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Reports

A Re-examination of the Use of the Silt/Clay Ratios as Indicators of Sedimentary Environments: A Study for Students*

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Gross lithologic aspect, based on textural analysis, is commonly used to identify certain sedimentary environments and consequently the genesis of the sedimentary deposit itself. Studies on fanglomerates, tills, fluvial and marine conglomerates are amongst several examples of this methodology. However, many sedimentary bodies may not include the coarser clastics in their mechanical composition and consequently the finer clastics must be studied in order to determine the sedimentary history of the deposit. Therefore as an additional treatment and evaluation of the analytical data, the silt-clay ratio is used as an aid in distinguishing different environments of sedimentary deposition.

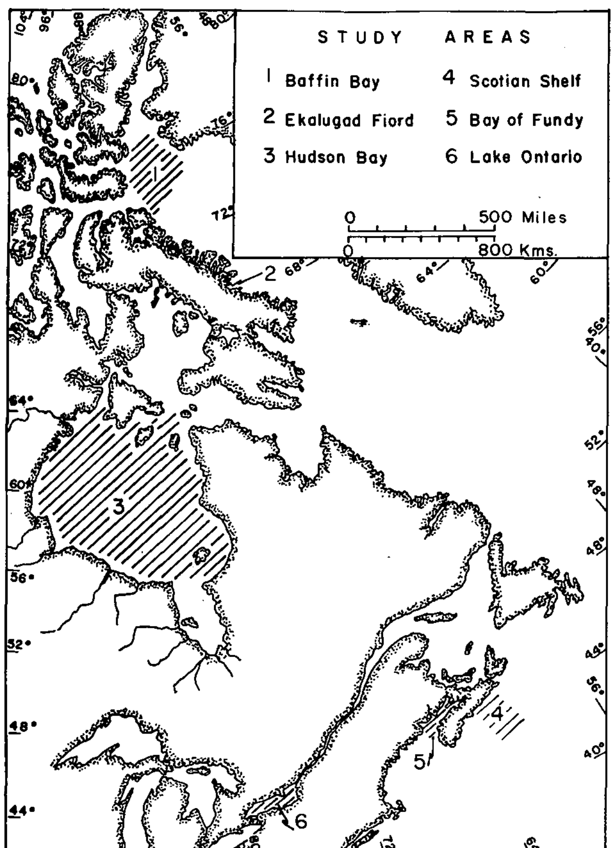

Figure 1 - Location of study areas.

The size frequency curve in Figure 2 illustrates the various major fraction of sediment subjected to textural analyses. In the use of silt/clay analyses many advantages over a similar analyses on the ratios of coarser clastics may be considered as follows: (1) if no coarse material is present, the silt and clay fractions can still be used for interpretative purposes; (2) the fine fractions (silt and clay) emphasize the aspect of low energy fields; (3) by using only the silt and clay, the analysis is not affected by erratic or spurious occurrences of the coarser fractions; (4) the analysis is not affected by errors common to the analysis of coarse material; and (5) the analysis affords a simple method of calculation.

Many investigators such as Doeglas (1946), Favejee (1960), Van Straaten (1963), Nota and Loring (1964), Brambatti and Venzo (1967), and Brambatti (1968) found that the silt/clay ratio was higher in the marine environment than in the non-marine sites of deposition. Many aspects such as mineralogy, electrolytic action of the salts in sea water and the presence of organic substance must be considered in the deposition of silt and clay particles and consequently the resulting silt/clay ratio of the deposit. However, other factors must also be considered when interpreting the significance of this ratio. These factors include the following: the mean grain diameter of the sediment sample; the distance of the sampling site from shore; the depth of water over the sampling site; the available size of sedimentary source material; the availability of transporting energy present from the sedimentary source to the site of deposition; and the inter-relationship of all these factors. It is the purpose of this study to demonstrate these relationships with the silt/clay ratio as a means of understanding sedimentation in various environments.

Methodology

The present study was designed to accommodate most aspects affecting the variability of the silt/clay ratio as observed from the textural analysis on the bulk sample. Samples were studied from both the marine and non-marine water bodies, and from depths of water ranging from those in the inshore zone to those at the bottom of major basins lying beyond the continental shelf. It was also important to consider the aspect of varying hydrodynamic vigour particularly current velocities associated with different sedimentary environments, and to compare sedimentation in different geographic areas. For these reasons the following sites were selected (Fig. 1): (1) Northern Baffin

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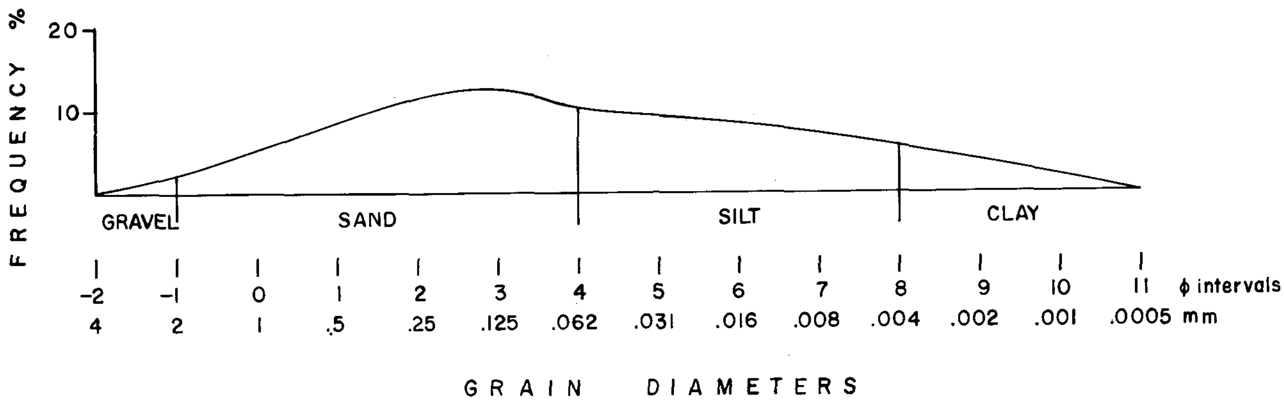

Figure 2 - Schematic frequency distribution curve showing the position of the silt and clay fractions and their designation according to the phi scale.

Bay: a low energy environment in an Arctic oceanic bay of moderate to great depth; current velocity generally less than 15 cm/sec (abststracted from the Pilot of Arctic Canada, 1970); (2)Ekalugad Fiord (Baffin Bay): an intermediate to low energy, glacial-marine environment of shallow depth; no data available on current velocities but they are assumed to be low (personal communications, R.J. Knight); (3) Hudson Bay: the intermediate energy environment of an epicontinental sea of moderate depth in sub-Arctic latitudes; from personal observation with Kelvin Hughes current recorder, velocities of bottom currents are less than 15 cm/sec in the deeper water but range to greater than 50 cm/sec in some western areas of the Bay (e.g. 200 cm/sec at Chesterfield Narrows according to Dohler, 1969); (4) the Atlantic Scotian Shelf: the intermediate to high energy environment of the open ocean in shallow to moderate depths; average current velocities range from 1 to 10 cm/sec in the deeper parts of the shelf to about 15 to 35 cm/sec over the shoals, to greater than 50 cm/sec, and in some cases up to 80 cm/sec, in the immediate inshore areas (abstracted from A.B. Grant and R.F. Reiniger, 1971); (5) the Bay of Fundy: the very high energy environment of a tidal marine bay of shallow to moderate depths, tidal current velocities range from 50 cm/sec to 200 cm/sec but, in certain areas such as Minas Passage have higher velocities which may range from 550 to 770 cm/sec (abstracted from Forrester, 1958, and Bedford Institute, 1966); and (6) Lake Ontario: a low to intermediate energy environment of a fresh-water body in shallow to moderate depths, current velocities range from 5 to 10 cm/sec (personal communication, E.B. Bennett, Canada Centre for Inland Waters, Burlington, Ontario).

Samples were obtained by various workers to whom the author is indebted for making the data available for this study. Such contributions came from the following: A.C. Grant (1970) for the Baffin Bay samples; R.J. Knight (1971) for the Ekalugad Fiord samples; C.J. Yorath (1967) for the Scotian Shelf samples; R.M. McMullen (Pelletier and McMullen, 1971) for Minas Basin (Bay of Fundy system) samples; and R.L. Thomas, A.L.W. Kemp and C.F.M. Lewis (1972) for the Lake Ontario samples. Samples from Hudson Bay (Pelletier, 1969) and Bay of Fundy (Pelletier and McMullen, 1972) were collected on cruises under the direction of the writer, as well as by others (Swift et al, 1973). These individuals carried out or supervised the textural analyses of their samples and prepared the tables of textural data for their respective studies. The writer re-calculated some of these data to obtain the silt/clay ratios and the relative amounts of silt and clay on a basis which considered those sizes less than .063 mm to constitute 100 per cent for each sample. This latter calculation would consider only the silt and clay sizes (Fig. 2).

A series of data analyses were then undertaken to demonstrate the distribution of silt and clay with depth, and the relationship of the silt/clay ratio to the mean diameter of the sediments, and to the sedimentary environment.

Silt Content and the Bathymetric Zones

Bathymetric zones are commonly established on the basis of broad geomorphic features as, for example, the continental shelf and the continental slope. However, the depths of these features are not uniform and the floor of such bodies as Lake Ontario and the Bay of Fundy lack these topographic expressions. Similarly it would be inadvisable to use an arbitrary depth for each zone in all water bodies as such depths would not be consistent with the varied bottom topography. Therefore for the purpose of this study it was decided to use sedimentary textural types to define bathymetric zones.

Textures have been used previously (Thomas *et al*, 1972) to define various depth zones and their relationship to available energy. Because of the general availability of finer sediment sizes, it was decided to relate the finer fractions to arbitrary depth zones. In areas lying beneath wave base, coarser clastics may be absent, but large quantities of silt and clay are generally available. Here

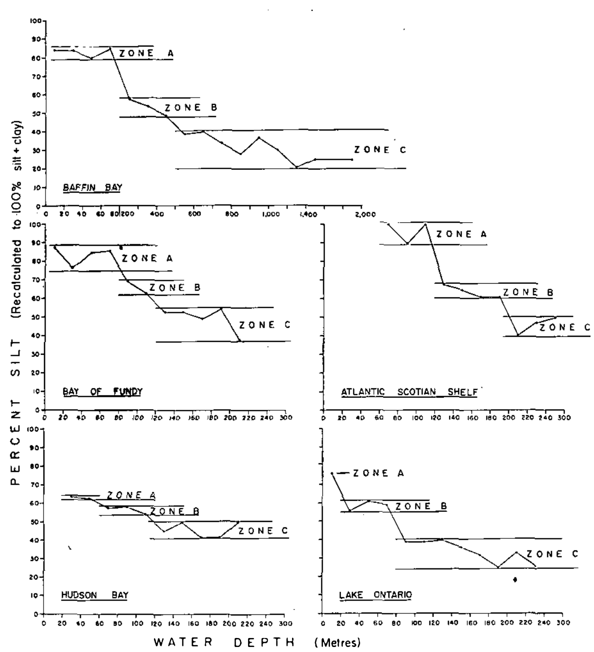

Figure 3 - Plot of percent silt [re-calculated from 100% mud] versus water depth which demonstrates the arbitrary designation of bathymetric zones accoring to the clustering values at different levels.

the silt would reflect the gentle hydrodynamic forces. Near shore where the content of silt is relatively too minor with respect to the large amounts of very coarse sediments usually found there, the movement of the coarse material would respond only to exceptionally competent energy conditions, and the sensitive response of silt to these conditions would be obscured. In cases where the mud content is minor, particularly in shallow water, the silt content may yield more meaningful information when the percentage of silt is re-calculated from a designated mud content of 100 per cent. This operation was carried out merely by excluding from the calculations the percentages of all sediment sizes coarser than silt. These re-calculated values were then averaged for the minor bathymetric zones, recorded in Table 1 (p. 6) and plotted in Figure 3.

In the respective plots for each water body indicated in Figure 1, a grouping of average values (Fig. 3) for certain bathymetric zones was noted. By arbitrarily assigning these values, the major bathymetric zones were inferred as follows: Zone A for shallow depths, Zone B for moderate depths, and Zone C for greater depths. These major bathymetric zones do not correspond in depth from area to area as they are related directly to the amount of silt at a given site. Because conditions governing sedimentation may vary widely from area to area, so the silt content must also vary. Therefore, these zones were designated separately for each water body with relation to the amount of silt in the sediment as silt content appears to represent a wider range of hydrodynamic environments than does the content of the coarser or finer fractions in sediments.

Generally these plots (Fig. 3) bear a similarity with each other except for that of Hudson Bay. Quite possibly the lack of sampling inshore may be reflected in this plot. A similarity exists in the curve drawn through the points in each graph which suggests a uniform process, or combination of processes and factors, acting on the sediments in their transport through the various bathymetric zones.

Percentages of Silt and Clay and Their Relationship to the Bathymetric Zones

Perhaps the best understanding of the silt/clay ratio and its relation to depth can be drawn from a graphical plot showing the percentage of silt versus the percentage of clay calculated from the entire sample and not just from a re-calculated mud content of 100 percent. Various workers have used a two-dimensional plot of percentage silt versus percentage clay, or a modification of this presentation (see Doeglas 1955, 1960, 1961 and Brambatti, 1967). However a general plot of these parameters for each sample and for all depths from a given area would present difficulties in interpretation in that a scatter plot might result due to the overlap of progressive sorting when proceeding from one bathymetric zone to the next. This reflects the fact that the coarser sediments occur near shore and the finer ones are found more exclusively offshore and in deeper water. Consequently the mud content will vary inversely with the coarser sediments as sites further from shore are sampled. Because of this general sediment distribution, the silt and clay percentages will similarly change inversely offshore providing no other processes but sorting are operating. In order to give a synthetic view of this phenomenon, the silt and clay percentages were plotted on graphs (Figs. 4-8) according to the major bathymetric zones A, B, and C which were previously described for Figure 3. They are semi-qualitatively designated as shallow, moderate and deep respectively. These silt/clay plots are also an expression of the silt/clay ratio, so that changes in value of this ratio can readily be detected from one zone to the next.

Generally for Zone A, the values of the silt/clay ratios plot above the 1:1 reference axis, and are consistently higher in a given area than for those values representing Zones B and C. For Zone B the plots of these ratios are dispersed somewhat asymetrically about the 1:1 reference axis with the greater weight of the distribution tending to lie above the reference axis. In all areas (Figs. 4-8) a distinct shift in the plots occurs from Zone A to Zone B in that the ratios generally lie further from the ordinate. This apparent clockwise rotation of the plot is a reflection of decreasing silt content with depth and hence a lower value of the silt/clay ratio.

Also distinctive for Zone B, in contrast to Zone A, is the tendency of the silt/clay ratio to plot further from the origin of the graphs. This phenomenon was noted previously (Pelletier, 1970) for nearshore, shallow-water sediment samples from the Bay of Fundy; that samples obtained near shore tended to have their silt/clay ratios plot closer to the origin of the silt/clay axis than did those occurring further seaward. This observation is interrelated with the fact that with the progressive increase of fines in the sample, the combined percentages of silt and clay approach a value of 100, at which point all values will plot on a diagonal line extending perpendicular to the 1:1 reference axis and intercepting the ordinate and abscissa at their respective 100 percentiles. (This is also the case when the silt and clay percentages are re-calculated on the basis of 100 percent mud, because only the fines are included in the calculation). In Zone B the tendency of the silt/clay ratios to plot along the 100 percent silt/clay line is apparent for those sediments from Hudson Bay (Fig. 5), Bay of Fundy (Fig. 7) and Lake Ontario (Fig. 8).

For Zone C in all areas, the shift in the plot of the silt/clay ratios away from the ordinate is evident. In certain cases such as the plots for Baffin Bay (Fig. 4), the Scotian Shelf (Fig. 5), and Lake Ontario (Fig. 6) this apparent clockwise rotation of the plots is a manifestation of the fact that almost all values of the silt/clay ratio lie beneath the 1:1 reference axis. This is due to the decreasing silt content and hence a lower silt/clay ratio. Also evident is the tendency for the ratios to plot near the 100 percent silt/clay line as demonstrated for Baffin Bay (Fig. 4), Hudson Bay (Fig. 5) and Lake Ontario (Fig. 6).

In order to explain these shifts in the silt/clay ratios proceeding from Zone A through to Zone B, it appears that water depth, distance from shore and hydrodynamic vigour are the main factors to be considered. The tendency of the silt/clay ratio is to become progressively smaller as water depth and distance from shore increase, and hydrodynamic vigour consequently decreases. Under such progressive conditions all ratios should eventually plot increasingly closer to the 100 percent silt/clay line, and ultimately coincide with the 100 percentile on the abscissa or clay axis. This trend appears to be the case for sediments from Baffin Bay (Fig. 4), Hudson Bay (Fig. 5) and Lake Ontario (Fig. 6). For the sediments from the Bay of Fundy (Fig. 7) and the Scotian Shelf (Fig. 8) this trend is not readily apparent and its lack of development may be due to conditions of greater hydrodynamic vigour. Such conditions would tend to yield an erosional regime by keeping the finest particles in a continuous state of transport.

This erosive action would still yield silt/clay ratios that could plot near, or on, the silt/clay line; however, it would also maintain a high silt/clay ratio and thus restrict the trend of the silt/clay ratio to develop toward the zero value located at the 100 percentile of the abscissa. In summary the following relationships are apparent: a decrease in the silty/clay ratio results from (1) increased depth, (2) distance from shore, and (3) decreasing competence.

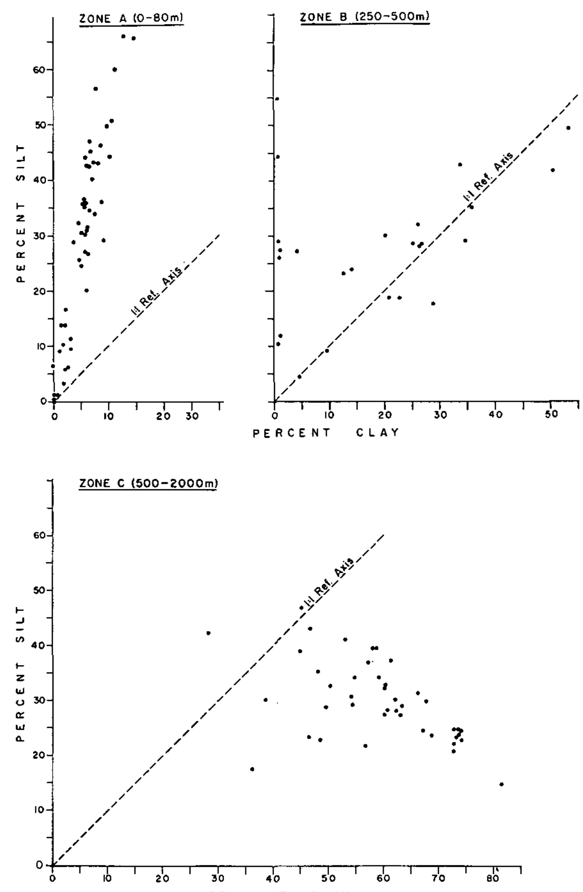

Figure 4 - Plot of percentage silt vs percentage clay for samples from Ekalugad Fiord [Zone A] and Baffin Bay [Aones B and C]. Data after R.J. Knight [1971] and A.C. Grant [1970]. Note: the 1.1 reference axis is used for convenience when examining the dispersal of the plot from Zone to Zone and area to area.

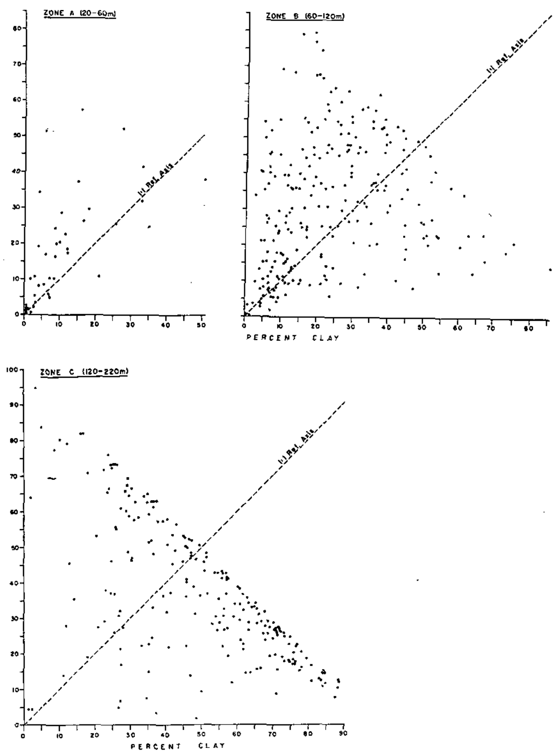

Figure 5 - Plot of percentage silt vs percentage clay for samples from Hudson Bay. Data after B.R. Pelletier [1969].

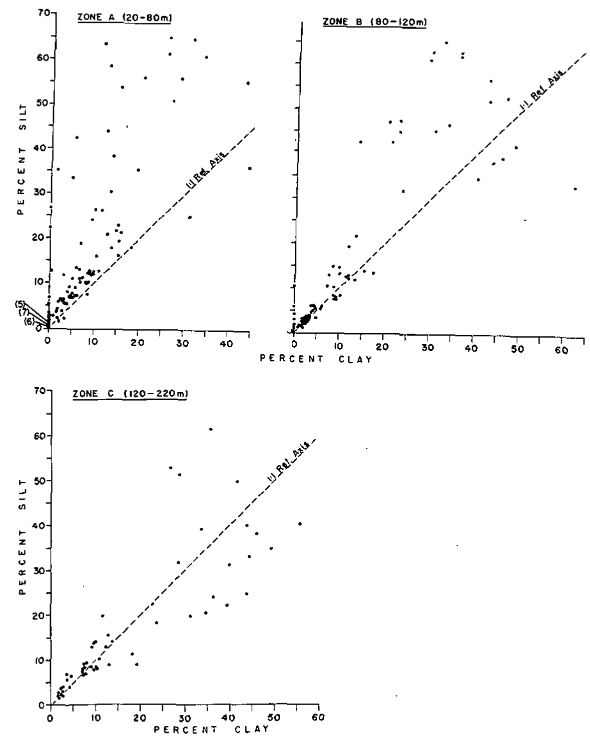

Figure 7 - Plot of percentage silt vs percentage clay for samples from the Bay of Fundy system. Data after B.R. Pelletier and R.M. McMullen [1972].

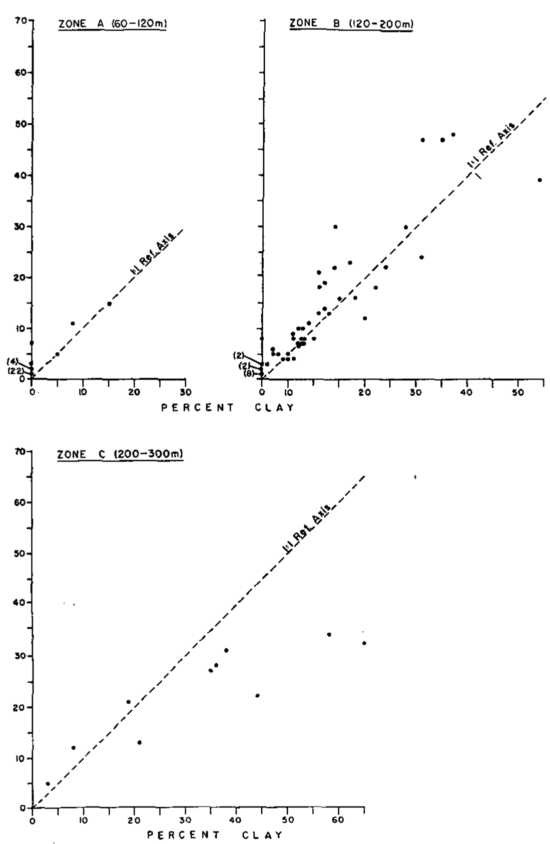

Figure 6 - Plot of percentage silt vs percentage clay for samples from the Atlantic Scotian Shelf. Data after C.J. Yorath [1967].

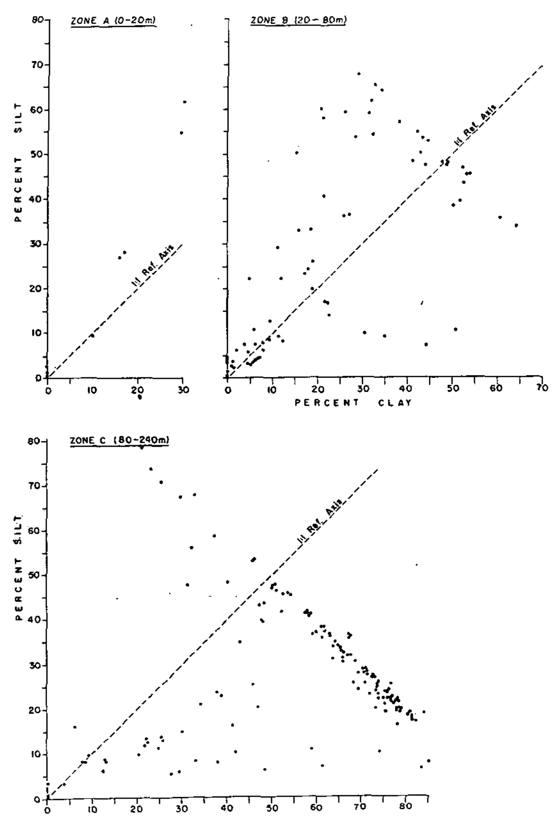

Figure 8 - Plot of percentage silt vs percentage clay for samples from Lake Ontario. Data from R.L. Thomas, A.L.W. Kemp and C.F.M. Lewis [1972].

Table 1 - Relationship of Average Silt/Clay Ratio and Silt Content (Re-calculated from 100% Silt + Clay), to Mean Grain Diameter ($\bar{x}$ ϕ) and Minor Bathymetric Zones in Various Hydrodynamic Environments

A. BAFFIN BAY:

Depth Ranges

Ekalugad Fiord (data from R.J. Knight, 1971)

Textural	0	20-	40-	60-
Parameters	20	40	60	80
Silt/Clay	5.41	5.35	5.97	5.4
Silt %	83.9	83.3	79.6	84.3
$\bar{x}$ ϕ	2.8	3.75	4.34	5.55

Northern Baffin Bay (data from A.C. Grant, 1970)

Textural	200-	300-	400-	500-	600-	700-	800-	900-	1000-	1200-	1400-	1600-	1800-
Parameters	300	400	500	600	700	800	900	1000	1200	1400	1600	1800	2000
Silt/Clay	1.41	1.39	0.93	0.64	0.62	0.44	0.39	0.58	0.45	0.26	0.35	-	0.32
Silt %	57.1	53.2	48.1	38.1	39.4	33.2	27.7	36.1	29.9	20.6	24.8	-	24.4
$\bar{x}$ ϕ	3.32	5.36	5.46	7.74	7.02	8.55	8.62	8.17	8.32	8.97	8.86	-	8.86

B. BAY OF FUNDY: (data from B.R. Pelletier and R.M. McMullen, 1972; and D.J.W. Swift *et al.*, 1973)

Textural	0-	20-	40-	60-	80-	100-	120-	140-	160-	180-	200-
Parameters	20	40	60	80	100	120	140	160	180	200	220
Silt/Clay	5.36	3.1	4.98	3.93	4.58	2.96	1.13	1.15	1.0	.93	.60
Silt %	81.0	76.1	84.4	85.7	69.0	62.7	52.5	52.5	48.8	52.2	37.7
$\bar{x}$ ϕ	2.59	1.75	.96	1.27	1.0	1.5	2.65	2.5	2.96	1.93	3.71

C. ATLANTIC SCOTIAN SHELF: (data after C.J. Yorath, 1967)

Textural	0-	20-	40-	60-	80-	100-	120-	140-	160-	180-	200-	220	240-	300
Parameters	20	40	60	80	100	120	140	160	180	200	220	240		
Silt/Clay	-	-	-	4	3.38	4	2.93	1.84	2.36	1.76	.72	.95	1.09	
Silt %	-	-	-	100	89.9	100.0	67.1	64.7	70.78	60.7	40.0	46.9	49.3	
$\bar{x}$ ϕ	-	-	-	1.06	1.39	.63	2.53	3.96	3.26	3.70	6.33	5.77	5.50	

D. HUDSON BAY: (data after B.R. Pelletier, 1969)

Textural	0-	20-	40-	60-	80-	100-	120-	140-	160-	180-	200-	220-
Parameters	20	40	60	80	100	120	140	160	180	200	220	240
Silt/Clay	-	1.8	2.3	1.72	1.86	2.18	1.63	.96	1.35	1.28	.89	1.23
Silt %	-	63.3	62.8	57.1	58.3	58.0	54.0	44.6	49.7	41.5	4.12	49.8
$\bar{x}$ ϕ	-	.78	1.46	2.26	2.16	4.06	4.87	6.06	6.01	6.95	6.69	5.96

E. LAKE ONTARIO: (data after R.L. Thomas, A.L.W. Kemp and C.F.M. Lewis, 1972)

Textural	0-	20-	40-	60-	80-	100-	120-	140-	160-	180-	200-	220-
Parameters	20	40	60	80	100	120	140	160	180	200	220	240
Silt/Clay	2.63	1.72	1.74	1.77	0.92	.75	.84	.72	.58	.36	0.55	0.35
Silt %	75.7	55.7	60.7	58.9	38.6	38.6	39.6	35.8	31.6	24.5	32.7	25.1
$\bar{x}$ ϕ	3.8	4.75	4.1	4.7	6.0	6.7	7.77	8.00	8.38	8.4	8.4	8.9

Table 2 - Frequency and Threshold Values of 1277 Silt/Clay Ratios for the Study Areas. (Threshold Values Underscored)

Silt/Clay Ratios	STUDY AREAS Baffin Bay	Ekalugad	Bay of Fundy	Lake Ontario	Hudson Bay	Scotian Shelf
0 - 1	53	1	47	163	233	17
1 - 2	13	1	112	45	147	32
2 - 3		3	24	12	70	2
3 - 4		4	4	4	26	2
4 - 5		8	1	1	8	
5 - 6		13	1		7	
6 - 7	1	9	1		6	
7 - 8		7			6	
8 - 9			1		2	
9 - 10					3	
10 - 11					1	
11 - 12						
12 - 13						
13 - 14						1
14 - 15						
15 - 16						
16 - 17						1
17 - 18						1
18 - 19						
19 - ∞			3	1	2	1
∞		3	108	21		42
TOTALS	67	51	302	247	514	96

In determining the average values of the silt/clay ratios for given bathymetric zones, certain high values tended to weight the average and produce spuriously high averages. Values of infinity were common, and this occurrence also posed a similar problem in moments. In order to obviate this effect of moments, a threshold value of the silt/clay ratio was selected separately for each environment. This value was selected on the basis of clustering of the calculated values according to frequency as shown in Table 2. The higher terminal limit (or ratio) of the cluster was selected as the value for converting all higher ratios to a threshold value. For cases in which the frequency of the ratios decreased gradually over several intervals of the silt/clay ratio, an arbitrary designation of approximately 95% of the total number of samples (exclusive of those yielding a silt/clay ratio of infinity) was chosen as the threshold. All other higher ratios, including those of infinity, were then converted to the highest ratio of the designated cluster.

This converted value of the silt/clay ratio is an artificial limitation. However it can also be inferred approximately by an examination of the relationship between the percentage of silt and the silt/clay ratio itself. Because the silt content increases inversely with the decrease in clay, the silt/clay ratio must correspondingly increase. Therefore a theoretical plot of the silt/clay ratio versus silt percentages (Fig. 9) will show an asymptotic relationship to a line lying parallel to the ordinate at some distance from the origin for increasing values of silt content and silt/clay ratios. A change in high values of the silt/clay ratio then would have very little meaning with reference to the silt content, but a similar change in the lower ratios would have more significance. For example, an increase in the ratio from 9 to 10 would mean a corresponding increase in relative percent of silt of less than one per cent; but an increase in the ratio from 1 to 2 would mean a corresponding increase in relative

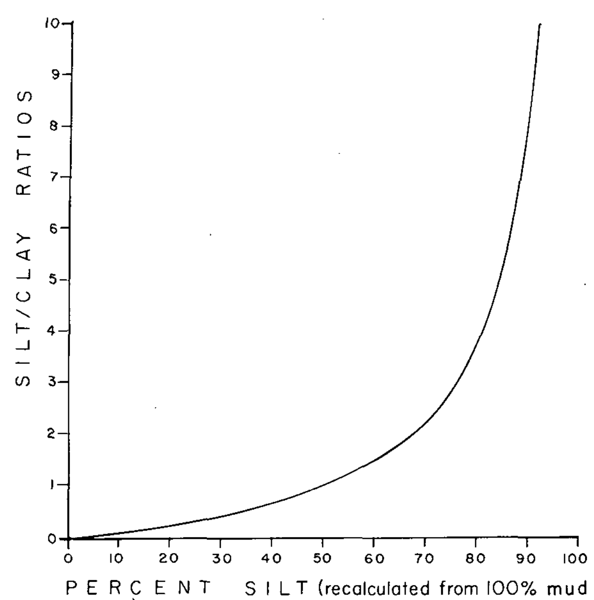

Figure 9 - The Asymptotic relationship of the silt/clay ratios vs silt percentage.

percent of silt of almost 17 percent. Because the slope of this asymptotic curve is effectively constant above values of 8 and the rate of change of gradient increases around 3 and lower, the threshold values of the silt/clay ratio of Table 2 can easily fall within the range of the silt/clay ratios of 3 to 8. Those threshold values selected in Table 2 may not be ideal, but within one or two units they are practical for the purpose of this preliminary study.

All silt/clay ratios are illustrated for each study area (see Figs. 4-8). However, the relationship of these ratios to the mean diameter of the sediment is not easily discernible in these figures but is apparent from the data of Table 1 and the graph in Figure 10. In this latter illustration, the average silt/clay ratio is plotted against the average of the phi mean diameter for each sample from the given minor bathymetric zone. The graph shows generally, that the higher silt/clay ratios are associated with the larger mean diameters and, as expected, the lower ratios are associated with the finer sediments. Although some of the higher silt/clay ratios are plotted in artificial positions due to the arbitrary assignment of the threshold values for these ratios, the relationship of the silt/clay ratio to the average mean diameter is clearly established: the ratios decrease with decreasing grain size.

As a corollary to this observation, the upper end of the curve must be examined and its shape discussed. Although the data are meagre for this plot, sufficient are on hand to suggest a possible asymptotic relationship of the increasing silt/clay ratio and increasing mean diameters. This is expected for a dynamic situation in which the finer particles are being eliminated by various agents of erosion, or a lack of deposition of fines, and the sediment is converted to a lag deposit. This lag deposit will consist of increasingly coarser particles, by virtue of elimination of the finer particles, and the deposit will tend to gravel sizes as an end product. As the clay is removed from the deposit and the relative silt content increases, the values of the silt/clay ratio must approach infinity and therefore, the curve at this upper end must become asymptotic to the abscissa.

Another important aspect of the silt/clay ratio-mean diameter plot (Fig. 10) is the degree of dispersion of the points about the curve. The data are widely dispersed in the coarser sediments, but plot closer to the curve with decreasing mean size. With the finest sizes, very little dispersion occurs at all. According to a suggestion by D.E. Buckley (Atlantic Geoscience Centre, personal communication), the scatter of points for cases in which the mean size is large is likely a reflection of the analyses when the clay size fraction is minimal. It therefore can be interpreted as an analytical and mathematical expression of the abundance of fine material.

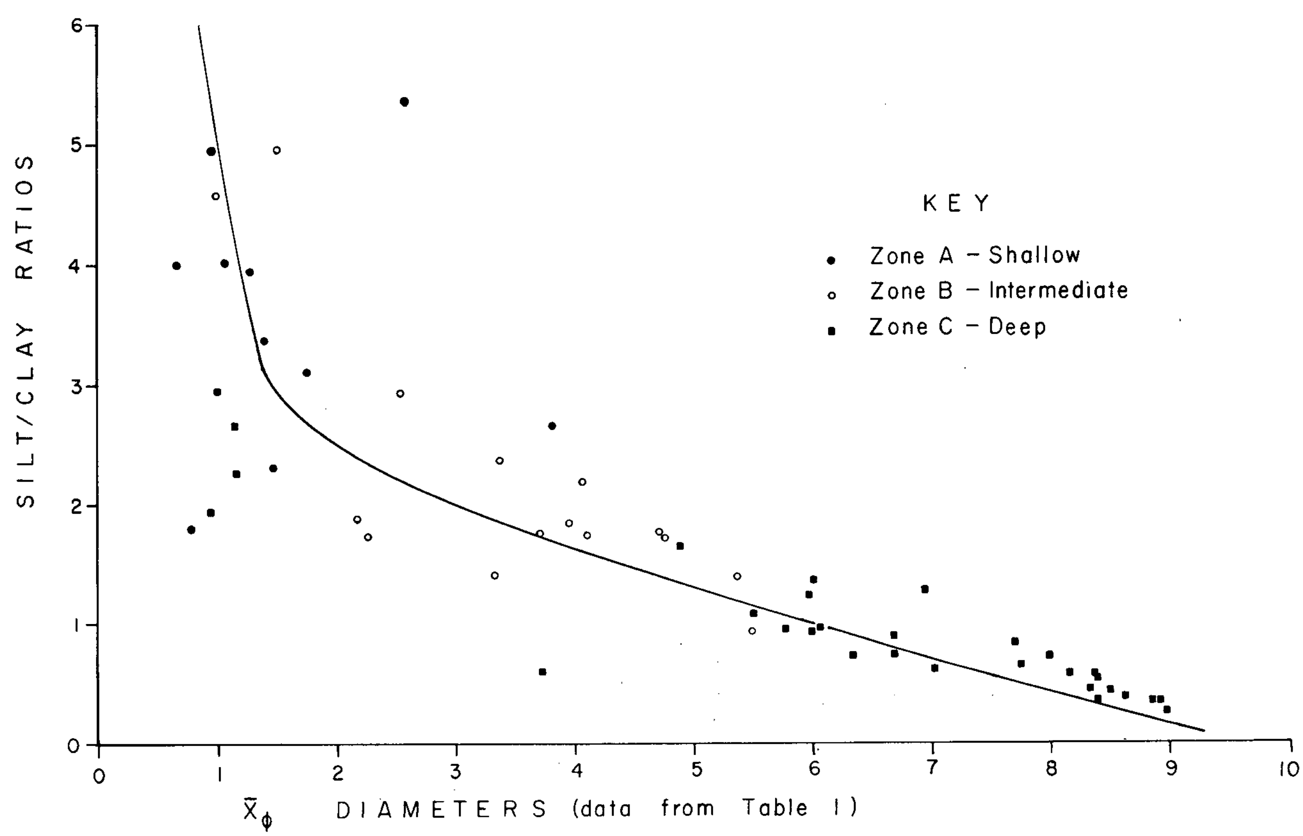

Figure 10 - The Asymptotic relationship of the silt/clay ratio and the phi mean diameter.

Table 3 - Summary of Relationships of Average Silt/Clay Ratios and Silt Content (Re-calculated from 100% Silt + Clay), to Mean Grain Diameter ($\bar{x}$ ϕ) and Major Bathymetric Zones in Various Hydrodynamic Environments

BAFFIN BAY:

Textural Parameters	Ekalugad Fiord (shelf) Zone A (0-80 m)	Northern Baffin Bay Zone B (200-500 m)	Upper (B) and Lower (C) Slopes Zone C (500-2000 m)
Silt/Clay	5.54	1.23	0.54
Silt %	82.54	51.50	34.40
$\bar{x}$ ϕ	3.92	5.14	7.85

BAY OF FUNDY:

Textural Parameters	Shallow Zone A (0-80 m)	Intermediate Zone B (80-120 m)	Deep Zone C (120-230 m)
Silt/Clay	4.58	2.45	1.04
Silt %	85.3	66.7	50.0
$\bar{x}$ ϕ	1.61	2.12	2.51

ATLANTIC SCOTIAN SHELF:

Textural Parameters	Banks Zone A (60-120 m)	Local Slopes Zone B (120-200 m)	Lower Slopes & Deeps Zone C (200-300 m)
Silt/Clay	3.73	1.97	.90
Silt %	95.6	64.7	45.0
$\bar{x}$ ϕ	1.48	3.7	5.86

HUDSON BAY:

Textural Parameters	Inner Shelf Zone A (20-60 m)	Outer Shelf Zone B (60-140 m)	Slope and Deeps Zone C (140-240 m)
Silt/Clay	2.22	1.45	1.13
Silt %	62.9	56.5	44.9
$\bar{x}$ ϕ	1.34	2.01	6.11

LAKE ONTARIO:

Textural Parameters	Shallow Inshore Zone A (0-20 m)	Intermediate Zone B (20-80 m)	Slopes and Basins Zone C (80-240 m)
Silt/Clay	2.63	1.77	.72
Silt %	75.7	58.2	35.0
$\bar{x}$ ϕ	3.8	4.5	7.66

The Relationship of the Silt/Clay Ratio, Sediment Size and Bathymetry to Hydrodynamic Vigour

Pertinent textural data such as the silt/clay ratio, the silt content re-calculated from a designated mud content of 100 percent, and the phi mean diameter of the sediment sample were averaged for all major bathymetric zones in each study area and recorded in Table 3. Without exception, and for each study area, a decrease in the value of these parameters takes place progressively from Zone A to Zone B, and finally to Zone C. As stated earlier, these changes appear to be inter-related with each other and appear to be related to the available energy in the sedimentary environment. The values of the textural data are related mathematically also, and therefore must coincide.

Exclusive of the silt content, the inter-relationships of these factors with reference to arbitrarily designated energy boundaries are depicted schematically in Figure 11. These energy boundaries are determined on the basis of the silt/clay ratio and the mean diameter of the sediment in combination with bathymetry and current velocities.

The combination of high silt/clay ratios, coarse mean diameters, and large silt content is found in the inshore sediments of Zone A from the Scotian Shelf and Bay of Fundy. Such sediments are interpreted as products of a high energy environment. Although the sediments from Ekalugad Bay properly belong to Zone A on the basis of bathymetry and silt content, they fall below the high energy area (Fig. 11) despite

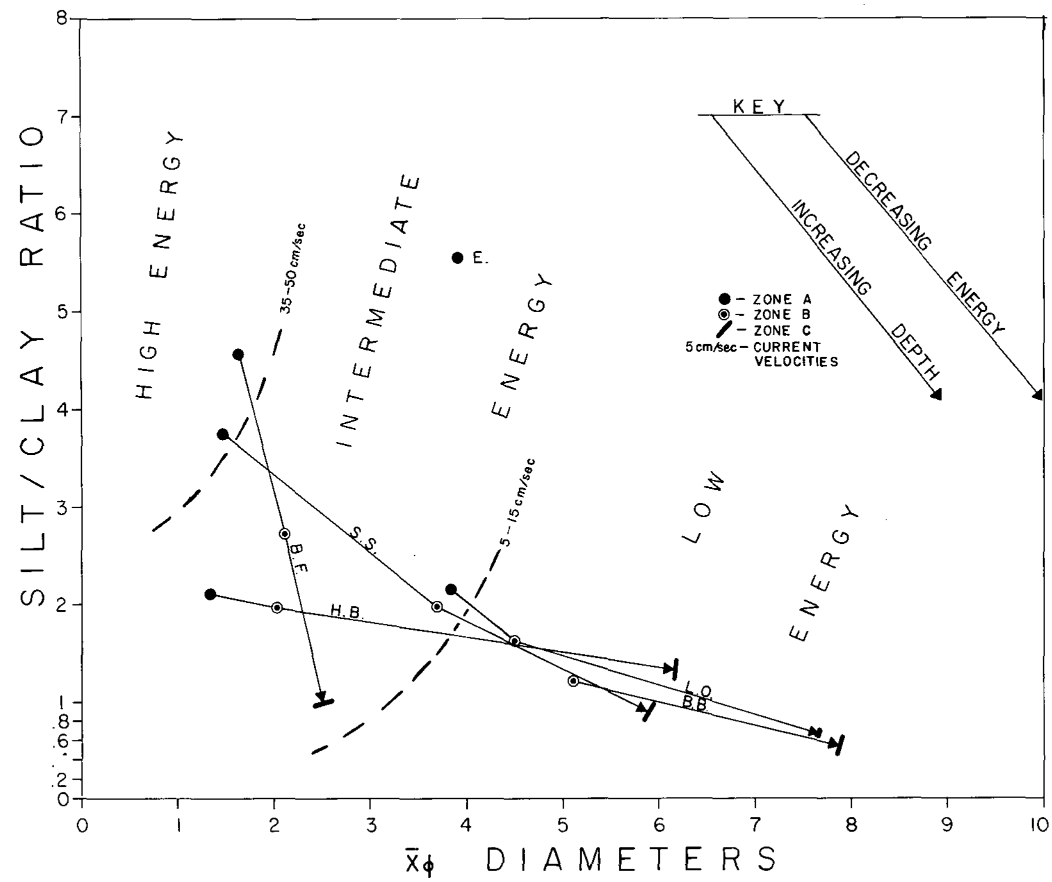

Figure 11 - Schematic representation showing the relationships of the silt/clay ratio and the phi mean diameter to [1] arbitrarily designated energy zones and [2] textural-bathymetric zones. [E-Ekalugad Fiord; SS-Scotian Shelf; B.F.-Bay of Fundy; HB-Hudson Bay; L.O.-Lake Ontario; and B.B.-Baffin Bay]. The solid line represents plot of curves from Zone A to Zone B to Zone C. Dashed line represents arbitrary boundary between energy fields, with approximate range of current velocities for those boundaries.

their high silt/clay ratios. This is due to the absence of sufficient hydrodynamic vigour. The weaker currents have permitted the deposition of fine sediments, which has produced a deposit with a small mean diameter. Therefore the mean diameter appears to be more significant than the silt/clay ratio as the constraining element in defining the energy boundaries.

In several cases the silt/clay ratios, and the mean sediment diameters are sufficiently large to require an intermediate level of energy to affect moderate sorting. These sediments which occur in the intermediate energy field are from the following: Zone A in Baffin Bay (Ekalugad Fiord), Zone A in Lake Ontario, Zone B over the Scotian Shelf, and Zones B and C in the Bay of Fundy and Hudson Bay. All other sediments are from an environment of low energy and include Zones B and C, from Lake Ontario and Baffin Bay, and Zone C from Hudson Bay.

Although the position and direction of the boundaries of the energy fields are speculative, the schematic representation of Figure 11, which infers decreasing energy with increasing depth resulting in decreasing sediment size, silt content and silt/clay ratios, appears to hold fairly consistently. Considerably more work is required to relate actual energy values to the plot of silt/clay ratios versus mean sediment diameters. The position and direction of the energy boundaries can then be reliably established.

Summary and Conclusions

The silt/clay ratio may be used for the purpose of distinguishing aqueous environments of deposition providing the following inter-relationship are understood: (1) nature and availability of material at the source area, (2) distance from source area, (3) depth of water, (4) energy available at the site of deposition, and (5) the action of electrolytes in sea water as well as other chemical, biochemical and organic processes. Generally the silt/clay ratio is higher in the marine environment than in the lacustrine, due mainly to the action of electrolytes on suspended sediments in the sea. However in deep marine waters, the silt/clay ratios have the same low values as those for sediments in the much shallower lacustrine bodies.

In the lacustrine and marine environment the silt/clay ratio generally decreases with the following: (1) a decrease in the mean size of the sediment, (2) increasing remoteness from shore, (3) increasing water depth, and (4) decreasing hydrodynamic vigour. The factor of progressive sorting is important and, in any given environment, the above relationships should hold. However if apparently anomalous situations arise, then the major factors listed here must be examined to determine in which area of their analyses the discrepancy lies. In any given environment the principles of mechanical sedimentation, such as those describing erosion, transportation and deposition should hold; therefore, it follows that deviant cases must be examined further in order to establish the correct environmental framework, and to determine the degree to which the sedimentary processes went to completion for that environment.

Data from these studies illustrate another significant observation that geological detritus undergoing erosion and sedimentary transport will tend, through the process of progressive sorting, toward the clay fraction as an end-member product providing the sedimentary processes tend toward decreasing energy. Thus through a study of the silt/clay ratio it becomes apparent that a ratio of zero is the ultimate of these processes. As such this zero ratio truly represents a zero transport potential for detritus undergoing mechanical sedimentation.

Other observations to support this concept of zero transport potential are as follows: (1) silt content relative to clay decreases with depth so that the respective silt/clay percentages will change progressively and inversely until the zero potential is reached; and (2) the scatter of the silt/clay ratios is greater with coarser sediments than with the finer ones.

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