Chemical Element Distribution in the Surface Sediments of Kane Basin

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ABSTRACT �

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Magnesium and a suite of first transition elements were analysed in the $<2\ \mu m$ fraction of glacial marine surface sediments of the Kane Basin. High concentrations of Mg, Mn, Cr, Co, Ni, Cu and Ti were observed in the western basin in relict sediment, tentatively identified as Ellesmere Island till, containing abundant mafic and carbonate rock detritus. However, Fe and Zn were enriched in the eastern basin where Zn-rich soil and vegetative detritus from Inglefield Land contribute to the sediment source.

Unlike other high latitude glacial marine argillaceous sediments which are generally depleted in element concentrations with respect to low-latitude deep-sea clays (NAIDU and HOOD, 1972; NAIDU *et al.*, 1975, 1976), the Kane Basin clay-size fraction is enriched in Fe, Mg, Ti, Cr and Zn, and depleted in Mn, Ni, Co and Cu when compared with tropical-temperate (non-polar) pelagic sediments. The Kane Basin sediment is enriched in Mg, Cr, Co, Ti and Zn, and depleted in Fe, Mn, Ni and Cu with respect to low latitude deep-sea clays. The bathymetry of Kane Basin, current activity there, and detritus derived from various provenances are responsible for this and are reflected by the elemental distribution in the basin's modern sediments.

ADDITIONAL INDEX WORDS: *Transition elements, relict sediment, detritus, clay-size fraction, bathymetry, sediment source*

INTRODUCTION

Although sediment textures and mass physical properties of Kane Basin and high-latitude Arctic glacial-marine sediments from other areas have been studied in some detail (PERRY, 1961; NAIDU and SHARMA, 1971; NAIDU, 1974; NAUGLER *et al.*, 1974; ROEDICK, 1974; KRAVITZ, 1976, 1983; DARBY *et al.*, 1989), little has been published on the chemistry of such sediments. NAIDU and HOOD (1972) analysed surface sediments of the western Beaufort Sea for several major (Fe, Mn, K, Na, Mg and Ca) and minor elements (Rb, Li, Zn, Ni, Co, Cu and U). They found that there was a concentration deficit for all elements analysed except U compared to low-latitude deep-sea sediments and observed that chemically, the Arctic sediments are similar to the Antarctic sediments studied by ANGINO (1966). NAIDU and HOOD (1972) suggested that glacial-marine sediments have a distinct chemical character and that geochemical criteria have potential use in the recognition of glacial-marine paleosediments. Similarly, NAIDU

et al. (1975) and DARBY *et al.* (1989) found that the Canada Basin (Arctic Ocean) deep-sea clays have a significant deficiency of Mn, Ca, Mg, Na, K, Rb, Co, Cu, Zn and Ni as compared with tropical-temperate deep-sea clays. They hypothesized that these differences in sediment chemistries may be related to regional differences in sources and input of volcanogenic deposits. Low heavy metal values (*e.g.*, Fe, 2.84%; Mn, 494 ppm; Cr, 64 ppm; and Co, 10 ppm) were also reported by ROBERTSON (1977) for surficial sediments from the south Bering Sea compared to surficial Gulf of Alaska surficial sediments (BURRELL, 1978) who attributed this to the generally coarser character of the sediment since finer-grained sediments generally contain higher concentrations of sorbed metals. PELLETIER and BUCKELY, in PELLETIER (1984), described the distribution of a suite of major and trace elements, C_{org} and CO_3 (Ca, Mg) in the eastern Beaufort Sea sediments in context of the Mackenzie river discharge and sediment texture.

As part of a study designed to understand the nature of sediment and sedimentary processes in Kane Basin, Fe, Mg, Mn, Cr, Co, Ni, Zn, Cu and Ti were analysed in the $<2\ \mu m$ fraction of surficial
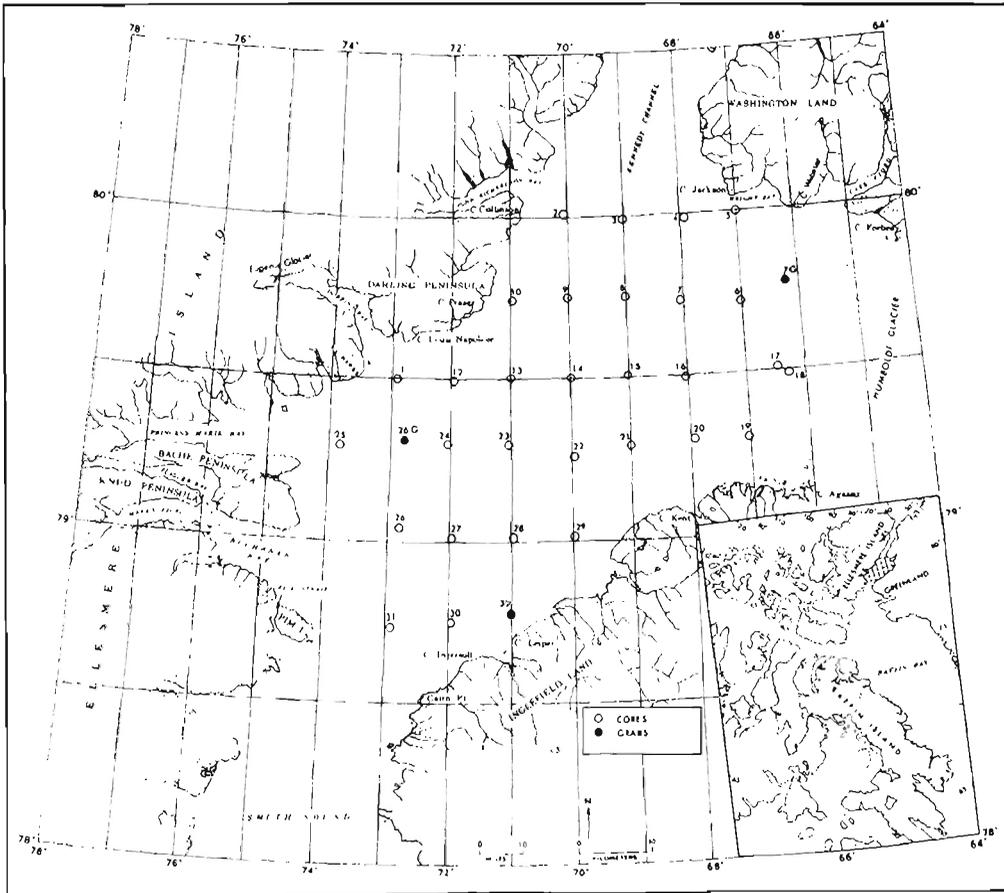
Figure 1   Index map of Kane Basin showing location of core and grab samples.

sediments of the Basin. We hypothesize that sed-
iment chemical analyses can be a useful charac-
teristic to identify sedimentary facies. We believe
this would be important in provenance elucida-
tion and for ascertaining the geological signifi-
cance, in terms of bathymetry and physico-chem-
ical and biological processes, on the distribution
and concentration of elements in sediments of
high-latitude basins.

AREA OF STUDY: PHYSICAL, GEOLOGICAL AND DEPOSITIONAL SETTING

Kane Basin is located in the southern part of
Nares Strait (Figure 1). It is bordered by north-
western Greenland on the east, by Ellesmere Is-
land on the west, and by Kennedy Channel and

Smith Sound on the north and south, respectively.
The portion of Greenland bordering Kane Basin
is generally flat. Humboldt Glacier which opens
into the Basin is approximately 100 m high and
100 km wide at tidewater, and divides the ice-free
Greenland coastal strip into two segments, Wash-
ington Land and Inglefield Land (Figure 1).

The western shore of Kane Basin, along Elles-
mere Island, extends about 140 km from Rice
Strait to Cape Collinson with a north-northeast-
ward trend, and has many east-west trending
fjords, some of which extend inland nearly 100
km. The topography of the coast rises abruptly
from sea level to rugged mountains with ice caps
and talus-covered slopes. The valley glaciers dis-
charge into bays and fjords. Eastern Ellesmere
Island is composed primarily of carbonates with

some sandstones, shales, siltstones, phyllites, and a few coal seams (KERR, 1967, 1968, 1976), whereas the northeast coast of the island contains scattered outliers consisting of nonmarine Tertiary clastics (MIALL, 1982).

These outliers are composed of conglomerates, sandstones, siltstones, shales, mudstones and coal. The sandstones frequently contain lithic fragments including basalt, palagonite, glass, and grains of plagioclase, amphibole, and pyroxene. Some of the clay matrices of the sandstones are composed predominantly of smectites with minor illite. Most of the sandstones identified were lithic arenites. Chlorite fragments, phyllite grains, and detrital carbonates were also found in some of the sandstones. Glacial debris, colluvial, fluvial, and marine deposits comprise the unconsolidated surficial material of eastern Ellesmere Island.

Large areas of Precambrian basement are exposed in Inglefield Land. According to DAWES (1976), the basement rocks are made up of crystalline limestone, variable calcsilicate rocks, argillaceous schists, and minor amounts of arenaceous rocks, intruded by gabbroic to granitoid rocks. Many of these crystalline basement rocks contain hypersthene and garnet. Overlying the Precambrian crystalline basement is a sequence of sedimentary rocks composed of siltstones, shales, limestones, dolomites, conglomerates, and sandstones (some of which are glauconitic). The crystalline basement in Washington Land is not exposed, but a thick section of sedimentary rocks (mostly carbonates) crops out there.

The Kane Basin is characterized by two large shallow troughs (Figure 2), separated by a broad NE-SW trending high with gently sloping flanks. The eastern trough begins at the northern end of Humboldt Glacier and extends to the southwest where it gradually deepens from approximately 200 m to more than 500 m. The western trough is shallower and parallels Ellesmere Island. The bottom of this trough is 200 to 300 m deep. A small, narrow trough 400 to 500 m deep is located along the south side of Bache Peninsula and joins the other troughs at the northern end of Smith Sound. A 250 m deep sill in the western part of Kane Basin isolates the basin at Smith Sound.

The circulation of water in Kane Basin is characterized by topographically controlled flow in two peripheral branches surrounding a central cyclonic gyre (MOYNIHAN, 1972; ADDISON, 1987). Water circulation along the eastern side of Kane Basin augmented by runoff from the Humbolt

Glacier moves southwestward along the eastern trough towards Smith Sound. Arctic water moves south along the western side of the basin and follows the trough from Kennedy Channel to Smith Sound. This flow is probably the major advection of water between the Arctic Ocean and Baffin Bay with minor reversals which coincide with diurnal tidal currents (MUENCH, 1971). Current measurements recorded a generally southward flow (MUENCH, 1971). The eastern part of Kane Basin, where wind conditions are less severe, is frequently more icebound than the western, northern, and southernmost areas (DUNBAR, 1979).

COMPOSITION AND DISTRIBUTION OF THE SURFICIAL SEDIMENTS

UCHUPI (1964) described grab samples from Kane Basin as gray to reddish-brown, poorly sorted, calcareous, sandy silts containing appreciable quantities of gravel. KRAVITZ (1976) identified three sediment provinces in Kane Basin based on textural and mineralogical characteristics. One province makes up the eastern, central, and southern basin, and contains both water- and ice-transported sediments. The gravels in these sediments are most similar to the basement rocks exposed on Inglefield Land and underlying Humboldt Glacier. The sediments' heavy mineral suite is dominated by garnet and hypersthene. Illite and quartz make up over 70% of its $<$ 2 μm fraction (KRAVITZ, 1982).

The second province encompasses the western basin and is dominated by relict, ice-transported diamictons. The gravels from this sediment are composed of carbonates and clastics. Clinopyroxenes are the primary heavy minerals. The clay mineral suite contains abundant illite but with a much higher proportion of smectite, chlorite and kaolinite than in the other two provinces. Carbonates replace quartz as the dominant non-hydrous aluminosilicate making up the $<$ 2 μm fraction (KRAVITZ, 1982).

The third province, the shallowest area in Kane Basin, includes the northernmost parts of the eastern and western troughs, and the northern topographic high from Kennedy Channel to approximately 79°28′N. The sediment here is also primarily ice-transported diamicton. These materials are similar in composition to the sediments from the first province except for a much higher proportion of carbonate-rich gravels and amphiboles in the heavy minerals.
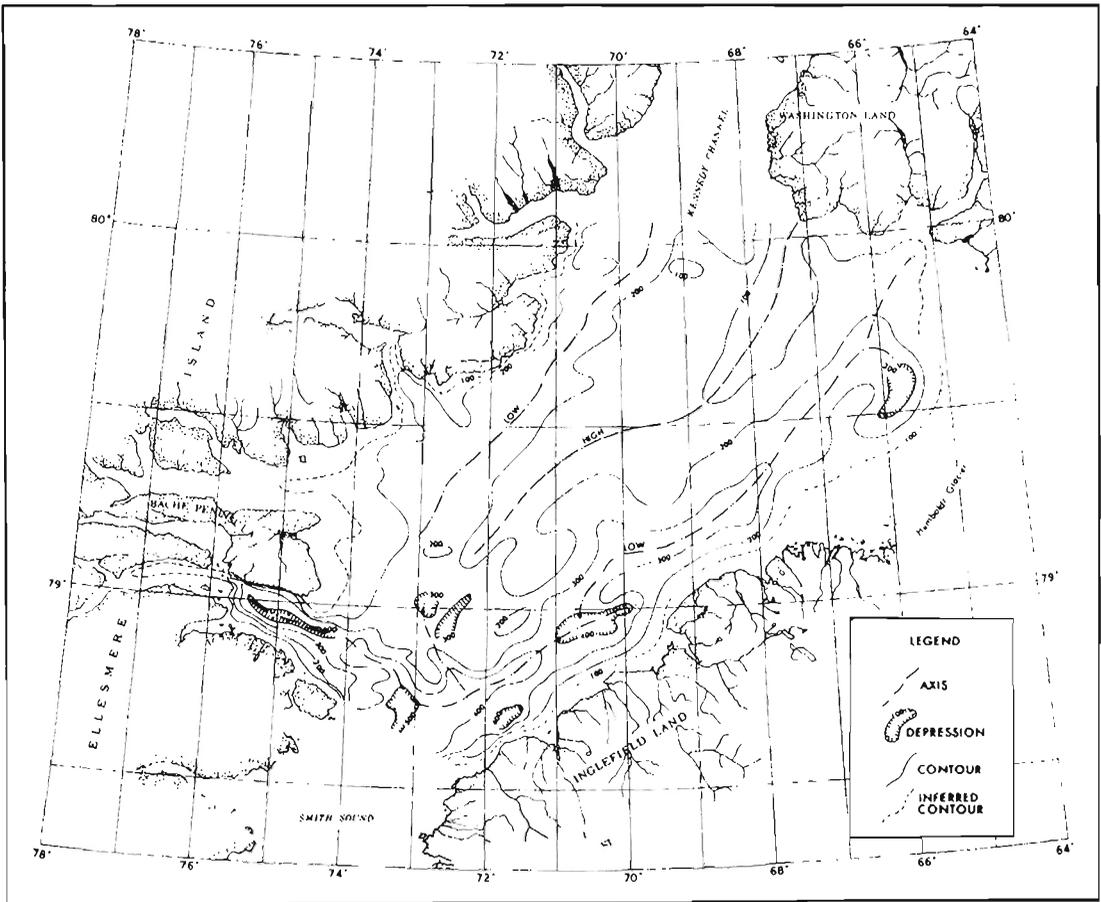
Figure 2.   Bathymetric map of the floor of Kane Basin. Contours are in meters below sea level. Compiled by F. Sorensen, Naval Oceanographic Office.

KRAVITZ (1983) subsequently refined the delineation of ice rafting and water transported sediments (off Humboldt Glacier and Inglefield Land, respectively), in the eastern basin and classified them as glacial-marine. Also, in the western Kane Basin sediment, a diamicton was believed to be till (Ellesmere Island till) as was the diamicton found in the third sediment province along the northern shoal areas of the topographic high (Greenland till).

MATERIALS AND METHODS

Sediment Sampling and Preparation

One core and one grab sample were collected at each station, except where very hard substrate was encountered. Twenty-eight cores and three grab samples were used in this study (Figure 1).

Stations were located on a grid pattern except where ice precluded following such a pattern. Surface sediment samples were taken with a shroud covered, "orange peel" type grab sampler, and were stored in glass jars. The cores were collected using "modified Ewing" open barrel gravity corers with barrels 3.4 m long and containing 6.4 cm ID polycarbonate liners. In the cores, only the surface sediment layer was sampled. The thickness of the layer varied (Table 1) and was determined by utilizing the following criteria: marked x-ray film density differences, textural variations, presence or absence of stratification, sharp or gradational contacts, color changes and variations in com-

Table 1. *Element values in ppm for the < 2 μm size fraction of surface sediments in Kane Basin Fe, Mg and Ti in %; other elements in ppm.*

Bottom Sample	Thickness (cm)	Fe	Mg	Mn	Cr	Co	Ni	Zn	Cu	Ti
* 2	(20)	7.90	3.80	640	200	130	IS	IS	248	4.60
* 3	(20)	5.80	2.80	350	140	74	230	220	200	1.80
* 4	(16)	1.70	.99	50	37	18	52	73	52	.43
5	(56)	3.80	2.50	176	58	22	50	91	20	.34
7	(10)	4.20	2.60	300	100	64	130	200	140	.62
8	(20)	3.40	2.40	240	76	58	100	180	129	.62
* 9	(38)	6.00	3.30	930	280	170	IS	IS	190	3.60
*10	(18)	6.70	3.40	560	240	120	320	510	248	IS
*11	(5)	5.60	3.20	412	110	67	146	157	157	.73
*12	(32)	5.60	4.00	540	260	130	IS	IS	512	2.10
*14	(90)	4.90	2.80	240	116	58	124	204	136	.67
15	(12)	5.90	3.60	280	110	72	140	230	204	.73
16	(45)	7.60	2.60	310	140	68	149	230	160	.75
17	(34)	7.90	2.50	310	140	71	130	280	180	.87
18	(10)	6.60	2.40	265	125	60	130	240	234	.79
19	(22)	5.10	2.20	190	96	68	120	190	112	.66
20	(21)	6.60	2.60	220	110	48	110	220	116	.56
21	(12)	6.20	2.40	243	130	62	130	222	152	.75
22	(36)	6.30	2.40	240	120	80	150	240	159	.91
23	(68)	7.30	3.20	293	155	78	170	318	142	1.14
*24	(23)	8.30	3.10	370	165	82	180	190	144	1.35
*25	(5)	6.80	3.30	380	130	60	100	160	128	.80
*26	(9)	7.70	3.40	310	140	68	160	200	168	1.20
27	(16)	14.00	3.80	440	230	108	240	630	272	IS
28	(20)	7.90	2.70	250	160	68	140	250	208	.81
29	(14)	6.00	2.50	205	130	60	110	200	160	.64
30	(68)	5.00	2.31	199	113	55	111	510	143	.61
31	(8)	6.50	2.80	230	125	60	120	180	120	.76
7G	(10)	5.50	2.60	260	96	60	88	200	132	.73
*26G	(10)	1.60	2.20	250	32	28	44	70	164	.59
32G	(10)	4.60	2.30	180	100	52	80	190	212	.51

*Samples from the relict sediment

IS = Insufficient sample

pactness and water content. The sample was composited from along the entire layer (unit), avoiding the sediment-liner interface in order to prevent contamination. When a grab sample was used, the sediment was homogenized and a representative portion taken.

Sediment samples were placed in glass beakers and dispersed in deionized/distilled water with repeated washing until the samples were free of salt (Cl-test by AgNO₃). The samples were poured into cylinders and deionized/distilled water added to obtain homogenous suspensions. No chemical dispersant was used. The < 2 μm material was repeatedly decanted off using the conventional time-settling velocities (KRUMBEIN and PETTIJOHN, 1938). Sediment suspensions were centrifuged and the clear supernatant liquid decanted. The remaining "clay" and water mixtures were thoroughly stirred and placed in porcelain dishes to dry. A portion of the dry sediment powder was taken into acid solution using the anhydrous lithium metaborate fusion technique (MEDLIN *et al.*, 1969). The chemical analysis does not include cations that were removed by the preliminary washings.

The elemental analysis was conducted by atomic absorption or plasma emission spectrometry using either an Instrument Laboratory (IL) model 353 AAS, a Perkin Elmer model 503 AAS, or an Applied Research Laboratories (ARL) model 35000c spectrometer. Accuracy of the elemental analysis was verified by analyzing USGS Standards G-2 and AVG-1, and comparing the results thus obtained with those summarized by FLANAGAN (1973). The analytical precision for Cr, Co, and Ni was ± 15%; Ti ± 10%; Fe, Mg, Mn, Cu and Zn ± 5%. All standards were prepared in the laboratory and utilized within 90 days of prepa-

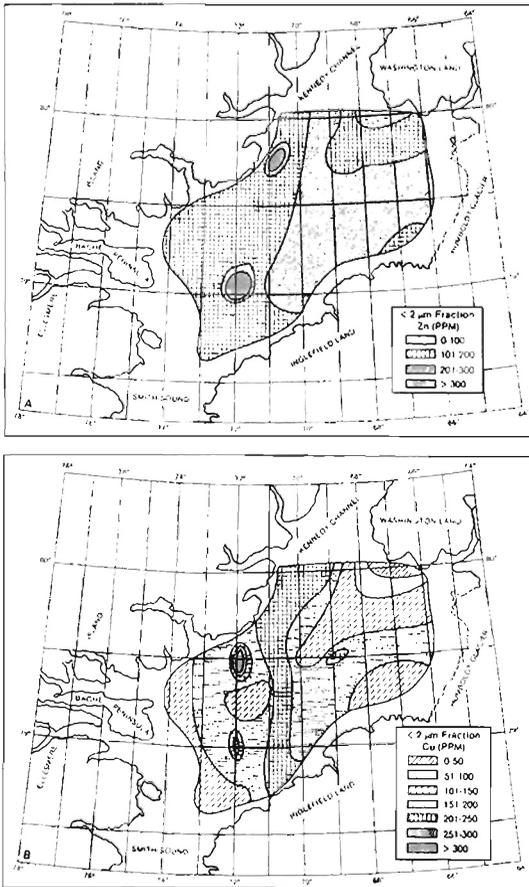Table 2. *Mean, standard deviation and range of concentration summary of chemical elements in Kane Basin surface sediment layer <2 μm size fraction.*

Element	N	Mean	Standard Deviation	Range
Fe%	31	6.10	2.21	1.60–14.00
Mg%	31	2.80	0.61	0.99–4.00
Ti%	29	1.06	0.93	0.34–4.60
Mn ppm	31	318	166	50–930
Cr ppm	31	134	58	32–280
Co ppm	31	72	32	18–170
Ni ppm	28	134	58	44–320
Cu ppm	31	172	82	20–512
Zn ppm	28	235	124	70–630

ration. The standards were diluted to the desired concentrations by addition of 3% nitric acid.

Statistical Analysis

The mean concentrations, standard deviations, and ranges for each element analysed were determined for comparison with published elemental data on high latitude glacial-marine sediments and low latitude deep-sea clays.

Student's t-test was performed to compare the population means of the element concentrations in the Kane Basin clay size fraction with those of the deep-sea sediments from the Canada Basin in the west Arctic Ocean (NAIDU *et al.*, 1976).

Pearson product moment correlation coefficients were calculated to determine if significant interelement relationships existed between element pairs. Subsequently, cluster analysis was used to show any groups of elements that were significantly interrelated. Finally, R-mode principal components factor analysis was performed to determine the influence (percentual) that related element groups had on the variance of the chemistry of the total sample suite.

RESULTS

Element distribution

The elemental concentrations for each sample are given in Table 1. The mean concentrations, standard deviations, and ranges for each element analyzed are presented in Table 2. Outlier values at both the high and low ends for the dataset are found for one or more elements in samples from Sample Sites S-2 (*i.e.*, Ti = 4.6%), S-4 (*i.e.*, Mg = 990 ppm), S-27 (*i.e.*, Fe = 14%) and others.

Geographic distributions of the elements are shown in Figures 3, 4, 5, 6 and 7. The distributions of Mg, Cr, Co, Mn, and Ti show higher concen-

Figure 3. Geochemical maps showing (A) the distribution of Fe and; (B) the distribution of Mg, in the < 2 μm fraction of the surface sediment layer.

trations in the western part of Kane Basin generally following the bathymetric low (Figure 2). The elements Mg, Co and Mn, together with Fe and Ni show "bull's eye" low concentrations just south of Dobbin Bay. These low concentrations, with the exception of Fe, are due to one sample (26G). Only Zn has higher concentrations in the eastern part of Kane Basin. The other elements have lower concentrations in the eastern part of the Basin with the exception of the "bull's eye" areas cited above. There appear to be higher concentrations of most elements off the plunge of the southwest end of the bathymetric high where there is a convergence of the southward flowing currents through the western and eastern troughs of Kane Basin.

Figure 4. Geochemical maps showing (A) the distribution of Mn and, (B) the distribution of Cr, in the < 2 μm fraction of the surface sediment layer.

Figure 5. Geochemical maps showing (A) the distribution of Co and; (B) the distribution of Ni, in the < 2 μm fraction of the surface sediment layer.

Table 3 shows that on the average, the Kane Basin surface layer sediment clay-size fraction is enriched in Mg, Cr, Ti and Zn with respect to low latitude deep-sea clays and depleted in Fe, Mn, Ni and Cu. The concentration of Co is essentially the same. Similarly, Kane Basin clay size fractions are enriched in Fe, Mg, Ti, Cr and Zn, and depleted in Mn, Ni, Co and Cu when compared to tropical-temperate (non-polar) pelagic sediments. This contrasts with the concentration deficits with respect to low latitude deep-sea sediments reported for all elements (Fe, Mn, K, Na, Mg, Ca, Rb, Li, Zn, Ni, Co, Cu) except U in sediments from the Beaufort Sea floor (NAIDU and HOOD, 1972), in the Arctic Ocean deep-sea clays with respect to non-polar deep-sea clays (Mn, Ca,

Mg, Na, K, Rb, Co, Cu, Zn and Ni; NAIDU et al., 1975) as well as in sediments from the Canada Basin in the west Arctic Ocean with respect to deep-sea sediments of tropical-temperate oceans (NAIDU et al., 1976). When a comparison is made with the chemistry of sediments from the Canada Basin reported by NAIDU et al. (1976), Student's t-test shows that Kane Basin clay size sediment has significantly higher population means (at the 95% confidence level) for the elements Fe, Mg, Co, Ni, Cu and Zn.

In comparison to the Beaufort Sea sediments reported on by PELLETIER and BUCKLEY in (PELLETIER, 1984), the Kane Basin sediments' < 2 μm size fractions have higher mean concentrations for elements studied in common (Fe, Mg, Ti, Cr, Co,

Figure 7.   Geochemical map showing the distribution of Ti in the < 2 μm fraction of the surface sediment layer.

Figure 6.   Geochemical maps showing (A) the distribution of Zn and; (B) the distribution of Cu in the < 2 μm fraction of the surface sediment layer.

Ni, Cu) except Mn and is the result of two factors: first, the provenance; second, the size fraction analysed.

Statistical Data

There are many element pairs with Pearson product moment correlation coefficients significant at 0.0001 and the high degree of correlation between most of the 9 chemical elements studied is evident (Table 4). For example, Cr correlates significantly with all the other elements analysed, Co with 7 and Ni with 6 of the 8 other elements. However, Fe correlated significantly with only Cr and Zn.

The degree of interelement correlations is shown by the cluster analysis results (Figure 8) in which

a significant cluster (r = 0.7) comprised of Fe, Cr, Co, Ni, Ti, Mg and Mn is found.

The influence of these interrelated elements was quantified to some degree by results from R-mode principal components factor analysis which attributed 80.3% of the variance in the chemistry of the samples to two factors. Factor 1, comprised of the elements Co, Cr, Mn, Mg, Cu, Ti and Fe, accounts for 52.2% of the chemical variance in the sample suite and Factor 2, comprised of Zn, Ni and Fe, accounts for 28.1% of the variance. There is a communality between 6 elements revealed as significant by cluster analysis (Figure 8) and those comprising Factor 1. Only Ni in the cluster analysis group and Cu in the factor analysis group do not show in the other group.

Factor 1 has its strongest loadings in sediments from sample sites S-9, S-12, S-2, S-27 and S-10 (Figure 1). Sediments from sample sites S-27 and S-10 had the strongest loadings of Factor 2. Except for Sample site S-27 located in a bathymetric low between the western and eastern troughs, the samples with the strongest factor loadings are located in the western bathymetric low (Figure 2).

DISCUSSION

We believe that distribution of elements in the < 2 μm size fraction of surface sediments in Kane Basin is influenced by three factors: source rocks and soils for the sediments, the current regime in the basin, and the basin's bottom topography.

Table 3. *Mean elemental concentrations of Mg, Mn, Cr, Co, Ni, Cu, Ti, Fe and Zn in the <2 μm fraction of surface layer sediments in Kane Basin versus mean concentrations in other sediments.*

Element	Kane Basin	Low-Latitude Deep-Sea Clay[1]	Non-Polar Tropical-Temperate Ocean Pelagic Sediment				Deep-Sea Sediment Canada Basin West Arctic Ocean[1]
Fe%	6.10	6.50	5.57	5.07*	5.16	5.22	5.00
Mg%	2.80	2.10			1.85	1.81	1.18
Ti%	1.06	0.46					
Mn ppm	318	6,700	6,900	4,800*	6,600	6,600	5,471
Cr ppm	134	90	99	102*	74		112
Co ppm	72	74	72	101*	101	104	53
Ni ppm	134	225	222	211*	200	205	68
Cu ppm	172	250	391	323*	338	348	57
Zn ppm	235	165	125		125	125	103

From TUREKIAN and WEDEPOHL (1961); WEDEPOHL (1956)

[1]Compiled by DARBY et al. (1989) and NAIDU et al. (1975, 1976), from CRONAN (1969); EL WAKEEL and RILEY (1961); GOLDBERG and ARRHENIUS (1958); and KRISHNASWAMI (1976)

NAIDU et al. (1976)

*Pacific Ocean clays without Fe-Mn nodules (CRONAN, 1969)

Higher concentration zones for Co, Cr, Mn, Ti and Mg are found along the western trough of the basin (Figures 3, 4, 5 and 7). These element concentrations in conjunction with relatively high smectite are best interpreted as being related to terrigenous sources dominated by basic rocks. In this region, sediments are probably relict in nature. First described by KRAVITZ (1976), these relict sediments contain litharenites abundant in phyllite and basalt fragments, clinopyroxenes, smectite and chlorite. It is believed that these materials originated in Tertiary rocks exposed on the Ellesmere Island coast adjacent to the Kennedy Channel and were formerly brought into the western basin by ice transport (KRAVITZ, 1983). Further, Mg in the sediments is most likely derived from the many dolomite and limestone outcroppings found along the east coast of Ellesmere Island. The strong southerly flowing current along the western trough of Kane Basin from Kennedy Channel to Smith Sound (MOYNIHAN, 1972) presumably keeps the relict sediment largely exposed by restricting the deposition of recent sediment into the western trough.

Correlation coefficients, cluster analysis and factor analysis show the element interrelationships in the western trough area. These analyses suggest that the interrelated elements have a common origin or respond similarly to geological-geochemical processes. The observation that one factor comprised of Co, Cr, Mn, Mg, Cu, Ti and Fe accounts for 52.2% of the variance in the chemistry of the dataset and has its strongest factor loadings in surface sediments from the western trough supports Ellesmere Island (relict sediment high in mafic materials and carbonate rocks) as the most likely provenance for these sediments.

The sediment on the eastern side of the basin is presumably derived primarily from three sources: the sedimentary rocks of Washington Land, the rocks underlying Humboldt Glacier, and the soils and rocks of Inglefield Land. The sediments are transported both by ice-rafting and water. Generally, the eastern basin sediments are recent deposits whose heavy mineral fraction is dominated by hypersthene and amphibole. The clay minerals are mostly illite with less than half the smectite content found in the relict sediment of the western trough (KRAVITZ, 1983).

Only Zn in the element distribution maps has a high value zone along the eastern trough area of Kane Basin (Figure 6). The soils and vegetation from Inglefield Land have high Zn concentrations

Table 4. *Pearson product moment correlation coefficients significant at 0.0001.*

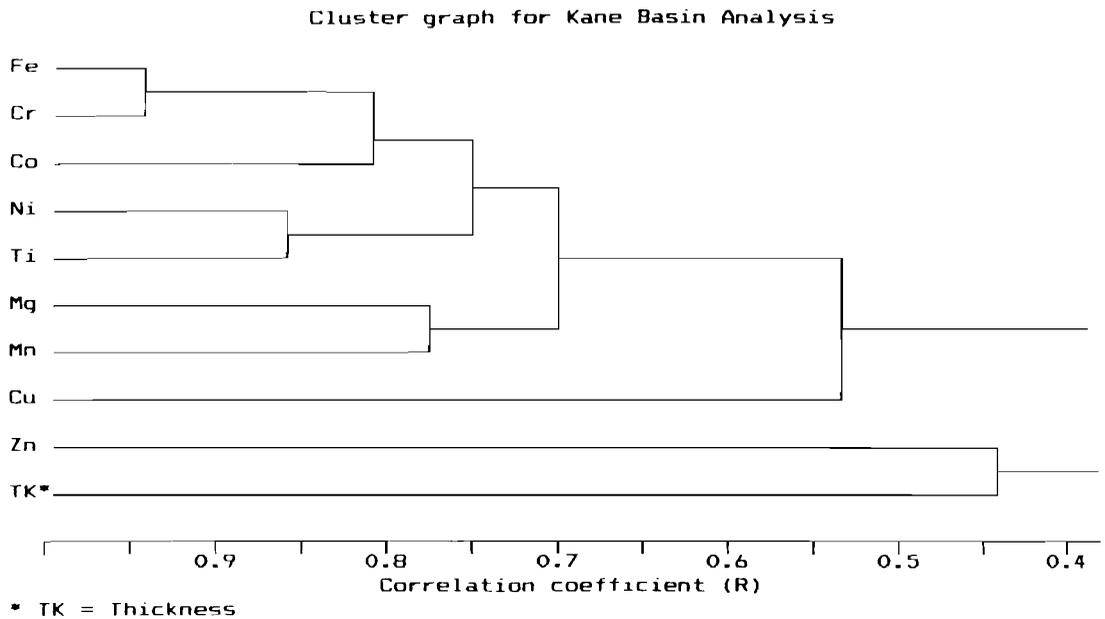|					
Cr-Co	+0.94	Mn-Cr	+0.84	Mn-Mg	+0.71
Mn-Co	+0.92	Mn-Ni	+0.81	Cr-Cu	+0.70
Ni-Co	+0.92	Cr-Zn	+0.77	Ni-Zn	+0.69
Ni-Cr	+0.89	Cr-Ti	+0.75	Fe-Zn	+0.66
Ni-Ti	+0.87	Cr-Mg	+0.75	Ni-Cu	+0.65
Mn-Ti	+0.86	Co-Zn	+0.73	Co-Cu	+0.65
Co-Ti	+0.85	Co-Mg	+0.72	Fe-Cr	+0.64

Cluster graph for Kane Basin Analysis

Figure 8. Cluster analysis of the geochemical data.

(TEDROW, 1970). Material discharged from these source areas into Kane Basin are transported to the southwest along the eastern trough and, therefore, leave the Zn chemical imprint there.

The surface sediment from S-27 (Figure 1) has unusually high concentrations for Fe (14%) and Zn (630 ppm) and relatively high concentrations of the other elements studied. The core contains brown to black-stained lithic fragments and the fine sand fraction contains 18% of opaque heavy minerals and 1% amphibole (KRAVITZ, 1983). It is located where the topographic high plunges to the confluence of the western and eastern topographic lows. The high concentrations of the elements may be due in part to adsorption onto Fe oxide coatings.

We contend that the generalization that glacial-marine argillaceous deep-sea sediments may have a distinct chemical character (concentration deficits with respect to low latitude deep-sea sediments) that can be used in the recognition of glacial-marine paleosediments (NAIDU and HOOD, 1972; NAIDU et al., 1976; DARBY et al., 1989) does not rigorously apply to the < 2 μm size fraction of Kane Basin sediments. NAIDU and his associates have suggested that probably because of the low adsorptive capacity and low influx of volca-

nogenic sediment phases, the glaciomarine sediments they investigated had relatively low elemental concentrations. In our study area, it appears that there are high inputs of some elements from metalliferous terrigenous sources. Consequently, the chemical imprint characteristic of glacial-marine sediments can vary from area to area and is most likely controlled by source area lithology, modified to different degrees by the regime of the depositional environments.

CONCLUSIONS

The regional distribution patterns of Mg, Cr, Co, Mn, Ti, Fe, Ni, Cu and Zn in Kane Basin surface sediments reflects the composition of terrigenous sources supplying detritus to the Basin. The current flow, known best in the western part of the Kane Basin, is southerly from the Arctic Ocean and within the basin is determined by the bottom topography which has western and eastern troughs separated by a topographic high. Sediment discharged from Ellesmere Island is transported and deposited along the western trough. It reflects the chemistry of recently deposited carbonate materials and previously transported relict diamictons containing phyllites and basalt-bearing litharenites and is probably the reason

for the high concentration zones for Mg, Co, Cr, Mn and Ti and to a lesser degree for Fe and Cu. Sediment discharged from eastern basin sources, primarily Inglefield Land, and deposited in the eastern trough, shows a high Zn concentration which may reflect the high Zn concentration in soils and vegetation in this provenance area.

ACKNOWLEDGMENTS

LITERATURE CITED

ADDISON, V.G., 1987. *The Physical Oceanography of the Northern Baffin Bay-Nares Strait Region.* M.S. Thesis, Monterey, California: Naval Postgraduate School.

ANGINO, E.E., 1966. Geochemistry of Antarctic pelagic sediments. *Geochimica et Cosmochimica Acta,* 30, 939–961.

BURRELL, D.C., 1978. Distribution and dynamics of heavy metals in Alaskan shelf environments subject to oil development. Unpublished Annual Report to NOAA Contract No. 03-5-022-56. Institute of Marine Sciences, University of Alaska.

BURRELL, D.C.; TOMMOS K.; NAIDU, A.S., and HOSKON, C.M., 1981. Some geochemical characteristics of Bering Sea sediments. *In:* HOOD, D.W. and CALDER, J.A. (eds.), *The Eastern Bering Shelf: Oceanography and Resources,* Volume 1. Seattle, Washington: University of Washington Press, pp. 305–319.

CRONAN, D.S., 1969. Average abundance of Mn, Fe, Ni, Co, Cu, Pb, Mo, V, Cr, Ti and P in Pacific pelagic clays. *Geochimica et Cosmochimica Acta,* 33, 1562 1565.

DARBY, D.A.; NAIDU, A.S.; MOWATT, T.C., and JONES, G., 1989. Sediment composition and sedimentary processes in the Arctic Ocean. *In:* HERMAN, Y. (ed.), *The Arctic Seas: Climatology, Oceanography, and Biology.* Van Nostrand Reinhold, pp. 657 720.

DAWES, P.R., 1976. Precambrian to Tertiary of northern Greenland. *In:* ESCHER, A. and WATT, W.A. (eds.), *Geology of Greenland.* The Geological Survey of Greenland, Copenhagen, pp. 248–303.

DUNBAR, M., 1979 Fall ice drift in Nares Strait, as observed by sideways-looking airborne radar. *Arctic,* 32, 283–307.

EL WAKEEL, S.K. and RILEY, S.P., 1961. Chemical and mineralogical studies of deep-sea sediments. *Geochimica et Cosmochimica Acta,* 25, 110–146.

FLANAGAN, F.J., 1973. Values for international geochemical reference samples. *Geochimica et Cosmochimica Acta,* 37, 1189–1200.

GOLDBERG, E.D. and ARRHENIUS, G.O.S., 1958. Chemistry of Pacific pelagic sediments. *Geochimica et Cosmochimica Acta,* 13, 153–212.

KERR, J.W., 1967. *Stratigraphy of Central and Eastern Ellesmere Island, Arctic Canada, Pt. 1, Proterozoic and Cambrian.* Geological Survey of Canada Paper 67-27, 63p.

KERR, J.W., 1968. *Stratigraphy of Central and Eastern Ellesmere Island, Arctic Canada Pt. II, Ordovician.* Geological Survey of Canada Paper 67-27.

KERR, J.W., 1976. *Stratigraphy of Central and Eastern Ellesmere Island, Arctic Canada, Pt. III. Upper Ordovician (Richmondian), Silurian and Devonian.* Geological Survey of Canada Bulletin 260.

KRAVITZ, J.H., 1976. Textural and mineralogical characteristics of the surficial sediments of Kane Basin. *Journal of Sedimentary Petrology,* 46, 710–725.

KRAVITZ, J.H. 1982. The 2 μm fraction of some high Arctic glacial and glacial marine sediments. *In:* EMBRY, A.F. and BALKWILL, H.R. (eds.), *Arctic Geology and Geophysics: Symposium Proceedings.* Canadian Society of Petroleum Geologists, Memoir 8, 552p.

KRAVITZ, J.H., 1983. Sediments and sediment processes in a high Arctic glacial-marine basin. Ph.D. Dissertation, Washington, D.C.: The George Washington University, 487p.

KRAVITZ, J.H., 1983. Glacial and glacial-marine sediment lithofacies of the Kane Basin. *In:* MOLINA, B.F. (ed.), *Glacial-Marine Sedimentation.* New York: Plenum Press, pp. 401–449.

KRISHNASWAMI, S., 1976. Authigenic transition elements in pelagic clays. *Geochimica et Cosmochimica Acta,* 40, 425–434.

KRUMBEIN, W.C. and PETTIJOHN, F.J., 1938. *Manual of Sedimentary Petrography.* New York: Appleton-Century-Crofts, 549p.

MEDLIN, J.H.; SUHR, N.H., and BODKIN, J.B., 1969. Atomic absorption analysis of silicates employing LiBO fusion. Atomic Absorption Newsletter, 8, 25–29.

MIALL, A.D., 1982. *Tertiary Sedimentation and Tectonics in the Judge Daly Basin, Northeastern Ellesmere Island, Arctic, Canada.* Geological Survey of Canada Paper 80-30.

MOYNIHAN, M.J., 1972. *Oceanographic Observations in Kane Basin, September 1968 and July-September 1969.* U.S. Coast Guard Oceanographic Report No. 55, 70p.

MUENCH, R.D., 1971. Oceanographic conditions at a fixed location in western Kane Basin, May 1969, *In:* MOYNIHAN, M.J. and MUENCH, R.D. (eds.), *Oceanographic Observations in Kane Basin and Baffin Bay, May and August-October 1969.* U.S. Coast Guard Oceanographic Report No. 44, pp. 1 5.

NAIDU, A.S., 1974. Sedimentation in the Beaufort Sea: A synthesis. *In:* HERMAN, Y. (ed.), *Marine Geology and Oceanography of the Arctic Seas.* New York: Springer-Verlag, pp. 173 190.

NAIDU, A.S. and HOOD, D.W., 1972. Chemical compo-

sition of bottom sediments of the Beaufort Sea, Arctic Ocean. *Proceedings of the 24th International Geological Congress,* Section 10, Canada, pp. 307–317.

NAIDU, A.S.; LEE, C.J., and MOWATT, T.C., 1976. Chemistry of deep-sea sediments in the Canada Basin, west Arctic Ocean. *In:* HOOD, D.W. and BURRELL, D.C. (eds.), *Assessment of the Arctic Marine Environment, Selected Topics.* Fairbanks: University of Alaska, Institute of Marine Science, Occasional Publication No. 4, pp. 121–129.

NAIDU, A.S. and MOWATT, T.C., 1983. Source and dispersal patterns of clay minerals in surface sediments from the continental-shelf areas off Alaska. *Geological Society of America Bulletin,* 94, 841–854.

NAIDU, A.S.; MOWATT, T.C.; HAWKINS, D.B., and HOOD, D.W. 1975. Clay mineralogy and geochemistry of some Arctic Ocean sediments significance on paleoclimate interpretation. *In:* WELLER, G. and BOWLING, S.A. (eds.), *Climate of the Arctic.* Fairbanks: University of Alaska, pp. 59–67.

NAIDU, A.S. and SHARMA, G.D., 1971. *Texture, Mineralogy and Chemistry of Arctic Ocean sediments.* Fairbanks: University of Alaska, Institute of Marine Science, Report, R71-16, 17p.

NAUGLER, F.P.; SILVERBERG, N., and CREAGER, J.S., 1974. Recent sediments of the east Siberian Sea. *In:* HERMAN, Y. (ed.), *Marine Geology and Oceanography of the Arctic Seas.* New York: Springer-Verlag, pp. 191–211.

PELLETIER, B.R. (ed.), with contributions by BORNHOLD, B.D.; BUCKLEY, D.E.; COSTASCHUCK, S.; FORBES, D.L.;

LEWIS, C.F.M.; LEWIS, C.P.; MATSUMOTO, E.; MEAGHER, L.; PELLETIER, B.R.; WALKER, D.A., and WONG, C.S., 1984. *Marine Science Atlas of the Beaufort Sea—Sediments.* Geological Survey of Canada, Miscellaneous Report 38, 29p.

PERRY, R.B., 1961. *A Study of Marine Sediments of the Canadian Eastern Arctic Archipelago.* Fisheries Research Board of Canada, Manuscript Report Series, 89, 80p.

ROBERTSON, D.E., 1977. Natural Distribution of Trace Metals in Three Alaskan Shelf Areas. Unpublished report to NOAA.

ROEDICK, C.A., 1974. Marine gravel deposits of the Beaufort Sea coast and shelf of the Beaufort Sea. *In:* REED, J.C. and SATER, J.E. (eds.), *Proceedings Volume of Beaufort Sea Coast and Shelf Research.* p. 511.

TEDROW, J.C.F., 1970. Soil investigations in Inglefield Land, Greenland. *Meddr. Greenland,* 188, 93p.

TUREKIAN, K.K. and WEDEPOHL, K.H., 1961. Distribution of the elements in some major units of the Earth's crust. *Geological Society of America Bulletin,* 72, 175–192.

UCHUPI, E., 1964. *Sediments and Topography of Kane Basin: Oceanographic Observations Kennedy Channel, Kane Basin, Smith Sound, and Baffin Bay.* U.S. Coast Guard Oceanographic Report No. 5, pp. 61–72.

WEDEPOHL, K.H., 1956. Spureanalytische untersuchungen an tiefseetonen aus dem Atlantik. *Geochimica et Cosmochimica Acta,* 18, 200–231.