13. STUDY OF SOME SAMPLES OF HOLE 398D, LEG 47B, WITH THE CORRESPONDENCE ANALYSIS METHOD

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ABSTRACT

The Cretaceous strata of Hole 398D (Cores 56 to 138) were studied by the correspondence analysis method to discover possible relationships between various sediments and their mineralogical components within the multivariate data set. This analysis defines variation trends in a given data set which are called factors and shown by associations or oppositions between components. Then samples and their components are plotted in the space defined by these factors.

The principal results of the correspondence analysis reveal: (a) the distribution of the samples as a result of calcite-silicate opposition; (b) the importance of the appearance of attapulgite in Core 78; (c) the black shales data set (Cores 56 to 99) explained by opposition between the carbonate and clay components and the content of attapulgite; (d) the remarkable regularity in the mineralogical composition of the hemipelagic sediments in Cores 78 to 99; and (e) the dispersion of hemipelagites in Cores 100 to 138 related to the depth of sedimentation with respect to the CCD, where the role of diagenesis is emphasized.

The average mineralogical composition of the hemipelagites is computed for the different sedimentary units (with minimum standard deviation), and the evolution between the different units is characterized.

DATA SET

This study involves 217 samples from Cores 56 to 138. Percentages are given for each sample's mineralogical components: calcite, quartz, K-feldspars, pyrite, and the clay fraction (including illite, chlorite, montmorillonite, attapulgite, and kaolinite). Various facies are considered, such as high and low carbonate, mudstone, silt, sand, debris flow, and mud flow.

CORRESPONDENCE ANALYSIS

The aim of correspondence analysis is to discover relationships between samples and their components within a multivariate data set. Every sample and element is "weighted," i.e., each value is divided by the sum of all values to give a bi-dimensional probability distribution. The correlation parameter associated with this distribution is chosen to be the metric χ^2 distance. Two symmetrical matrices are established, one containing the distances between samples and one of the distances between components.

From these matrices (representing the spaces R^J and R^I where J and I are, respectively, the number of elements and samples), eigen vectors and eigen values are extracted. These vectors and values provide factors which express trends of variation in the data set. Both samples and components are plotted on the same plane of factorial axes. To help evaluate a factor's significance, the absolute contribution of every sample and component is calculated. This value expresses the amount contributed by that sample or component to the dispersion along the factor, and enables the recognition of the samples or components which are responsible for the appearance of this factor.

Details of this method are described in Benzecri (1979) and Teil (1975).

PREPARATION OF THE DATA SET

For each mineral component, the complete data set is plotted on histograms (Figure 1). Four classes of percentages are defined for a given component according to the profile of the histogram (Table 1); however, only the presence or absence is defined for attapulgite, pyrite, zeolite, pyroxene, and feldspars. As a result of reducing the too extreme variations of some components, e.g., calcite and attapulgite, possible associations and oppositions between components are more easily discovered. Moreover, the importance of error due to mineral misidentifications is diminished because the standard deviation in each class is greater than the error due to mineralogical analysis (5 to 10%).

RESULTS OF ANALYSIS

Analysis of the Samples as a Whole

The results of analysis of the matrix (217 X 10) for three factorial axes are as follows:

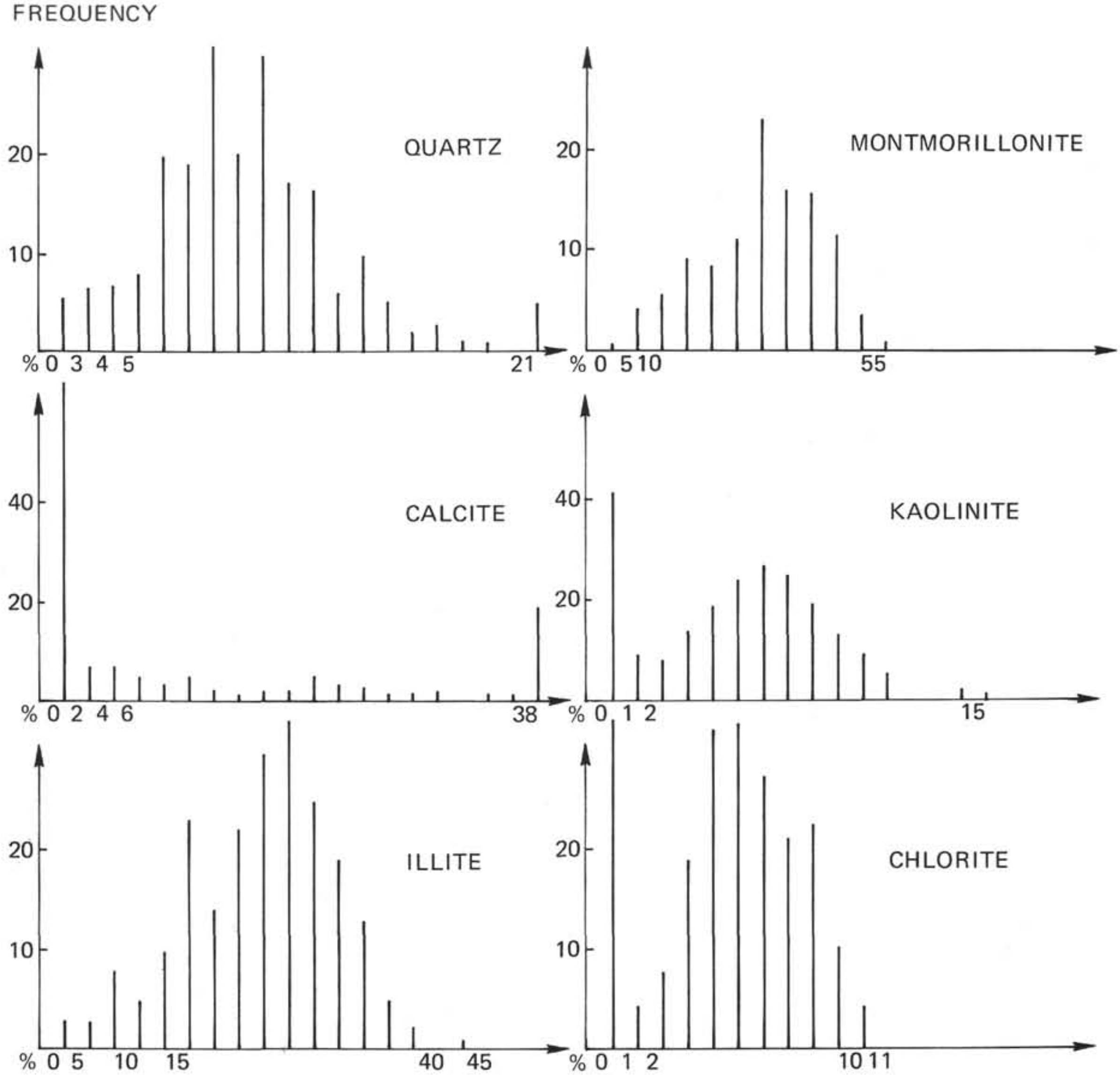

Figure 1. *Histogram of different mineral components.*

Factor 1 (38.6%)[a]	Factor 2 (22.1%)	Factor 3 (12.9%)
Calcite: (−69)[b]	Pyrite (−14)	Montmorillonite (−17)
Kaolinite: (13)	Calcite (−12)	Attapulgite (26)
	Attapulgite (52)	Pyrite (13)

[a]Percentage of the total of the data "cloud."
[b]Absolute contribution of the component to the factor, negative signs characterize non-association between components.

The first factor, calcite-kaolinite opposition, indicates the well-known opposition between carbonate and the silicate contributions. The geological significance of Factors 2 and 3 is cancelled partially by the presence of attapulgite, which affects samples from Cores 60 to 78. Nevertheless, these factors show that the presence of attapulgite above Core 78 takes place in a non-carbonate environment. An ellipse is

TABLE 1
Classes of Percentages Based on Histograms

Component	0	1	2	3
Pyrite	0	>0		
Pyroxene	0	>0		
Quartz	⩽6	6-9	9-12	⩾12
K-feldspar	0	>0		
Plagioclase	0	>0		
Calcite	<2	2-10	10-40	⩾40
Attapulgite	0	>0		
Kaolinite	<3	3-6	6-8	⩾ 8
Illite	0	0-20	20-30	⩾30
Chlorite	⩽1	1-5	5-7	⩾ 7
Montmorillonite	0	0-30	30-40	⩾40
Zeolite	0	>0		

computed (Figure 2) which shows the scatter of samples for a given facies. Note the broad dispersal of hemipelagites (Figure 2, ellipse 2) and clastic input (ellipses 3 and 4) with respect to the relative concentration of calcareous mud (from Cores 131 to 138) and sand, which both trend to the calcite pole. This analysis provides general information on the importance of the opposition of clay and carbonate and the mineralogical scatter of different facies. More interesting and detailed results are obtained in the following analysis which deals with a further reduced data set.

Analysis of the Black-Shales (Cores 56 to 99)

Factor 1 (51.4%)	Factor 2 (14.3%)	Factor 3 (12%)
Kaolinite (−14)	Calcite (−21)	Montmorillonite (−9)
Chlorite (−15)	Kaolinite (−11)	Quartz (−5)
Calcite (48)	Attapulgite (60)	K-feldspar (−6)
		Pyrite (63)
		Calcite (9)

The oppositions seen in Analysis 1 are present in this analysis, probably showing that some factors which govern sedimentation remain active from Hauterivian (Core 138) to Cenomanian time (Core 56). Factor 1 again shows opposition between the carbonate and clay fractions. The geochemical significance of Factor 2 is now more evident even though the total inertia is low. Attapulgite develops at the expense of kaolinite and calcite. The third factor, which is of lesser importance, may be related partly to the degree of diagenesis because the most clearly diagenetic mineral is pyrite, and partly to the type of supply (terrigenous or carbonate).

Stratigraphically, the factorial analysis differentiates between Cores 78 to 99, which have approximately the same behavior; Cores 65 to 78, where attapulgite appears; and the more calcitic Cores 60 to 65, which initiate a trend towards the higher $CaCO_3$ content of Cores 57 to 59 (see Figure 3, arrows).

Analysis Without the Black-Shales" (Cores 100 to 138)

Factor 1 (45.2%)	Factor 2 (19.4%)	Factor 3 (10.2%)
Calcite (−76)	Montmorillonite (−34)	K-feldspars (−46)
Kaolinite (10)	Pyrite (4)	Quartz (−15)
		Kaolinite (17)
		Pyrite (11)

This analysis defines several groups in the various hemipelagic sediments along the factorial axis (Figure 4).

The first group consists of Cores 131 to 138, which are known to have high levels of $CaCO_3$ and were deposited above the CCD. Second is the group encompassing Cores 128 to 131, which have peculiarities caused by high content of pyrite and kaolinite. The third group is a wider set from Cores 100 to 120, which are less differentiated. Fourth is an intermediate group (Cores 120 to 128) between no. 1 and no. 3 that is the result of having a depositional depth close to the CCD, as shown by other methods (de Graciansky et al., this volume). These four groups are related to the position of the

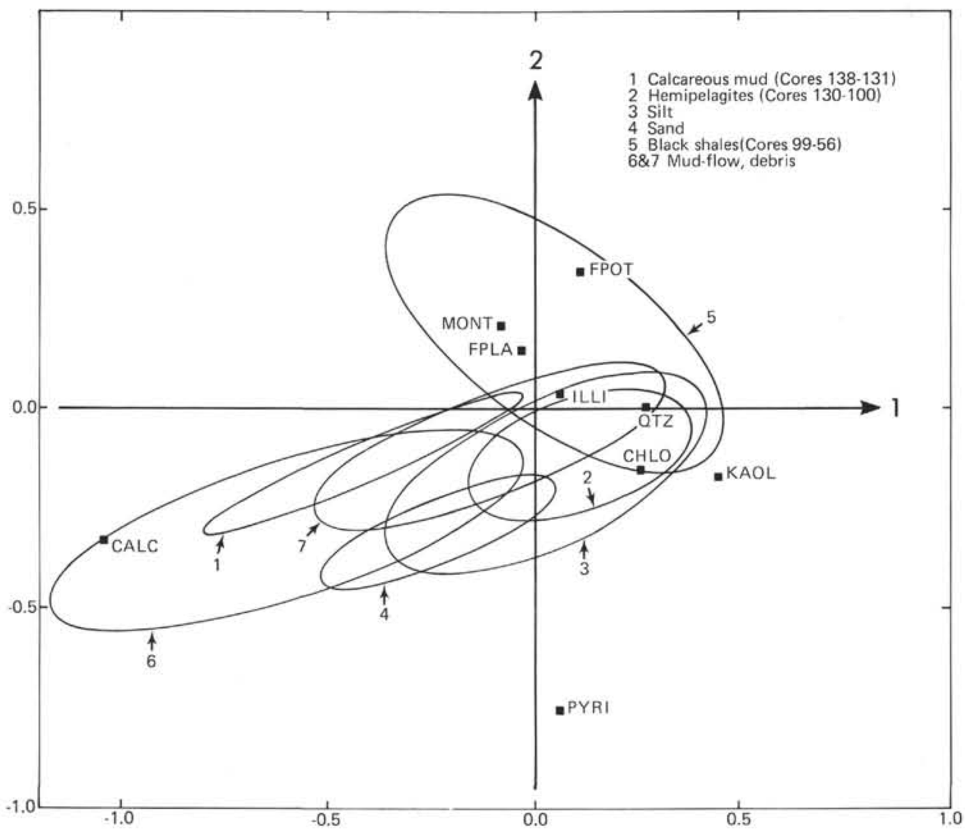

Figure 2. *Ellipses of facies distribution in the factorial plan.*

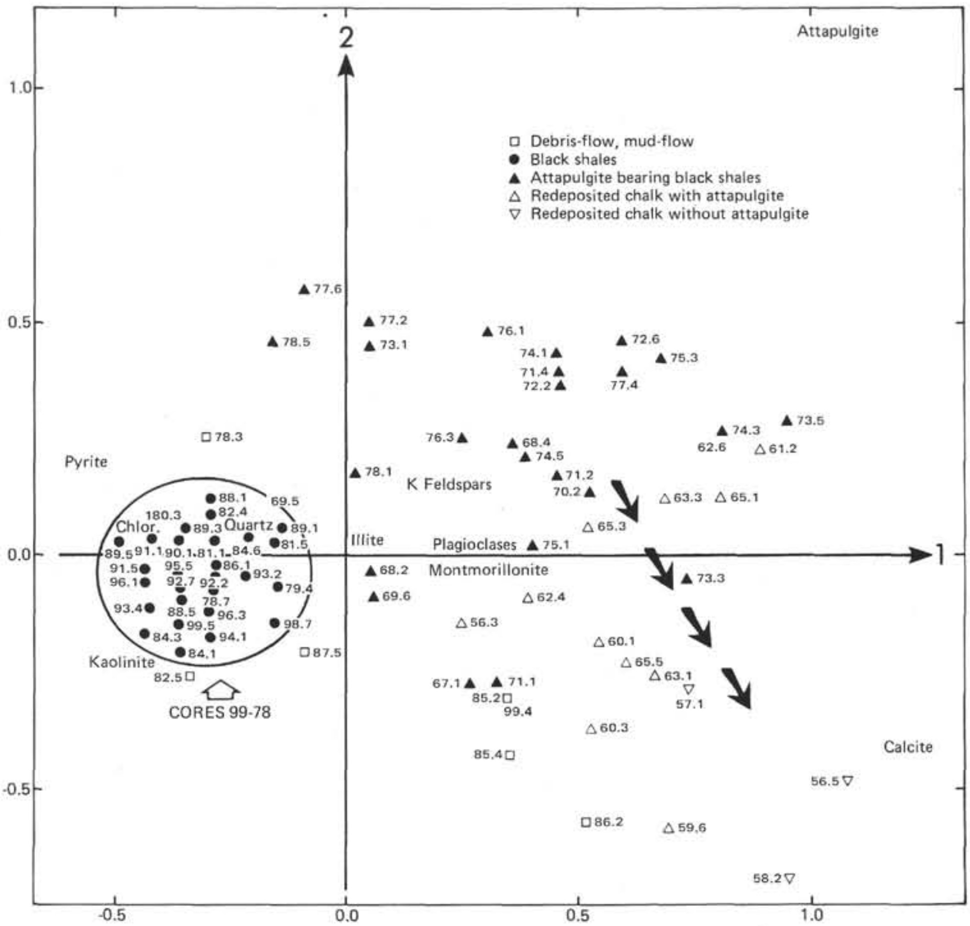

Figure 3. *Analysis of the "black shales."*

sea floor with respect to the CCD. Correspondence factor analysis seemingly confirms results obtained by micropaleontological and lithological study methods.

Within this analysis, the first factor of note is the constant opposition between the input of sedimentary components with high levels of carbonates and silicates. The second factor shows a clear opposition between montmorillonite and pyrite, resulting from different diagenetic paths. This factor was partially masked in the preceding analysis. The third factor has no evident geochemical significance; it perhaps indicates an evolution in the terrigenous source, except where the K-feldspars weight is high.

It is possible to differentiate the clastic supply of Cores 124-125 and 104-105 on the factorial plane. Sands trend to the calcite pole, as previously noted.

CONCLUSIONS

Correspondence analysis confirms results found by other methods, detects differentiations in apparently homogeneous lithological units, and provides hypotheses for the relationships between the different components. Table 2 presents the computed average mineralogical composition for the fine-grained mudstones belonging to each definable group, and the standard deviation for each average value. These values provide average mineralogical compositions of sediments which are the most representative of pelagic environmental conditions. The standard deviation provides information about the relative stability of the various sediment sources for a given period of geologic time.

From these analyses, it appears that:

1. The quartz, feldspar, kaolinite, and illite percentages increase and the calcite percentage decreases below Cores 130-131. The change is rapid, as shown by the high standard deviations, and is related to the initiation of a rise of the CCD, shown by other study methods. The high percentage of pyrite in Cores 129-130 is linked to diagenetic conditions which have not been dealt with here.

2. From Cores 103 to 128, the spread of hemipelagite points is too broad for the calculation of useful average values.

3. Within Cores 129-130 and 78 to 99, the detrital characteristics of the black shales are observed with high content of terrestrially derived minerals (quartz, k-feldspar, and clays). The low $CaCO_3$ content results from the relation of the depth of deposition to the CCD. The low values for different standard deviations in Cores 78 to 99 demonstrate a remarkable uniformity in hemipelagic sedimentation during this period. This allows ready computation of the budget of the various components in the hemipelagic sediments.

4. In Cores 78 and higher, there is a marked evolution characterized by a diminition in the terrigenous mineral supply and detrital influences. This diminition becomes

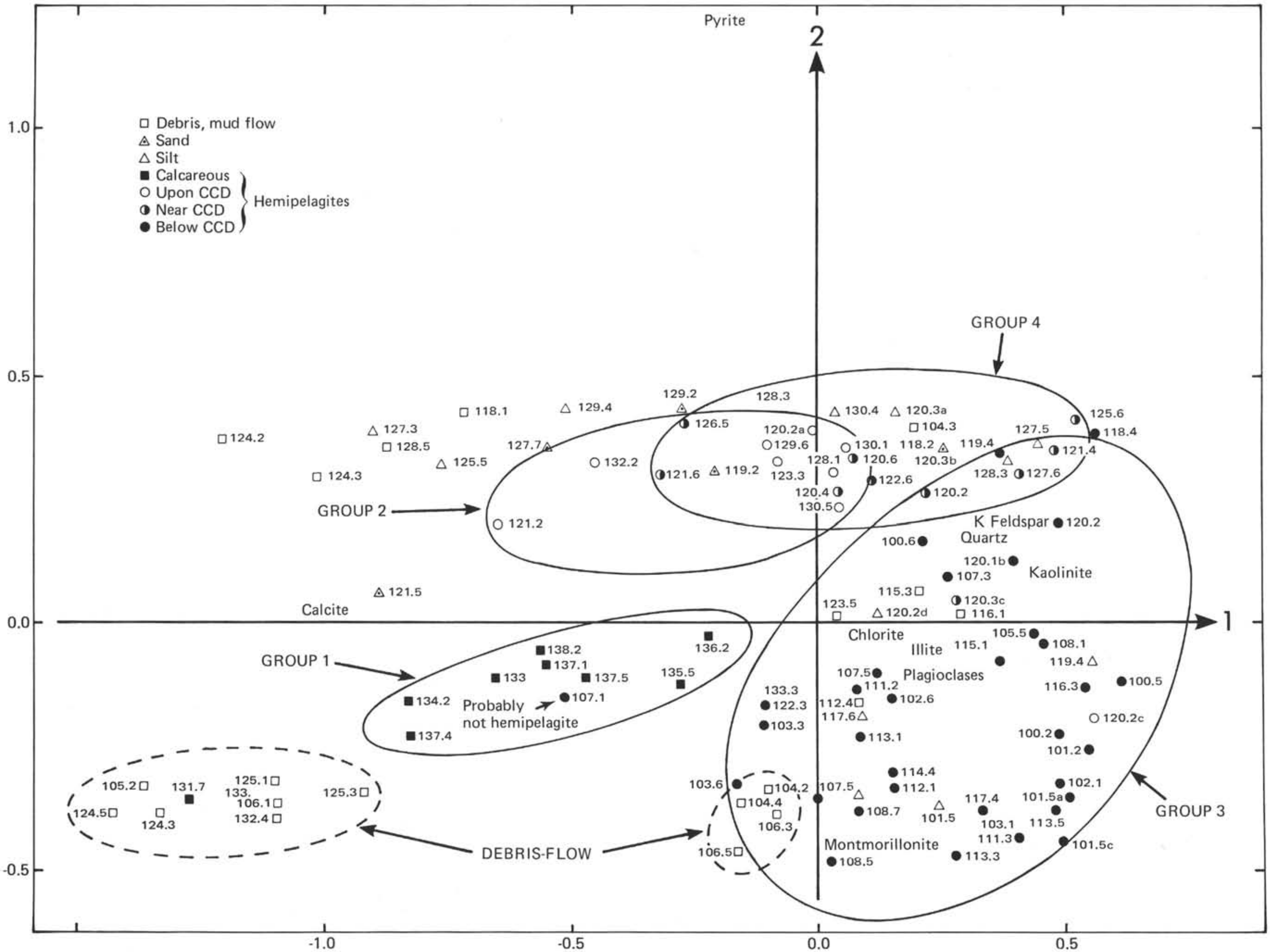

Figure 4. *Analysis of samples from Cores 138 to 100.*

TABLE 2
Average Values for Percentage of Mineralogical Compositions in Hemipelagites

	Pyrite	Quartz	K-Feldspar	Plagioclases	Calcite	Attapulgite	Kaolinite	Illite	Chlorite	Montmorillonite
Cores 56-60 redeposited chalks	0	5.5[a]±2.4[b]	1 ±1	2.2 ±1.3	40 ±10	0	3 ±3	13 ±4	0	34 ±2
Cores 60-70 redeposited chalks	0	6.8 ±1.4	2.2 ±1	2.4 ±0.7	18.6 ±9	4.5 ±5.3	2.2 ±2.7	20 ±5.6	1±2	42 ±6
Cores 68-78 Attapulgite bearing black shales	0.4	8.1 ±1.6	2.2 ±1.2	2.8 ±1	8.1 ±9.3	12 ±7.1	2.4 ±2.8	23.5 ±39	4.2 ±3.3	35 ±8
Cores 78-99 Black shales	0.5 ±1	11 ±1.5	2.1 ±1.1	3 ±1.5	0.3 ±1.1	0	8.9 ±2.4	28 ±3.8	7.5 ±1.8	37±6
Cores 100-128	No average values, the scattering of mineralogical compositions is too wide									
Cores 129-130 First graded sequences	3.7 ±3.3	12.3 ±5.3	1.5 ±1.6	2.3 ±1.2	27 ±10	0	6.5 ±2.4	21.5 ±6.5	5 ±2.6	17 ±5.6
Cores 131-138 Alternating marls and white limestone	0	7 ±2.5	0.4 ±0.8	12 ±1	44 ±16	0	0.5 ±1	13 ±4	4 ±1.5	19 ±7

[a]Average value.
[b]Standard deviation.

progressively more balanced and is replaced first by increasing carbonate redeposition and then by seawater influences, as observed elsewhere by sedimentological methods (de Graciansky and Chenet, this volume). Changes in mineralogical content mark this evolution in Hole 398D.

Unfortunately, the reintroduction of terrigenous detrital components in and above Core 58 could not be displayed here because of the reduced data set.

The appearance of attapulgite in significant amounts at a specific stratigraphic level was noted. From Chamley et al., (this volume), it is probably of detrital origin. Also notable is the abundance and uniformity in the amount of montmorillonite which is related to the erosion of continental soils from a low-lying poorly drained source, as pointed out by Chamley et al. (this volume).

Correspondence factor analysis thus confirms some results already obtained by other methods and provides a quantitative aspect to the mineralogy of the different sediment sources.

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