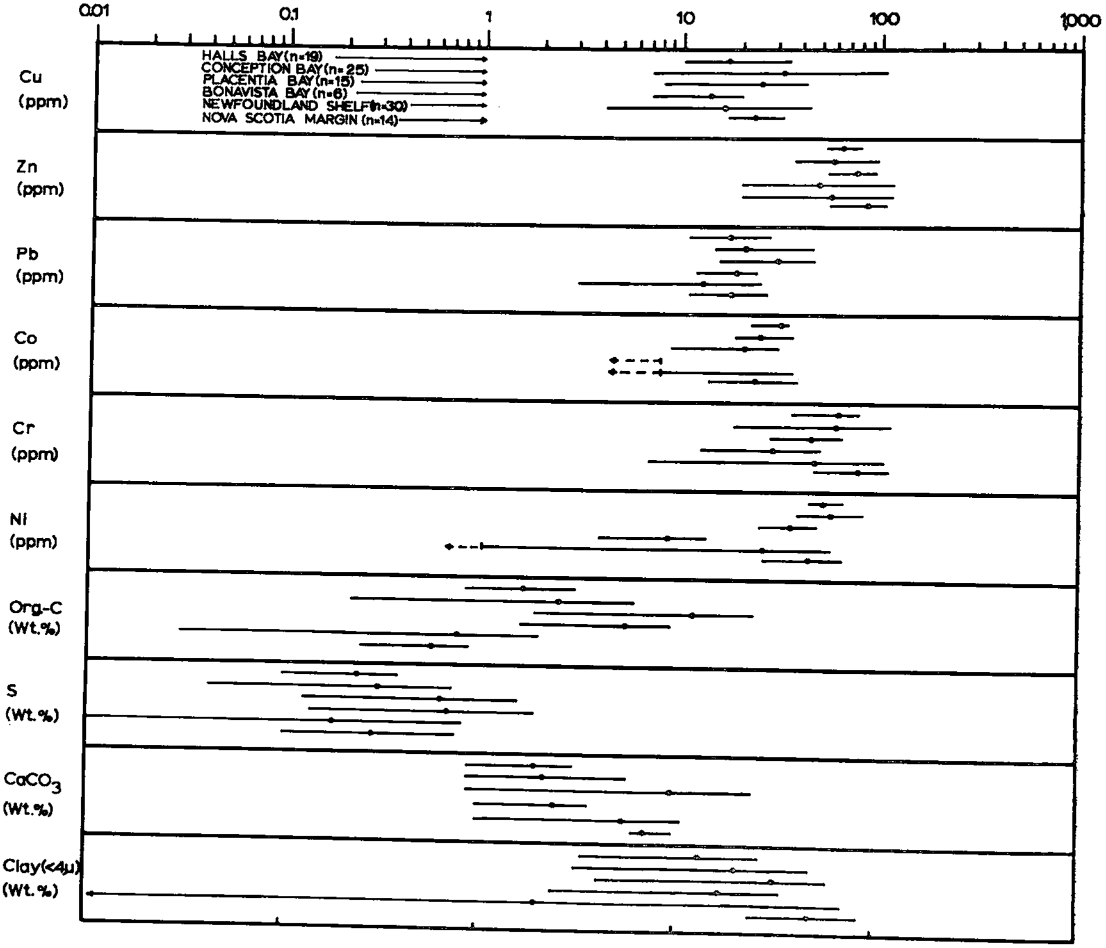


FIG. 3. Concentrations of trace elements, Org. -C, S, and $CaCO_3$ and clay content of sediments.

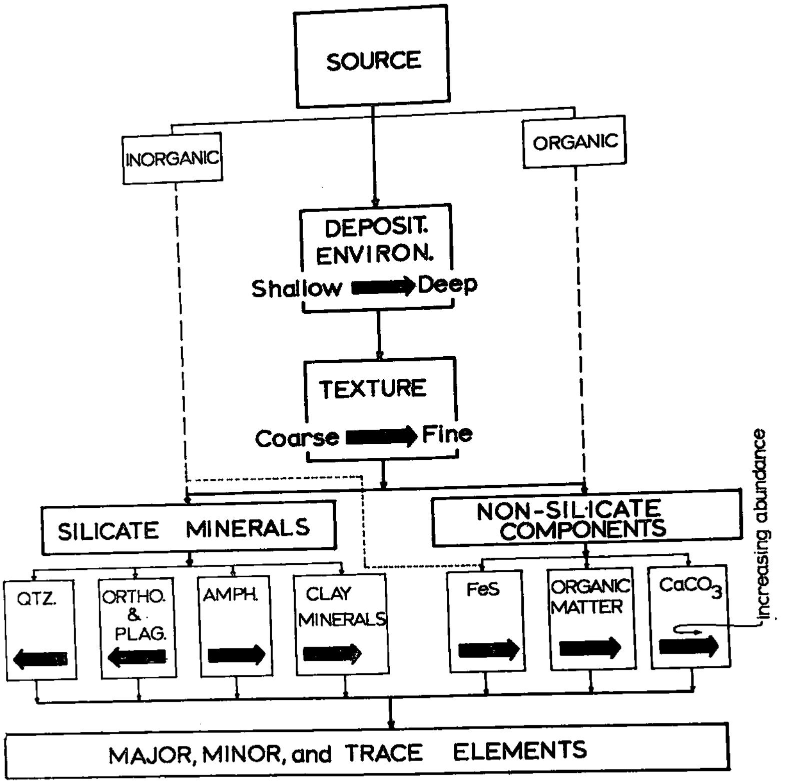


FIG. 4. Schematic illustration of the relationships among major factors that control the geochemistry of detrital marine sediments.

geographic areas. Mineralogical analysis shows that quartz and feldspar comprise the bulk of the sediments, there are lesser amounts of clay minerals and $CaCO_3$, and occasional amphibole. Clay minerals in most suites are a subequal mixture of chlorite and illite, but in addition to these minerals, the core samples and some shelf samples contain subordinate amounts of kaolinite and montmorillonite (Piper *et al.* in press).

GENERAL RELATIONSHIPS

General conclusions can be drawn from these results regarding the factors that regulate geochemical variability of detrital marine sediments. These factors are schematically illustrated in Figure 4.

The components of the sediments are grouped into *silicate minerals* and *non-silicate components*. Individual species and quantities present will be a function of their *source.* In addition to source, the abundance of individual components is regulated by sediment *texture,* which in turn is related to *depositional environment* since finer-grained sediments occur in deeper water.

We have related sediment chemistry quantitatively to texture (clay content), and only indirectly to mineralogy because quantitative mineralogical analysis of sediments is difficult and questionable by routine methods. The following general relationships, applicable to all the suites of samples, have been established on the basis of linear regression analysis of the components as a function of clay content.

(I) Concentrations of the three non-silicate components — $CaCO_3$, organic matter (calculated from organic-C concentrations using the VanBemmelen factor of ×1.72), and FeS (calculated from S concentrations) vary from less than 1 to more than 20%, less than 1 to almost 50%, and from trace quantities to more than 5%, respectively (Fig. 3). With few exceptions these components are positively correlated (significant at the 95% confidence level) with clay content. This is the expected relationship for organic matter and iron sulfides which accumulate in fine-grained sediments. The higher $CaCO_3$ content of finer-grained sediments is thought to be a result of biodegradation of shell debris and tests of foraminifera in all the sediments, as well as to the occurrence in outer-margin sediments of coccoliths and/or glacially comminuted limestone (D. J. W. Piper, personal communication 1975).

(II) Concentrations of major and minor elements which comprise silicate minerals vary inversely with those of non-silicate components due to dilution (Slatt 1974b). Therefore, in order to relate oxide data to texture and mineralogy we have re-calculated the data on a non-silicate free basis by multiplying the correction factor [100/ (100 − wt. % loss-on-ignition)]. Regression analysis shows that Al_2O_3, MgO, and Fe_2O_3 concentrations are positively correlated with clay content and SiO_2 is negatively correlated owing to the greater abundance of clay minerals in finer-grained sediments and lesser abundance of coarser-grained quartz and feldspar (Fig. 4). In most suites, K_2O concentrations are either slightly positively correlated or do not vary significantly with clay content because orthoclase is concentrated in coarser-size fractions and illite is concentrated in finer fractions. Na_2O concentrations generally decrease slightly with clay content owing to dilution of Na-feldspar by clay minerals, but significant quantities of clay-size feldspar are present in many samples (Piper *et al.*, in press). Only Newfoundland shelf and Bonavista Bay samples show a positive correlation between Na_2O and clay content which may be due to the presence of clay-size Na-plagioclase. With the exception of sediments from Halls Bay, CaO in samples is almost entirely bound in $CaCO_3$.

(III) Concentrations of each trace element are almost always positively correlated with clay content. Although this relationship is partly a result of the ability of clay minerals and organic matter to adsorb trace elements, it is also a result of trace elements which occur in mineral and biogenic $CaCO_3$ structural sites. Extrapolation of linear regression equations to 0% clay for samples from the four inlets usually showed less than a 100% increase in elemental concentrations over the clay ranges encountered (Fig. 3) (for an example, see Slatt 1975). Therefore, elements in structural sites of minerals coarser than clay-size (0.004mm) contribute significantly to the total-sediment trace-element composition (Jones 1972) as do elements in structural sites of clay minerals (Hirst 1962b). For some suites of samples, regression analysis of some elements vs. clay content exhibited a considerable scatter of data points about a positive linear trend. The cause of this scatter is discussed in subsequent sections.

The above three relationships serve to demonstrate the necessity of taking into account the effect of sediment texture on chemical composition when comparing suites of sediments. Calculated average elemental concentrations are biased according to the number of coarse- or fine-grained samples included in the average (Slatt 1975).

(IV) Besides the above relationships, Table I shows that there are variations in the relative proportions of major, minor and trace elements among the suites of sediments. Whereas variations in CaO are a result of biogenic $CaCO_3$, those of Na_2O, K_2O, Fe_2O_3 and MgO probably reflect different source-rock compositions and/or proportions, as well as possible textural variations. For trace elements, orders of abundance are similar to those of average nearshore sediments (Hatcher & Segar 1974). Zn and Cr are most common and Ni is abundant in all but Bonavista Bay sediments. Co, Cu, and Pb occur in smaller concentrations, but variations in relative proportions of these elements among the suites also reflect different source-rock compositions.

PLOTS OF TRACE ELEMENTS VERSUS CLAY CONTENTS

Because of a large scatter of data points for some plots of trace-element concentrations vs. clay content, we have found this method of graphic presentation of data to be unsuitable for evaluating trace-element variability of a suite of sediments and particularly for comparing suites. A better plot is the ratio [(ppm trace element/% clay) vs. % clay] because it takes into account the textural effect and because

TABLE 1. RELATIVE PROPORTIONS OF MAJOR, MINOR AND TRACE ELEMENTS.

Area	Major and minor elements	Trace elements
Halls Bay	$SiO_2>Al_2O_3>Fe_2O_3>Na_2O>CaO>MgO>K_2O>TiO_2>MnO>P_2O_5$	$Zn\geq Cr\geq Ni>Co>Pb\geq Cu$
Conception Bay	$SiO_2>Al_2O_3>Fe_2O_3>Na_2O>K_2O>MgO>CaO>TiO_2>P_2O_5>MnO$	$Zn\geq Cr\geq Ni>Cu\geq Co\geq Pb$
Placentia Bay	$SiO_2>Al_2O_3>CaO>Fe_2O_3>Na_2O>K_2O>MgO>TiO_2>P_2O_5>MnO$	$Zn>Cr>Ni>Pb>Cu>Co$
Bonavista Bay	$SiO_2>Al_2O_3>Na_2O>K_2O>Fe_2O_3>CaO>MgO>TiO_2>P_2O_5>MnO$	$Zn>Cr>Pb>Cu>Ni>Co$
Newfoundland Shelf	$SiO_2>Al_2O_3>Fe_2O_3>CaO>MgO\geq K_2O\geq Na_2O>TiO_2>P_2O_5>MnO$	$Zn\geq Cr>Ni>Co\geq Cu>Pb$
Nova Scotia outer margin	$SiO_2>Al_2O_3>Fe_2O_3>CaO>K_2O>MgO>Na_2O>TiO_2>P_2O_5>MnO$	$Zn>Cr>Ni>Co>Cu>Pb$

the degree of scatter of data points is considerably reduced by using clay content as both variables. For this latter reason, geochemical trends for suites of sediments can be compared more easily. Hirst (1962b) has used a similar method of plotting sedimentary geochemical variables (for example Co/Al vs. Al) to suggest associations between specific minerals and elements.

In the following examples, the trace element-clay plots are used to detect localized enrichment of trace elements in marine sediments derived from mineralized bedrock and to differentiate and correlate sedimentary facies and their sources.

TRACE-ELEMENT ENRICHMENT IN MARINE SEDIMENTS DERIVED FROM ONSHORE MINERALIZED BEDROCK

Halls Bay, north-central Newfoundland

Halls Bay (Fig. 5) is located within mainly volcanic terrain of the Central Mineral Belt of Newfoundland. Ordovician volcanic rocks of the Lushs Bight Group which crop out on the northwest side of the inlet contain Cu-mineralization. Slatt (1975) has shown that fine-grained sediment derived from the Lushs Bight drainage basin is transported easterly across Halls Bay and that net deposition occurs on the east side. Trace element-clay plots (Fig. 5) show that Cu is enriched in sediments on the east side relative to those elsewhere. None of the other five trace elements is similarly enriched (Fig. 5). The Cu-enriched sediment is derived from onshore mineralized bedrock and follows the fine-grained sediment dispersal path (Slatt 1975).

Conception Bay, southeastern Newfoundland

Conception Bay (Fig. 6) is primarily within a Precambrian sedimentary terrain. Cambro-Ordovician shales and sandstones which underlie Bell Island contain Fe-ore horizons. As well, scattered Cu-mineralization occurs in Precambrian volcanic rocks of the Harbour Main Group which crops out along the south shore (V. S. Papezik, personal communication 1975). Comparative trace element-clay plots indicate that, relative to sediments in the central part of the inlet, those near Bell Island are enriched in Cr and possibly Pb, and those in a fringing inlet (Holyrood Bay) near the mineralized volcanics are enriched in Cu and Pb. There is no local enrichment of Ni, Co, or Zn (Fig. 6). These anomalies undoubtedly reflect derivation of the sediments from local mineralized sources.

The above examples demonstrate the first-order imprint on derived sediments of trace-element composition of local-source lithologies. The results also demonstrate the applicability of trace-element geochemistry of marine sediments to mineral exploration, particularly at the reconnaissance level (Slatt 1975).

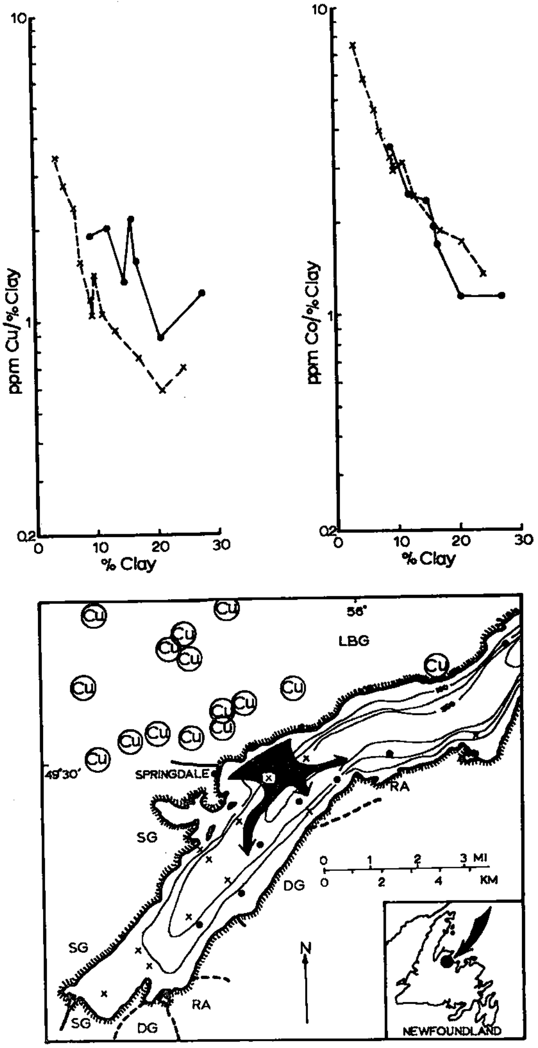


FIG. 5. Trace element/clay vs. clay plots for surface sediments in Halls Bay, north-central Newfoundland. Geographic distribution of samples and known Cu occurrences in Lushs Bight Group (LBG) rocks (circled Cu) are also shown. RA = Roberts Arm Formation, SG = Springdale Group, and DG = plutonic rocks. Plots of Pb, Zn, Ni and Cr are similar to that of Co. Arrows denote the dispersal path of fine-grained sediment and Cu (after Slatt 1975).

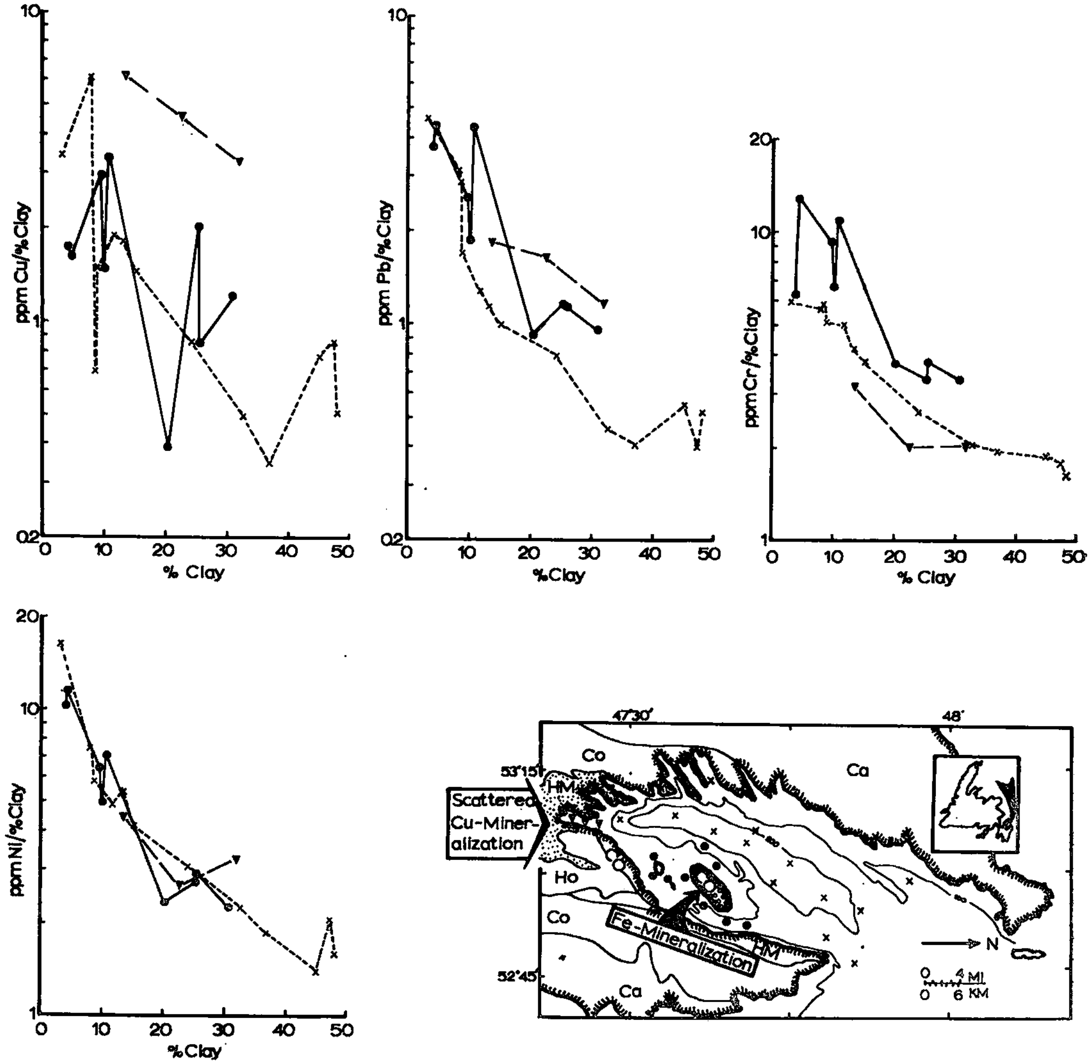
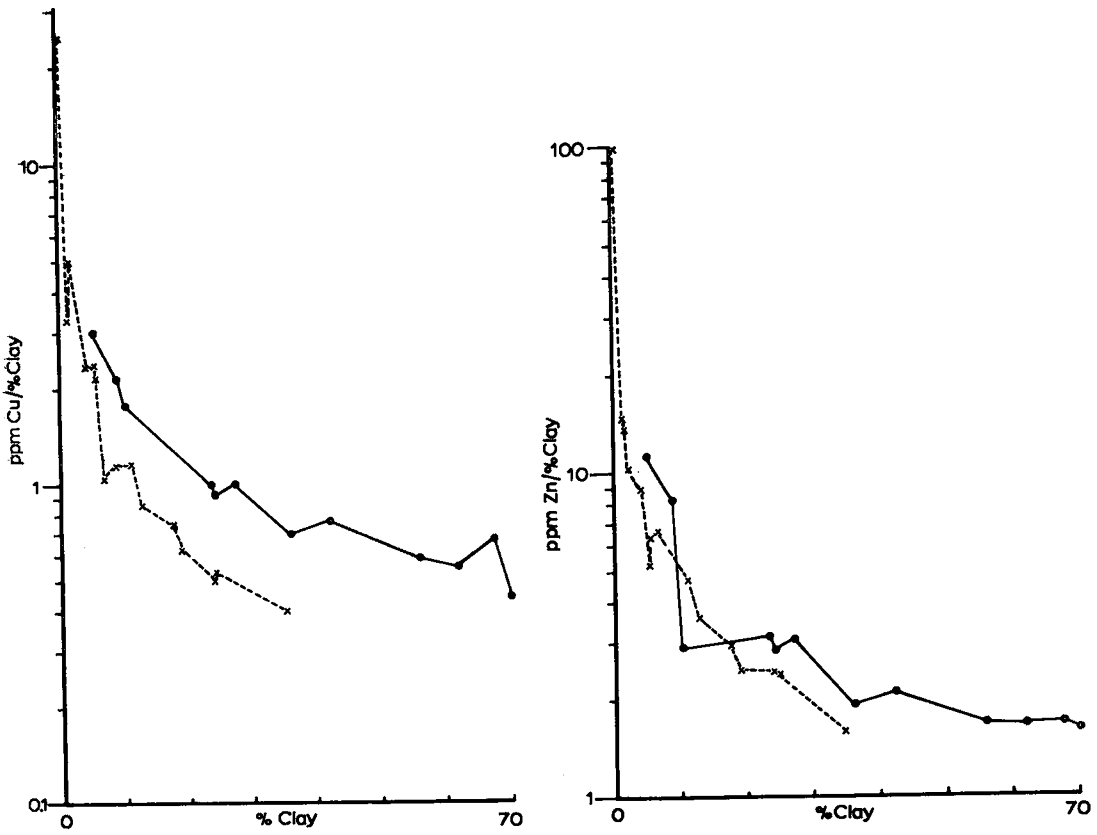


FIG. 6. Trace element/clay vs. clay plots for surface sediments in Conception Bay, southeastern Newfoundland. Geographic distribution of samples and location of Fe mineralization in Cambro-Ordovician Rocks (CO) of Bell Island and Cu mineralization in Harbour Main Group volcanic rocks (HM) are also shown. Ca = Cabot Group and Co = Conception Group. Plots of Co and Zn are similar to that of Ni.

PROVENANCE AND DIFFERENTIATION OF SHELF SEDIMENTARY FACIES BY TRACE-ELEMENT CHEMISTRY

Trace element-clay plots of surficial sediments on the Newfoundland continental shelf (Fig. 7) indicate that the sediments can be subdivided into inner and outer facies on the basis of Cu content; outer-shelf sediments are relatively impoverished in Cu. Plots for other elements do not display the clear two-fold subdivision shown by Cu, even though there appear to be similar trends.

The occurrence of Precambrian-Paleozoic rocks and Mesozoic-Tertiary coastal-plain strata which underlie the Newfoundland shelf is shown in Figure 7. Petrographic studies (Slatt 1974d) indicate that these lithologies are the respective sources of the inner- and outer-shelf glacially-derived sediments. Clay mineral analysis has shown the outer-shelf facies to contain somewhat more kaolinite and montmorillonite than the inner-shelf facies (Piper *et al.*, in press). Thus the facies differentiation is probably due to lower Cu concentrations in coastal-plain strata. Alternatively, sedi-



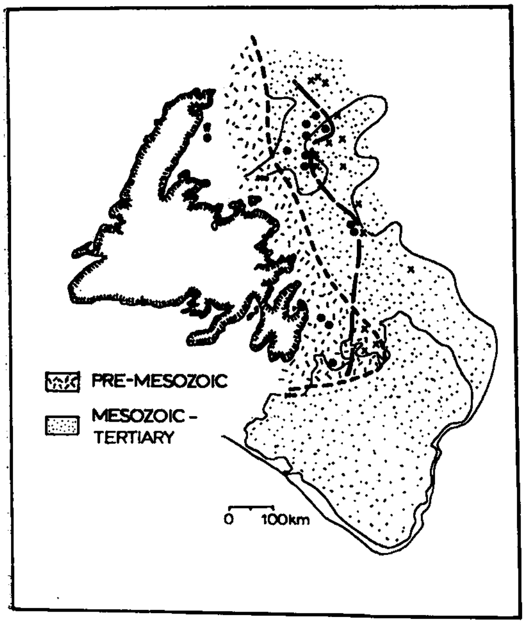


FIG. 7. Trace element/clay vs clay plots for surface sediments on the Newfoundland continental shelf. Geographic distribution of samples and contact (small dashes) between underlying Mesozoic-Tertiary coastal-plain strata and pre-Mesozoic rocks (after Grant 1972) are also shown. Plots of Cr, Co, Pb, and Ni are similar to that of Zn. Boundary between outer Cu-poor sediments and inner Cu-rich sediments is shown by large dashes.

ments on the inner shelf contain slightly higher concentrations of $CaCO_3$ than those on the outer shelf (average of 6.4% vs. 4.7%) so Cu could be associated with the biogenic fraction. However, the minor differences in $CaCO_3$ content suggest this is not the case.

The occurrence of the contact between outer Cu-poor and inner Cu-rich sediments seaward of the contact between the underlying source rocks is a result of net easterly sediment transport on the shelf (Slatt, in prep.).

DIFFERENTIATION OF SURFICIAL SEDIMENTS IN FOUR NEWFOUNDLAND INLETS BY TRACE-ELEMENT CHEMISTRY

Bedrock geology in Halls Bay and Conception Bay has already been mentioned. Bedrock lithologies in Bonavista Bay and Placentia Bay (Fig. 1) are similar to those in Conception Bay except that more volcanic rocks occur in the Placentia Bay area (Williams 1967).

Very little is known about the bottom environment in these inlets. In Placentia Bay, bottom waters are well-oxygenated and a thermocline develops during spring-summer runoff, but is absent in winter (Willey, in prep.). One set of STD measurements indicates there is a shallow summer thermocline in Conception Bay (Allen, 1971). A counter-clockwise gyre of the Labrador Current is thought to pass through Conception, Placentia, and Halls Bay (Slatt 1974a, 1975; Stehman, in prep.). This information, plus the facts that the inlets are all in a

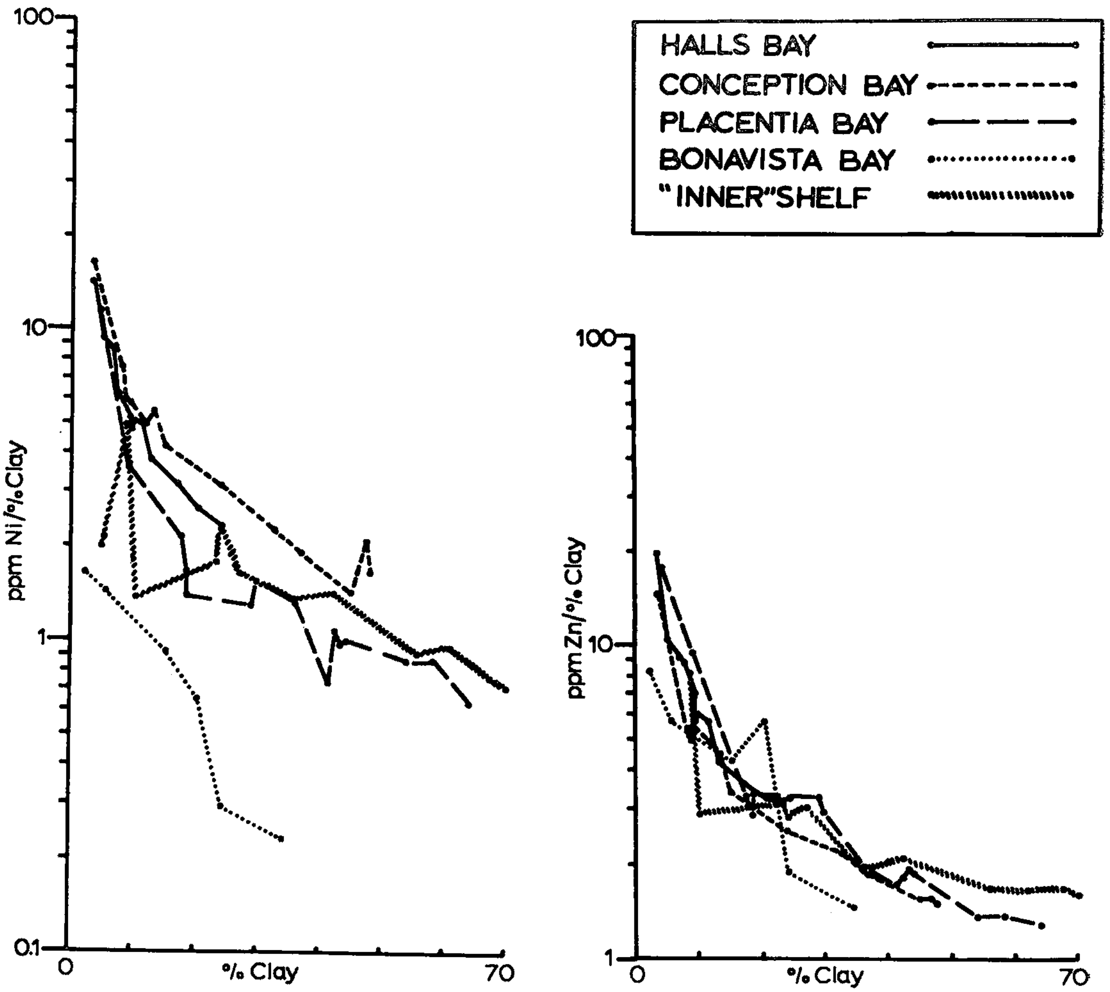


FIG. 8. Trace elements/clay vs. clay plots for surface sediments in the four inlets (Fig. 1) and on the inner Newfoundland shelf (Fig. 7). Plots of Co, Pb, and Cr are similar to that of Ni, and a plot of Cu is similar to that of Zn.

similar structural setting and all are glacially-overdeepened (Fig. 1) suggest that the bottom environment in each is similar.

Comparative trace element-clay plots for sediments in the four inlets and the inner Newfoundland shelf are presented in Figure 8. Anomalous samples in Halls Bay and Conception Bay sediments (Figs. 5 and 6) have been omitted from the plots. Sediments in the four inlets can be differentiated on the basis of Ni, Co, Pb, and Cr contents, but not on the basis of Cu and Zn (Fig. 8). Trace-element concentrations of inner-shelf sediments are clearly different from those in Conception Bay and Bonavista Bay sediments, but only subtly different from those in Halls Bay and Placentia Bay sediments.

Inlet sediments may be either locally-derived or transported landward from the adjacent shelf (Meade 1969). The comparative trace element-clay plots suggest each suite is locally-derived. This interpretation is supported by variations in relative proportions of major, minor and trace elements comprising the sediments (Table 1) as well as by independent sedimentological studies in Conception Bay (Slatt 1974a), Halls Bay (Slatt 1975), and Placentia Bay (Stehman,

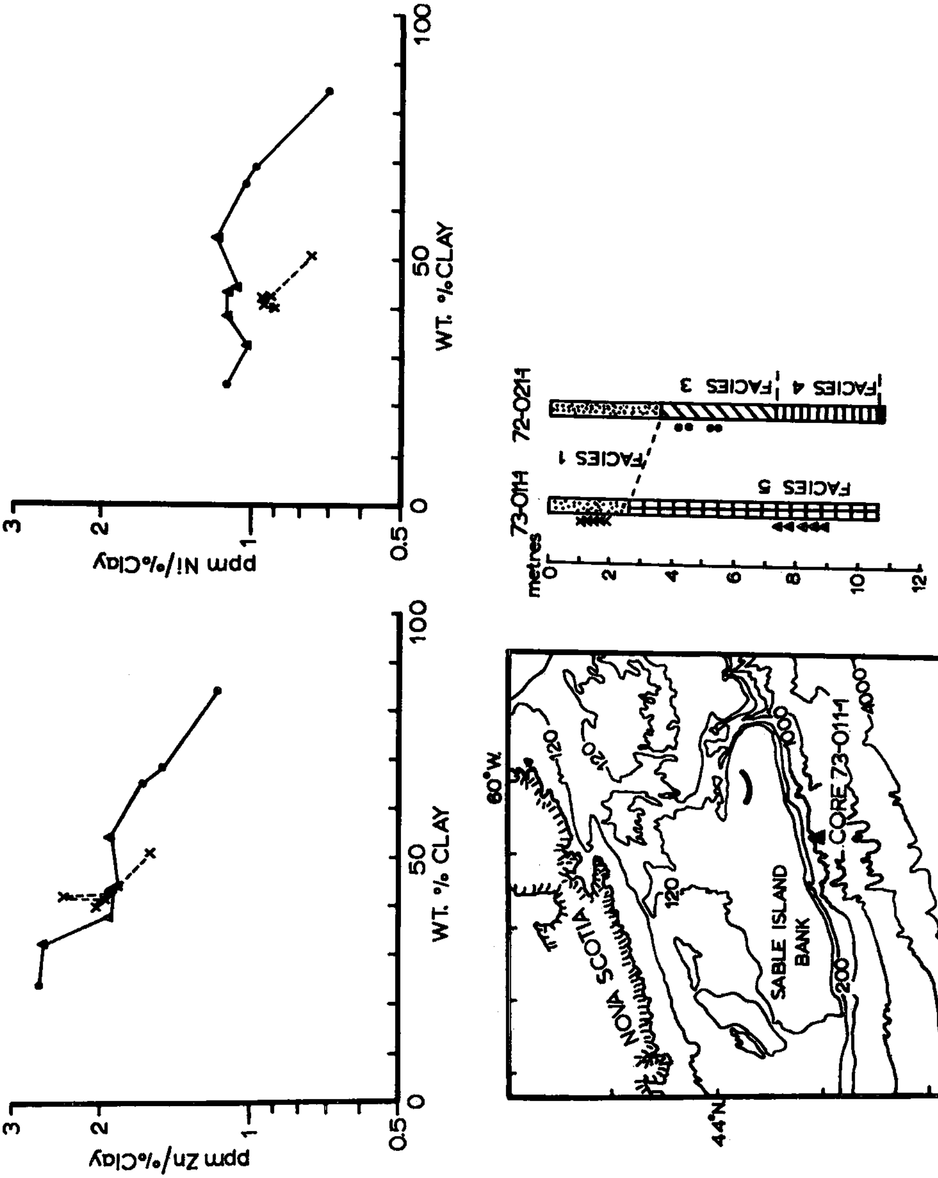


FIG. 9. Trace elements/clay vs. clay plots for Nova Scotia continental slope and rise sediments. Core locations and sample depths within cores are also shown. Plots of Pb and Cu are similar to that of Zn, and plots of Co and Cr are similar to that of Ni. Facies numbers are after Piper (1975).

in prep.). Although the over-all *mineralogical* composition of the sediments in each area is similar (Fig. 4), different trace-element concentrations are attributed to variations in elemental composition of local source rocks and/or variations in the quantity of source rocks that contribute to the sediments.

DIFFERENTIATION AND CORRELATION OF LATE-QUATERNARY OUTER-MARGIN FACIES BY TRACE-ELEMENT CHEMISTRY

Two 10-metre cores were obtained from the Nova Scotia continental slope (core 73-011-1) and adjacent rise (core 72-021-1) (Fig. 9) (Piper 1975). The uppermost facies in both cores (Facies 1 of Piper 1975) is Holocene olive or brownish-grey mud with fine sand beds that have been deposited by the cumulative processes of slumping, turbidity currents and bottom currents. The lowermost facies (Facies 5 of Piper 1975) in core 73-011-1 consists of late-Wisconsin ice-rafted brownish-grey sandy mud with some coarse sand and granules. The middle facies (Facies 3 of Piper 1975) of core 72-021-1 consists of late-Wisconsin greyish-red fine mud or clay with rare ice-rafted particles and local sand and/or mud laminae. Although problematical, Facies 3 is thought to be the reworked equivalent of the slope ice-rafted Facies 5.

Comparative trace element-clay plots show that the late-Wisconsin Facies 3 and 5 in the slope and rise cores can be correlated and both can be differentiated from the slope Holocene Facies 1 on the basis of Ni, Co, and Cr (Fig. 9). Plots of Zn, Pb, and Cu (Fig. 9), do not show this trend.

The results support Piper's (1975) interpretation that the late-Wisconsin rise facies originated at the continental slope and that Holocene and late-Wisconsin sediments are derived from different sources. Variations in trace-element chemistry of the facies are not a result of variations in biogenic $CaCO_3$, since concentrations are similar in both.

CONCLUSIONS

(1) One hundred and nine sands and muds analyzed from Newfoundland inlets, the adjacent continental shelf, and the Nova Scotia outer continental margin consist mainly of quartz and feldspar, with smaller amounts of clay minerals (mainly illite and chlorite), amphibole, organic matter, biogenic $CaCO_3$ and iron sulfides. Trace, major and minor-element chemistry of the sediments is regulated by the abundance and species of these components present, which is ultimately related to their source. Aside from source, the abundance of these components varies with texture, which is related in turn to the nature of the depositional environment.

(2) The effect of texture on chemical composition must be taken into account in any comparative sedimentary geochemical study because computed average chemical compositions vary with the number of coarse- and fine-grained samples included in the average. An effective way to do this is to plot the ratio trace element (or major element) concentration/clay content *against* clay content.

(3) Such plots are used in a number of examples to demonstrate that the trace-element composition of derived sediments is a first-order reflection of the chemical composition of parent lithologies, as well as a result of the proportions of lithologies contributing to the sediments. This is because the major concentrations of trace elements occur in mineral structural sites. For these reasons, trace-element chemistry can be used for provenance studies, mineral exploration, and correlation and differentiation of marine sedimentary facies.

Surficial sediments in two Newfoundland inlets are locally enriched in certain trace elements owing to their derivation from nearby onshore mineralized bedrock. On the basis of Cu content, Newfoundland continental-shelf surficial sediments can be divided into outer and inner facies, each derived from a different underlying source. Surficial sediments in four Newfoundland inlets and on the inner shelf are differentiated on the basis of Ni, Co, Pb, and Cr concentrations, which suggest the sediments in each area are locally derived. Late-Wisconsin continental slope and rise facies off Nova Scotia can be correlated by Ni, Co, and Cr concentrations and can be differentiated from Holocene facies, suggesting a different origin for the two.

(4) With the exception of only a few samples, individual trace elements occur in concentrations of less than 100 ppm in all areas. Trace elements as well as organic matter, and sometimes other components, are useful indicators of man-induced chemical pollution. Because none of the areas studied has been affected by industrialization, the natural concentration levels presented in this paper can be utilized either for comparative studies in similar industrialized coastal environments, or in these same areas in the event of future industrialization/urbanization.

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