12. GEOCHEMICAL INVESTIGATION OF SEDIMENTS FROM THE BRAZIL BASIN AND THE RIO GRANDE RISE[1]

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ABSTRACT

The distributions of calcium carbonate, of amorphous silica, and of 21 chemical compounds and elements in sediments of Holes 515A, 515B, 516, 516F, 517, and 518 are highly nonuniform; they change depending on the sediment types, grain size, and mineral composition.

The main source of the lithogenous elements (K, Li, Rb, Fe, Ti, Zr, Ni, Cr, Sn) is terrigenous matter of South America. These elements correlate well or at least satisfactorily with each other and with the sum of clay minerals. $CaCO_3$, amorphous SiO_2 and organic C form a second group, the main source of which is biota of the ocean. Zn, Cu, Ba, Mo, (V, Na) are a third group, which is supplied by both terrigenous and biogenic matter.

Judging by the distribution of chemical elements and components in sediments of Site 515, this area of the Brazil Basin is characterized by the rather constant conditions of pelagic terrigenous sedimentation from upper Eocene till Holocene. Small changes in chemical composition of sediments throughout the section are linked mainly to the evolution of subaerial source provinces, changes in hydrodynamic regime, and fluctuations of the ocean level.

The chemical composition of sediments from the Rio Grande Rise sites suggests the existence of three main stages of sedimentation in this area. The first stage is the initial period of sediment accumulation on basalts at the beginning of the Late Cretaceous. Then followed sedimentary conditions notable for their sharp changes in chemical composition and type. Beginning in the middle Eocene and persisting into the Holocene, stable conditions of sedimentation characterize a third stage, represented by the formation of approximately 700 m of nannofossil oozes of rather monotonous chemical composition.

METHODS

The distribution of 21 elements and compounds, $CaCO_3$, and amorphous SiO_2 in sediments from Sites 515, 516, 517, and 518 (Fig. 1) were studied according to the same methods used to analyze the cores drilled during Leg 39 (Emelyanov, 1977). Our new results on recent sediments are compared with those based on cores drilled during Leg 39 (Emelyanov, 1977; Emelyanov and Trimonis, 1977). Li and Rb were added to the number of chemical elements in the Leg 39 study, and these were determined by the atomic-absorption method proceeding from the same solution aliquot as that for Fe and Mn. Cd, Be, and Ge were not detected by the accepted methods (the sensitivity is more than 6 ppm for Cd, more than 1 ppm for Be, and more than 1 ppm for Ge). Mo is also practically not identified (less than 5 ppm of Mo), except for 27 to 51 ppm of Mo found only in muds from the lower portion of Hole 515B (Cores 40 to 56). These results seem to be exaggerated; however, they are still listed with chemical analyses in the Appendix.

In order to reveal the mineral forms of chemical elements as well as the correlations of them with lithogenous and authigenic minerals, the bulk mineral composition of all samples from Holes 515A, 515B, 516, 516F, 517, and 518 was studied by the use of X-ray diffractometer DRON-1.5. These X-ray data are corrected for the presence of amorphous phases.

The chemical analyses were done in accordance with the geologic standards of the Soviet Union (SGD-1, SG-1, and ST-1) and the German Democratic Republic. The analytic data for Holes 515A and 515B were calculated by our computer routine, "Geokhimik" (Emelyanov, et al., 1981). That program calculates averages, quadratic mean deviations, asymmetry, and excess, empirical distribution for each element, as well as correlation and regression coefficients, and the values of the regression line crossing. All the analyses and calculations are made in the Laboratory of Atlantic Geology, Atlantic Department of P. P. Shirshov Institute of Oceanology, U.S.S.R. Academy of Sciences, under the senior author's guidance. (Analysts were Ts. Kh. Yablunovskaya, N. G. Kudryavtsev, T. I. Anisimova, N. B. Vlasenko, G. S. Khandros, and A. S. Kozhevnikov.)

RESULTS

Site 515 (water depth 4252 m)

Our sediment samples from Holes 515A and 515B are Eocene to Quaternary. On the basis of their composition, they belong to three lithologic units (see site chapter, Site 515, this volume).

Unit 1 consists of 180 m of Pliocene to Quaternary gray brown terrigenous muds interbedded with layers enriched in carbonate biogenic matter. The entirety of Hole 515A and the upper nine cores from Hole 515B correspond to this unit.

The terrigenous muds of Unit 1 are not uniform in chemical composition despite their seemingly uniform lithology (Figs. 2 and 3). The contents of one group decrease down Hole 515A (organic C, Na, Cr, Ba), while those of a second group increase (Mn, Fe, Ti, P, K, Zr, Ni, V, partially Zn, Cu), and the quantities of a third group of elements remain almost constant ($CaCO_3$, amorphous SiO_2).

By their chemical composition, the muds of Hole 515A may be divided into three different subunits (Fig. 2); a fourth subunit is distinguished in Cores 515B-1 to 515B-9 (Fig. 3). Chemical Subunit 1a (Core 515A-1) is represented by low-manganese terrigenous muds (0.39% Mn) with somewhat elevated concentrations of $CaCO_3$, Fe, and Cu. The main characteristics of Chemical Subunit 1b (Cores 515A-2 to 515A-13) are the low quantities of Mn and the high quantities of Na. Separate, sharply expressed maximum contents of Cu and Zn are also characteristic of the muds of this subunit (Table 1). The main specific feature of Chemical Subunit 1c muds (Cores 515A-14 to 515A-27) is the increased amount of Mn (0.20–

[1] Barker, P. F., Carlson, R. L., Johnson, D. A., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office).

Table 1. The ranges and average contents of elements in lithologic subunits of Holes 515A and 515B.

Subunit	Hole	Cores	Age	Lithologic description	Content (%) $CaCO_3$	C_{org}	$SiO_{2amorph}$	Ti	P	Fe
1b	515A	2 to 13	Quaternary	Gray brown terrigenous mud	0–7.50 2.48 (12)	0.18–0.30 0.25 (12)	0.50–0.65 0.55 (3)	0.45–0.59 0.54 (12)	0.04–0.06 0.05 (12)	4.50–5.62 4.98 (12)
1c	515A	14 to 27	Quaternary	Gray brown terrigenous mud	0–5.32 1.97 (12)	0.15–0.25 0.18 (12)	0.4–0.55 0.48 (2)	0.49–0.60 0.55 (12)	0.05–0.08 0.06 (11)	4.80–5.46 5.16 (12)
1d	515B	1 to 9	Quaternary–Pliocene	Gray brown terrigenous mud	0.50–2.64 1.32 (8)	0.12–0.16 0.14 (8)	0.5–0.55 0.52 (2)	0.48–0.54 0.51 (8)	0.05–0.09 0.07 (8)	4.92–5.11 5.03 (8)
1a–d	515A 515B	1 to 27 1 to 9	Quaternary–Pliocene	Gray brown terrigenous mud	0–8.50 2.00 (33)	0.12–0.30 0.20 (33)	0.4–0.65 0.52 (7)	0.45–0.60 0.55 (33)	0.04–0.09 0.06 (32)	4.50–5.62 5.15 (33)
2a	515B	10 to 46	Miocene	Dark greenish gray siliceous mud and mudstone	0–8.50 2.02 (35)	0.10–0.22 0.15 (35)	0.8–1.52 1.09 (11)	0.39–0.52 0.45 (24)	0.04–0.09 0.05 (33)	3.68–5.16 4.31 (32)
2b	515B	47 to 55	Oligocene	Dark greenish gray terrigenous mudstone	0–9.30 2.94 (8)	0.12–0.18 0.15 (8)	— —	0.49–0.53 0.50 (3)	— —	3.69–5.33 4.03 (7)
2a–b	515B	10 to 55	Miocene–Oligocene	Dark greenish gray mudstone	0–9.30 2.21 (43)	0.10–0.22 0.16 (43)	0.8–1.52 1.09 (11)	0.39–0.53 0.48 (27)	0.04–0.09 0.05 (32)	3.68–5.33 4.39 (39)
1–2	515A 515B		Quaternary–Oligocene	Terrigenous mud and mudstone	0–9.30 2.46 (78)	0.10–0.30 0.18 (78)	0.4–1.52 1.00 (18)	0.39–0.60 0.51 (61)	0.04–0.09 0.06 (64)	3.68–5.62 4.73 (74)

Note: For each subunit, the first line contains the ranges of the elements and compounds; the second line contains the average values. The number in parentheses is the number of analyses performed.

0.78%), as well as increased quantities of some other elements of the second group. Despite this increase, these sediments still correspond to low-manganese ones (0.20–5.00%). In their chemical composition, the muds of Chemical Subunit 1c are most similar to recent terrigenous pelagic ones, particularly to red clays of the Brazil Basin (Emelyanov, 1977). The muds of Chemical Subunit 1d (Cores 515B-1 to 515B-9) are characterized by almost the same composition as that of the muds of Chemical Subunit 1c, with the exception of Ba, V, Cu, and Mn (Fig. 3). There is considerably more of the first two elements in the muds of Chemical Subunit 1d, and less of Cu and Mn.

The X-ray analyses of sediment mineral composition also showed some changes in content of clay and clastic minerals within Unit 1. The composition of Sample 515A-1-1, 130–135 cm (Chemical Subunit 1a) is 23% montmorillonite, 12% illite, 6% kaolinite and chlorite, 10% quartz, 4% plagioclase, and 9% calcite. The sediments of Chemical Subunit 1b contain somewhat more kaolinite and chlorite, but less quartz. Calcite is practically absent. The quantity of kaolinite and chlorite are the same in the third chemical subunit as in Chemical Subunit 1a, but there is more montmorillonite; X-ray analysis identifies only low quantities of carbonate minerals in some samples. Compared to other chemical subunits, the sediments of Chemical Subunit 1d are highly enriched in montmorillonite. Only trace amounts of kaolinite and chlorite and small amounts of quartz, plagioclase, and calcite are found, but up to 3% K-feldspar occurs. These changes in the mineral composition of sediments probably control those registered in the microelement analyses.

The muds of Unit 1 (Holes 515A and 515B) are similar in chemical composition to those of the upper unit from Hole 355 (Cores 1 to 15). Somewhat smaller amounts of organic C (C_{org}), Fe, Ti, Cr, V, Ni, and Zn, larger ones of Ba and Cu, and much more Na and K occur in the muds of Holes 515A and 515B. The Mn and Zr contents are almost the same as in the muds of Hole 355. Thus, despite their overall similarity, muds from Holes 515A and 515B contain more of the biogenic components (excluding C_{org}) and less of the lithogenous elements than the muds of Hole 355.

The correlations between element pairs: (Fe and Mn, K and Na, Cu and Zn, Ni and Cr, Li and Rb) in the muds of Unit 1 are weak (Table 2). The distributions of these elements are most often directly dependent on one another in Recent sediments of the Atlantic Ocean (Emelyanov, 1982). Therefore, the accumulation of the element pairs mentioned in the Pliocene-Quaternary period differ from the Recent, and the pairs of these elements were probably represented by different minerals or mineral combinations. On the other hand, there are some clear positive correlations: Li, Rb, Ni, Zr, V, and Mo with K; Sn and Ba with Ni; Zr and Mo with Li; Mo and Sn with Rb; Mo with Zr; and Mo and Sn with V (Table 2). Because K, Li, Rb, and in most cases Na are typical lithogenous elements, one may state that the elements connected with K, Li, Rb, and Na (specifically Zr, Ni, Cr, V, Mo, and Sn) are represented exclusively by terrigenous (alumosilicate) matter.

Compared to Recent terrigenous muds of the Atlantic Ocean (less than 10% $CaCO_3$ and amorphous SiO_2), Unit 1 muds are notably enriched in Na and poor in C_{org}, P, and Cr (Table 2). Although both are linked most often with the presence of iron sulphides in sediments, the maxima of Zn and Cu generally do not coincide with one another (Fig. 2). The very great values of the quadratic mean deviation also suggest the great irregularity in Cu and Zn distributions (less irregular for Ba, V, and Mn) (Table 2).

Unit 2 (Cores 515B-10 to 515B-55) consists of 435 m of Oligocene to lower Pliocene dark greenish gray ter-

Table 1. (Continued.)

Mn	Na	K	Content (ppm) Cu	Zn	Ni	Cr	Li	Rb	Ba	Zr	V	Mo	Sn
0.06–0.12 0.08 (12)	1.87–2.84 2.50 (12)	2.06–2.71 2.42 (12)	54–261 92 (12)	106–365 154 (12)	47–76 60 (12)	49–68 62 (12)	59–74 69 (12)	100–130 121 (12)	330–570 436 (12)	71–120 97 (12)	36–94 58 (12)	<5–8 3 (12)	— 3 (12)
0.11–0.79 0.29 (12)	1.78–2.32 1.96 (12)	2.22–2.66 2.49 (12)	65–114 86 (12)	126–278 145 (12)	59–90 74 (12)	45–60 52 (12)	65–76 70 (12)	109–148 124 (12)	190–886 294 (12)	78–180 120 (12)	53–300 87 (12)	<5–10 <5 (12)	<6–12 <6 (12)
0.06–0.21 0.17 (8)	1.54–2.15 1.98 (8)	2.32–2.72 2.54 (8)	51–82 71 (8)	129–148 137 (8)	62–90 70 (8)	46–62 54 (8)	66–84 74 (8)	116–152 139 (8)	340–1313 693 (8)	95–190 122 (8)	97–290 177 (8)	<5–12 8 (8)	<6–12 9 (8)
0.06–0.79 0.19 (33)	1.54–2.84 2.20 (33)	2.06–2.72 2.52 (33)	51–261 86 (33)	106–365 149 (33)	47–90 69 (33)	45–68 57 (33)	57–84 72 (33)	100–152 129 (33)	190–1313 430 (33)	71–190 114 (33)	36–300 101 (33)	<5–12 4 (33)	<6–12 <6 (33)
0.04–0.60 0.10 (32)	1.84–2.75 2.22 (32)	1.82–2.40 1.99 (32)	36–91 64 (32)	100–142 116 (32)	36–82 56 (32)	30–57 44 (32)	45–65 55 (32)	77–122 101 (32)	210–1160 470 (35)	51–230 113 (35)	71–146 110 (35)	<5–31 12 (35)	<6–15 8 (35)
0.03–0.60 0.13 (7)	1.42–2.11 1.57 (7)	1.72–2.43 2.05 (7)	26–84 55 (7)	82–132 112 (7)	41–60 46 (7)	38–58 50 (7)	40–53 44 (7)	80–120 101 (7)	220–420 319 (8)	63–105 81 (8)	84–141 99 (8)	31–50 43 (8)	<6 <6 (8)
0.03–0.60 0.11 (39)	1.42–2.75 2.17 (39)	1.72–2.43 2.07 (39)	26–91 65 (39)	82–142 119 (39)	36–82 56 (39)	30–58 46 (39)	40–65 55 (39)	77–122 104 (39)	210–1160 458 (43)	51–230 109 (43)	71–146 112 (43)	<5–50 17 (43)	<6–15 5 (43)
0.03–0.79 0.15 (74)	1.42–2.84 2.19 (74)	1.72–2.72 2.27 (74)	26–261 74 (74)	82–365 133 (74)	36–90 62 (74)	30–68 51 (74)	40–84 63 (74)	77–152 115 (74)	210–1313 446 (77)	51–230 111 (77)	36–300 106 (77)	<5–50 12 (77)	<6–15 5 (77)

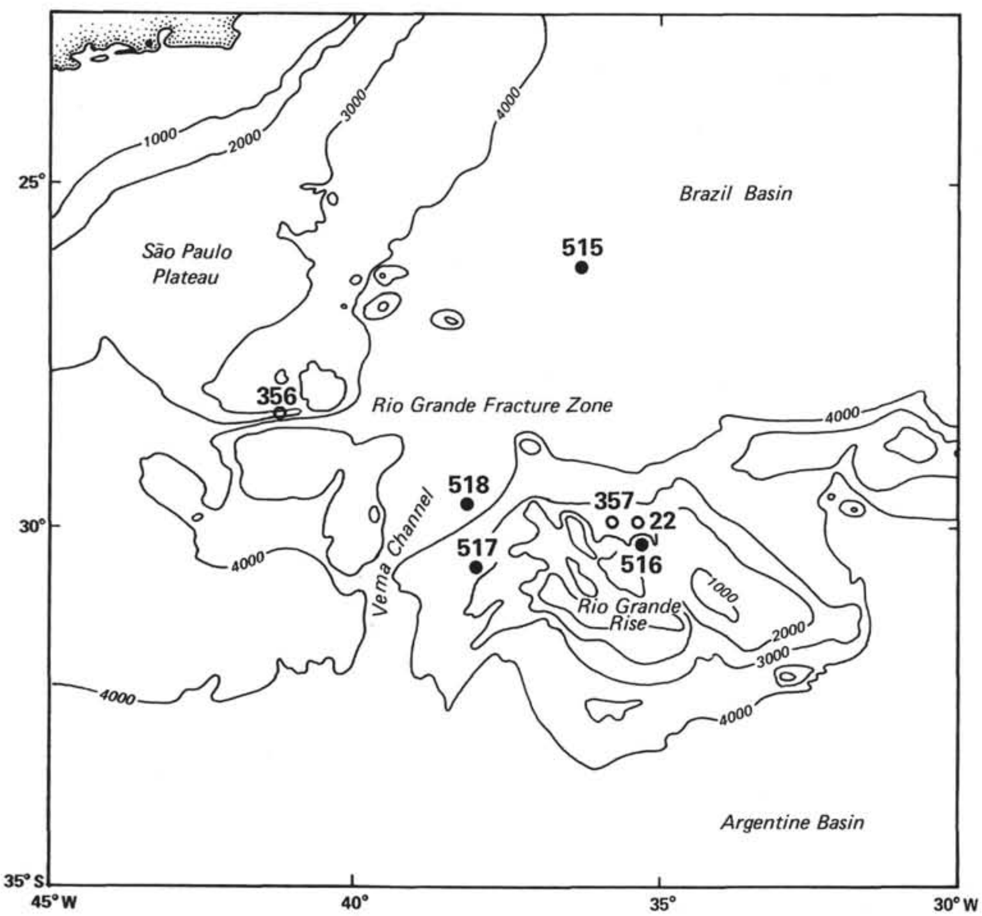


Figure 1. Location of DSDP Sites 22, 356, 357, and 515–518.

rigenous mudstones, sometimes enriched in siliceous biogenic remains (Fig. 3). On the basis of the content of biogenic siliceous matter, Unit 2 was divided into two subunits, Subunits 2a (Cores 515B-10 to 515B-46) and 2b (Cores 515B-47 to 515B-55). Subunit 2a is relatively enriched in diatoms, radiolarians, and sponge spicules, which, according to the smear slide data, make up 15% of the total volume. Subunit 2b, however, is almost devoid of siliceous microfossils (see site chapter, Site 515).

Unit 2 differs considerably from Unit 1 in chemical and in mineral composition (Table 1). Our X-ray diffractograms indicate that Unit 2 contains more mont-

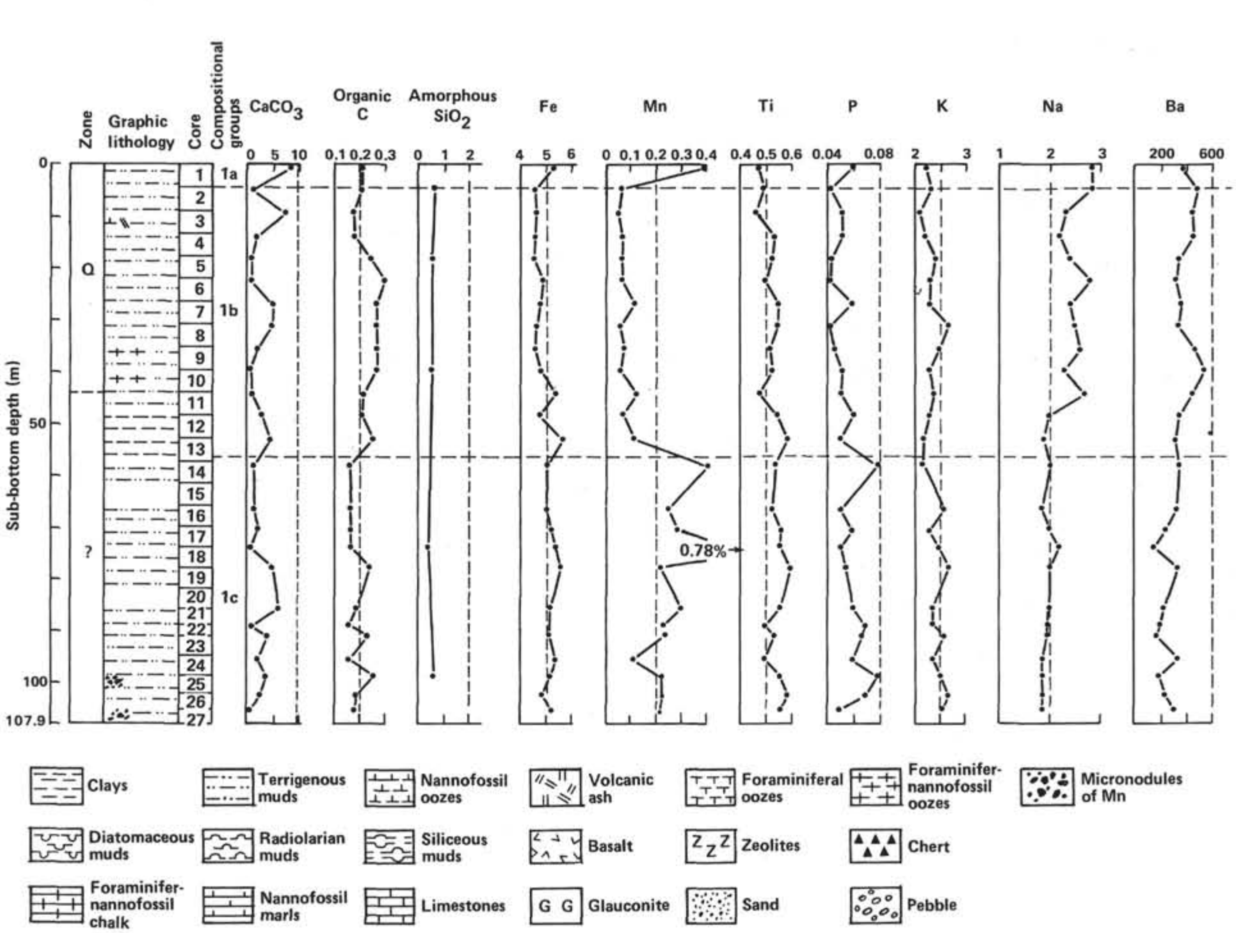


Figure 2. Lithologic composition of Hole 515A (water depth 4252 m) and distribution of chemical components and elements in sediments. In Figures 2-7, the following components are expressed in %: $CaCO_3$, organic C, amorphous SiO_2, Fe, Mn, Ti, P, K, and Na. Ba, Cu, Zn, Ni, Cr, V, Li, Rb, Zr, and Mo are expressed in $\times 10^{-4}$%.

morillonite than Unit 1 and lacks both kaolinite and chlorite. Cristobalite and sometimes pyrite occur sporadically throughout. In the Unit 2 muds, the typically lithogenous elements (C_{org} and K, Fe, Ti, Mn, Cu, Zn, Rb, and Li) are less abundant and amorphous SiO_2 is slightly more common. The amorphous SiO_2 content, although somewhat greater, does not exceed 5-10%; therefore, the sediments may not be related to low-siliceous ones. They are merely typical terrigenous mudstones with enhanced contents of siliceous remains. Separate interbeds in this unit contain sharply increased quantities of Mn (up to 0.60%), so that the sediments qualify as "low-manganese" sediments. Increased contents of other trace elements are not found in these "low-manganese" sediments. Some samples from Unit 2 muds contain high amounts of Ba (up to 1160 ppm), Zr, and V. The maxima of these elements and of Mn do not generally coincide; each is caused by the presence of different minerals enriched in one element. If these interbeds of so-called "low-manganese" muds (those with more than 0.20% Mn) were excluded from Subunit 2a, the Mn contents in the remainder of this subunit would be quite low, ranging from 0.03 to 0.10%. Phosphorus is also present in low quantities (0.04-0.06%), and Fe amounts are also lower than in Unit 1 (3.60-5.00%, rarely more).

The terrigenous mudstones of Subunit 2b are very similar in chemical composition to those of Subunit 2a, but differ from them in their lesser concentrations of Na and greater abundance of Mo (Fig. 3). The other contents of the "low-manganese" interbeds in the lower parts of Subunit 2b (Core 515B-55, 0.60% Mn) do not differ from the overlying mudstones. The content of the dominant minerals within these subunits varies within close ranges, except for the notably smaller amounts of illite in Subunit 2b.

The correlation coefficients of elements in mudstones of Unit 2 are slightly different from those in sediments of Unit 1. The correlations of trace elements with the lithogenous elements K, Li, and Rb are considerably weaker than for Unit 1.

An unconformity at the bottom of Core 515B-55 is clearly represented by coarse-grained sediments consisting of subrounded grains of fine-grained quartz, sand, glauconite admixture, biotite, heavy minerals, fish teeth, and bones. The sediment color becomes brownish gray. Unit 3 (Cores 515B-56 and 515B-57) is greenish gray, zeolitic Eocene mudstones. Fe, K, Na, Zn, Ni, and Zr increase in the upper part of this unit, compared to the sediments of Unit 2. $CaCO_3$ also increases downhole, and the sediments can be classed as "low-carbonate" (the carbonates consist mostly of nannofossils). Zeolites

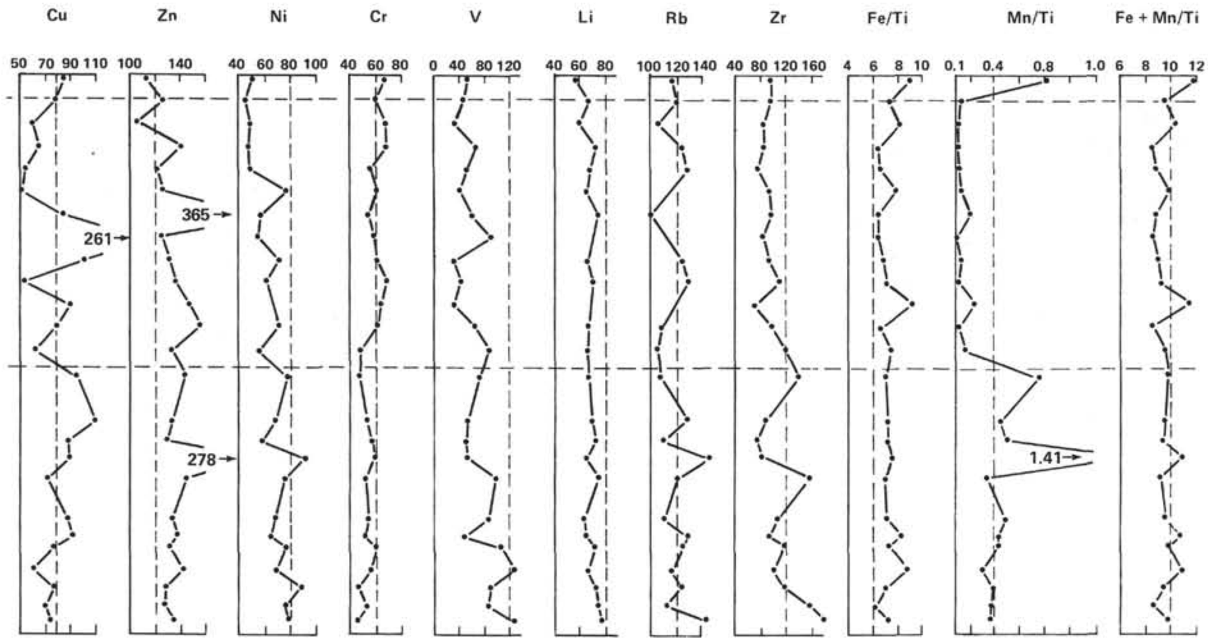


Figure 2. (Continued.)

occur everywhere, and, according to our X-ray data, clinoptilolite accounts for 15% of the sediment encountered in 515B-57-1, 44–48 cm.

In comparison to the average element composition of Recent terrigenous pelitic muds of the Atlantic Ocean (Emelyanov, 1977), some of the sediments of Holes 515A and 515B contain considerably less C_{org}, and P, Fe, Cu, Ni, Cr, Ba, Zr, and V, but more Ti (Table 3). Compared to subaerial clays and shales (Vinogradov, 1962), the muds of Holes 515A and 515B are poorer in P, Ni, Cr, Rb, Ba, and Zr, but richer in Fe, Mn, Cu, and Mo, and three times as rich in Na (Tables 1 and 3).

Site 516 (water depth 1313 m)

Judging by the shipboard reports (see site chapter Site 516, this volume), the sediments from Holes 516 and 516F represent a complete section spanning the Quaternary to the Upper Cretaceous and are underlain by basalts. Their chemical composition is much more heterogeneous than those recorded for our Site 515 samples. The ranges of quantities for, first, the biogenic components, $CaCO_3$, amorphous SiO_2, and C_{org} and, second, K, Na, and some trace elements are very wide. The maximum quantities of components and elements are from 100 to 1000 times more than the minimum ones. At Site 516, eight lithologic units are distinguished on the basis of lithologic and chemical composition. Figures 4 and 5 show the lithologic compositions of Holes 516 and 516F, respectively.

Unit 1 (Cores 516-1 to 516-44 and 516F-1 to 516F-4) is 198 m of weakly consolidated, Quaternary to lower Miocene, pale brown to white carbonate muds. X-ray diffractograms indicate that the bulk of the sediment (75–89%, in Hole 516) consists of calcite in the form of biogenic remains of nannofossils and planktonic foraminifers. A small quantity of terrigenous components and clay minerals (mainly illite) makes up from 5 to 7%; feldspars, quartz, and mica are present; volcanic glass, Mn micronodules, pyrite, and biogenic siliceous detritus occur. C_{org} is rare; its content decreases from 0.21% in the upper parts of the unit to 0.10–0.12% in the lower. Increased Mn, Zn, Ni, and especially Na characterize Unit 1 sediments. These element concentrations are notably higher than those in nannofossil oozes near the top of the lithologic column at Site 357 (Emelyanov, 1977). $CaCO_3$ increases, but Mn (especially on the carbonate-free basis), amorphous SiO_2, Zn, and Cr decrease from bottom to top of Unit 1.

The Leg 72 shipboard scientists distinguish an interval of Mn-oxide, sand, and granule-size foraminifers in Core 516-16 (see Subunit 1b, site chapter, Site 516, this volume). The muds of this core do not differ in chemical composition from the nannofossil oozes located above except for higher $CaCO_3$ (a maximum for Site 516). On a carbonate-free basis, however, Core 516-16 is notable for considerably increased C_{org} (1.50%), Fe (8.50%), Mn (0.52%), and Ni, Cr, Cu, Zn, and Li.

Unit 2 (Cores 516F-4 to 516F-18) is represented by 127 m of lower Miocene to upper Oligocene nannofossil and foraminiferal-nannofossil chalk (Fig. 5). The sediments of Unit 2 are darker than those of Unit 1, but are very similar in chemical composition. As far as the mineral composition is concerned, the main distinction is that Unit 2 is relatively rich in both plagioclase and K-feldspars. A relative increase in the quantity of sponge spicules (up to 10%) is characteristic. The quantities of C_{org} and of the remaining chemical elements are very low.

Unit 3 (Cores 516F-19 to 516F-50) is represented by 302 m of light gray, olive gray, and greenish gray upper Oligocene to middle Eocene nannofossil and nannofos-

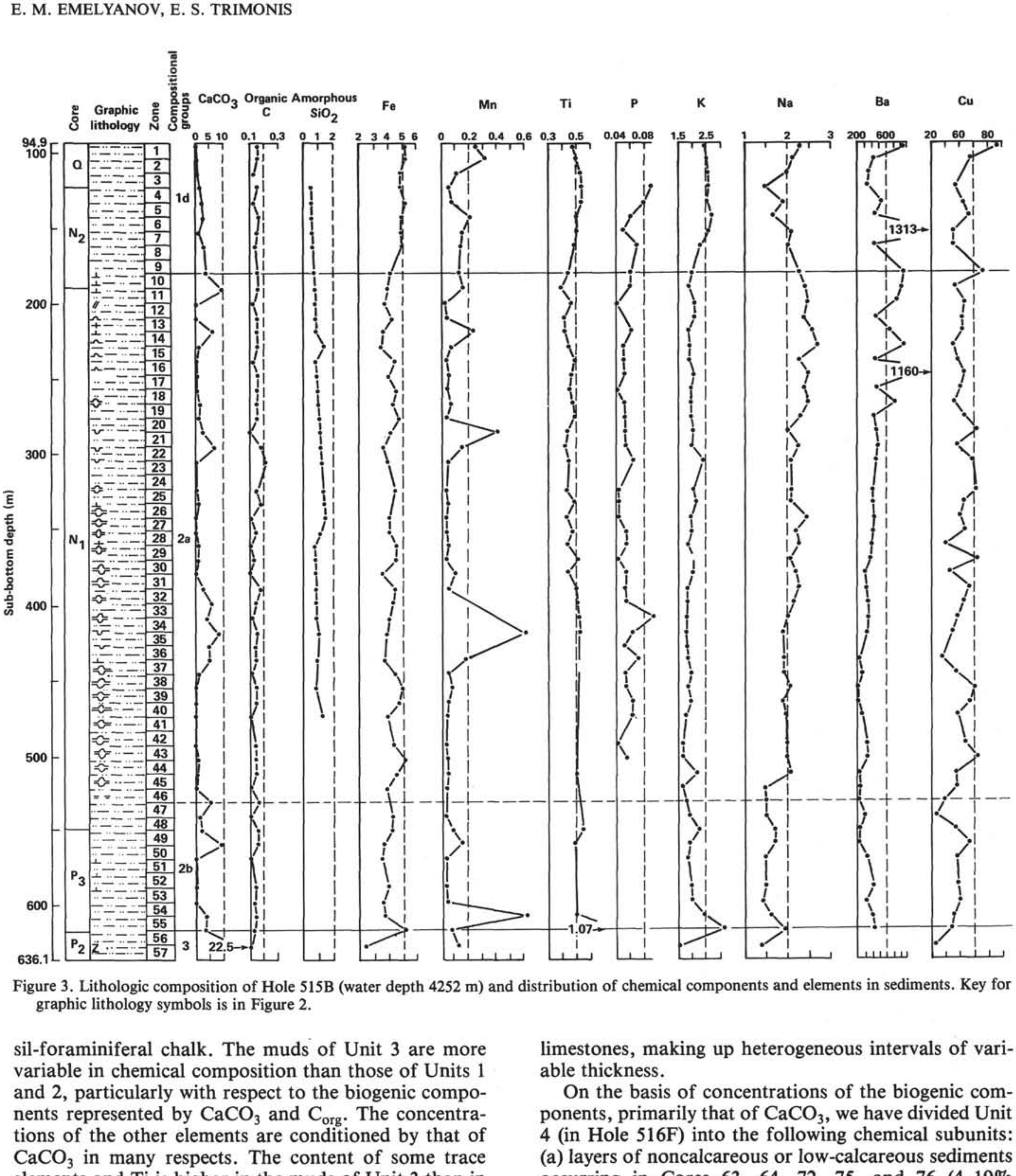


Figure 3. Lithologic composition of Hole 515B (water depth 4252 m) and distribution of chemical components and elements in sediments. Key for graphic lithology symbols is in Figure 2.

sil-foraminiferal chalk. The muds of Unit 3 are more variable in chemical composition than those of Units 1 and 2, particularly with respect to the biogenic components represented by $CaCO_3$ and C_{org}. The concentrations of the other elements are conditioned by that of $CaCO_3$ in many respects. The content of some trace elements and Ti is higher in the muds of Unit 3 than in those of Unit 1.

Unit 4 (Cores 516F-50 to 516F-79) is represented by 240 m of mainly dark gray, olive gray, yellowish brown, and reddish brown nannofossil and foraminiferal limestones of the middle Eocene. Unit 4 sediments are heterogeneous in both lithologic and chemical composition. Turbidites enriched in volcanogenic matter constitute about one-third of the unit. These layers alternate with limestones, making up heterogeneous intervals of variable thickness.

On the basis of concentrations of the biogenic components, primarily that of $CaCO_3$, we have divided Unit 4 (in Hole 516F) into the following chemical subunits: (a) layers of noncalcareous or low-calcareous sediments occurring in Cores 63, 64, 72, 75, and 76 (4–19% $CaCO_3$); (b) layers of calcareous sediment in Cores 53, 62, and 77 (35% $CaCO_3$), and (c) the remaining carbonate sediments (50–86% $CaCO_3$). Between 0.12 and 0.78% C_{org}, large quantities of Zr (140–340 ppm), V (up to 110 ppm), Li (up to 300 ppm), and Cr (up to 149 ppm) are found in noncalcareous and low-calcareous sediments (those with less than 30% $CaCO_3$). Calcareous sediments contain from 0.09 to 0.15% C_{org}; some inter-

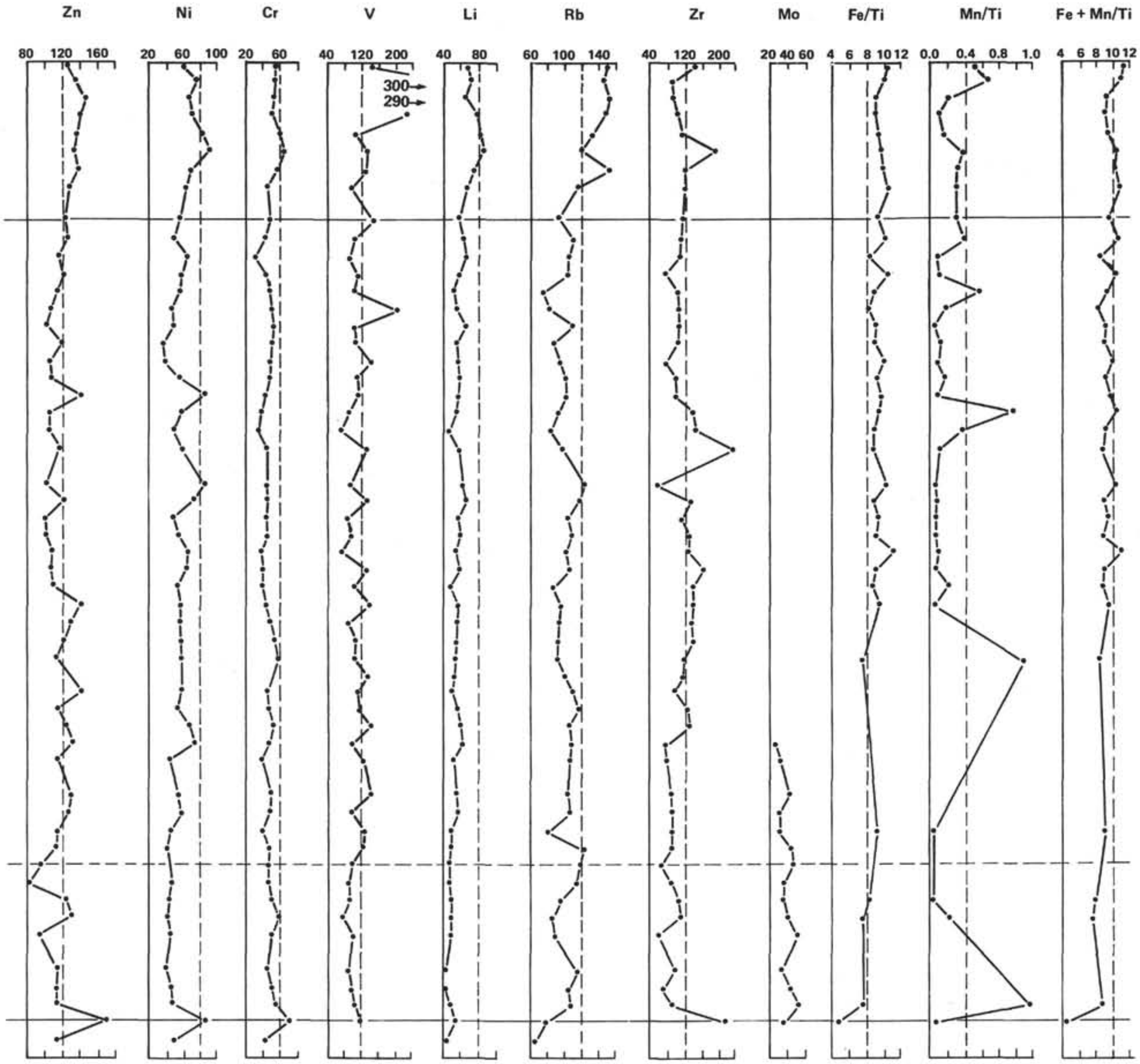


Figure 3. (Continued.)

beds are greatly enriched in Zr, Ba, Ni, and V. Carbonate sediments contain from 0.09 to 0.24% C_{org}, and some interlayers are notably enriched in Mn and Cr. These results of chemical analyses suggest that Unit 4 muds should be divided into independent chemical subunits.

Unit 4 differs somewhat from Unit 3 in mineral content. First, montmorillonite and illite are more abundant in Unit 4, and, secondly, relatively high amounts of dolomite and pyrite occur in some samples (Samples 516F-69-1, 124–128 cm; 516F-70-1, 56–60 cm; 516F-72-2, 50–54 cm).

The lower parts of Unit 4 (Cores 516F-78 and 516F-79) are a dark brown limestone of the Upper Cretaceous. This limestone together with clastic and volcanogenic sediments (turbidites) was formed by slumping. The sediments of Core 516F-79 contain increased quantities of C_{org} (0.54%).

Unit 5 (Cores 516F-80 to 516F-93) is 126 m thick and consists of two subunits. Subunit 5a (Cores 516F-80 to 516F-86) is represented by lower Eocene to Paleocene microcrystalline gray, light gray, and light greenish gray limestones with thin interbeds of dark greenish gray sediments, which are probably enriched in organic matter. These sediments are heterogeneous in chemical composition. Their upper portion contains from 47 to 55% $CaCO_3$, and the middle and lower ones have from 70 to 86% $CaCO_3$. The C_{org} content is low (0.09–0.18%). Subunit 5b (Cores 516F-86 to 516F-93) is represented by Paleocene and Maestrichtian interbedded reddish limestones and reddish brown marly limestones. $CaCO_3$

Table 2. Correlation coefficients (×100) of chemical elements and average contents of chemical elements in Eocene-Pleistocene sediments of Holes 515A and 515B.

Element or component	CO_2	Ti	P	Fe	Mn	Na	K	$CaCO_3$	$SiO_{2amorph}$	C_{org}	Cu	Zn	Ni	Cr	Li	Rb	Ba	Zr	V	Mo	Sn	Average value	Quadratic mean	Asymmetry	Excess
Unit 1 (Cores 515A-1 through 515A-27 and 515B-1 through 515B-9, 33 samples																									
CO_2		30	13	40	-2	32	4	100	32	35	18	10	-17	41	-4	-39	-13	8	-19	-3	-11	1.02	1.05	1.34	1.27
Ti			19	36	14	-35	34	31	14	27	21	32	26	-30	37	-19	-39	31	2	16	-5	0.55	0.04	0.42	-0.69
P				32	14	-49	13	13	-4	-41	-17	3	37	-37	33	3	-16	29	30	18	35	0.06	0.01	0.52	-0.11
Fe					41	-19	18	40	27	-7	-3	8	32	-19	-1	-4	-15	27	8	23	10	5.17	0.33	0.21	-0.06
Mn						-11	6	-3	-12	-32	6	28	46	-8	-7	22	-22	11	2	6	-1	0.19	0.15	2.09	5.72
Na							-34	31	10	55	24	4	-46	55	-60	-27	15	-45	-47	-46	-29	2.23	0.35	0.71	-0.05
K								5	14	-6	35	-5	48	-28	51	44	-2	45	42	53	15	2.52	0.17	0.40	-0.80
$CaCO_3$									32	36	19	10	-16	40	-2	-40	-14	9	-19	-3	-11	2.19	2.19	1.24	0.95
$SiO_{2amorph}$										2	26	-9	-5	14	-1	-26	13	17	4	13	8	0.92	0.21	-1.46	0.37
C_{org}											23	13	-10	29	-14	-44	-18	-8	-46	-16	-47	0.20	0.05	0.38	-1.07
Cu												1	-9	-6	-19	-8	-12	-14	-10	-16	-7	86	38	3.81	16.83
Zn													12	-2	20	-11	-11	-7	-7	-12	-6	148	51	3.91	14.88
Ni														-34	39	18	-23	51	26	40	3	68	13	0.13	-0.43
Cr															-19	-18	15	-23	-35	-11	-22	58	7	0.66	0.18
Li																15	9	62	33	64	7	72	6	0.58	0.44
Rb																	33	4	62	35	44	129	13	0.47	-0.70
Ba																		10	10	20	9	430	209	2.84	9.70
Zr																			18	64	-6	114	30	1.12	0.74
V																				53	74	99	66	1.84	3.14
Mo																					16	5	3	1.10	-0.40
Sn																						5	3	1.48	0.32
Holes 515A and 515B, 77 samples																									
CO_2		21	32	-16	23	2	4	99	27	8	-5	16	3	28	-2	-23	3	19	-12	-4	-15	1.19	1.80	3.97	22.09
Ti			36	68	29	-42	66	22	-22	30	32	44	39	49	58	44	-42	8	-2	3	-17	0.51	0.05	0.16	-0.73
P				29	34	-38	33	33	-15	-18	-4	20	31	15	36	24	-12	21	17	-8	2	0.06	0.01	0.95	0.88
Fe					23	8	57	-13	-32	18	34	31	53	40	68	60	-21	12	-2	-38	-1	4.73	0.55	-0.08	-0.68
Mn						-2	35	25	-12	-3	12	29	36	32	18	24	-6	14	-3	-13	-9	0.15	0.15	2.18	5.12
Na							3	4	6	34	23	6	-7	16	17	-10	38	1	-29	-55	21	2.19	0.36	0.10	-0.25
K								7	-24	37	44	30	52	45	74	66	-3	33	-35	-38	-4	2.27	0.28	0.19	-0.80
$CaCO_3$									27	10	-3	17	3	30	-1	-23	3	20	-12	-5	-15	2.46	3.37	3.14	14.60
$SiO_{2amorph}$										-14	-1	-19	-26	-19	-33	-42	15	7	4	14	4	1.00	0.18	-0.99	3.49
C_{org}											29	23	20	21	35	11	5	8	-32	-23	-12	0.18	0.06	2.23	7.52
Cu												16	17	20	29	24	-6	2	-9	-23	-8	74	30	4.27	26.89
Zn													29	27	38	21	-10	2	-8	-18	-7	133	38	4.89	28.38
Ni														12	62	46	-19	30	9	-41	2	62	13	0.39	-0.42
Cr															42	37	0	-9	-23	-9	-12	51	9	0.37	-0.03
Li																66	10	31	4	-59	8	63	10	-0.04	-0.65
Rb																	-5	2	20	-28	0	115	18	0.25	-0.33
Ba																		13	7	-19	34	446	217	2.06	4.68
Zr																			12	-38	-8	111	32	1.09	2.29
V																				13	44	106	46	1.96	6.85
Mo																					-13	12	15	1.67	1.35
Sn																						5	4	1.55	0.84
Unit 2 (Cores 515B-10 through 515B-55, 43 samples).																									
CO_2		35	54	-12	63	9	36	100	13	9	2	45	2	47	4	-10	12	26	-8	-6	-17	1.04	1.29	1.25	0.49
Ti			5	36	33	-55	27	36	-18	8	6	45	-1	61	-16	1	-31	-1	23	52	-5	0.48	0.04	0.73	-0.36
P				-23	51	-5	5	55	-10	-17	-20	48	-5	32	-15	-8	1	20	2	-6	-22	0.05	0.01	1.54	3.62
Fe					-18	12	-18	-12	-39	-14	30	26	41	0	37	23	-25	-3	27	-15	3	4.39	0.39	0.44	-0.14
Mn						1	39	64	11	0	-4	16	9	44	-4	-8	10	14	-5	-3	-11	0.11	0.15	2.69	6.54
Na							13	9	16	16	19	7	19	-20	70	-27	57	35	8	-72	57	2.17	0.36	-0.42	-0.67
K								36	4	33	14	19	11	3	11	-5	14	42	-9	-16	1	2.07	0.18	0.48	0.89
$CaCO_3$									13	8	1	45	3	47	4	-10	12	26	-7	-6	-17	2.21	2.68	1.18	0.25
$SiO_{2amorph}$										-6	-12	-10	-25	-11	-15	-15	16	4	-26	-4	-4	1.05	0.13	2.03	4.74
C_{org}											15	20	18	-25	30	-2	26	15	-6	-12	12	0.16	0.05	4.38	22.61
Cu												29	26	4	34	-11	11	25	32	-16	-6	65	14	-0.12	0.27
Zn													23	22	10	-2	-4	13	32	1	-5	119	14	0.18	0.10
Ni														-21	51	27	-11	12	1	-43	9	56	11	0.69	0.25
Cr															-18	-11	2	-14	15	41	-1	46	7	0.61	0.90
Li																24	40	28	22	-64	33	55	7	-0.17	-0.43
Rb																	-26	-16	1	3	-24	104	11	-0.22	-0.74
Ba																		16	0	-34	49	458	224	1.57	1.98
Zr																			9	-58	-8	109	33	1.12	3.17
V																				1	4	112	19	0.24	-0.55
Mo																					-23	17	18	0.86	-0.87
Sn																						5	4	1.56	0.92

Note: C_{org} = organic C; $SiO_{2amorph}$ = amorphous SiO_2.

content ranges from 41 to 84%; C_{org} content is low (0.09–0.15%).

Unit 6 (Cores 516F-93 to 516F-124) consists of 240 m of Maestrichtian to Coniacian-Santonian, light gray to dark gray marly limestones and claystones. The sediments of an upper part (Subunit 6a, Cores 516F-93 to 516F-111) contain 50–75% $CaCO_3$ and 0.09–0.24% C_{org}. Below 1130 m sub-bottom (Subunit 6b, Cores 516F-111 to 516F-124), marly limestones and claystones are similar in their chemical composition to the sediments lying above. $CaCO_3$ content ranges from 53 to 71%; C_{org} varies from 0.12 to 0.18%.

The sediments of Units 5 and 6 differ from one another in mineral composition. Illite is the predominant clay mineral in Unit 6; montmorillonite, kaolinite, and chlorite were also detected. Quartz makes up from 3 to 21%, and feldspars from 7 to 8%. As the X-ray data show, the sediments of Unit 6 are notable not only for the variety of sediment-forming minerals, but also probably for the better crystallization of clay matter.

Unit 7 consists of Cores 516F-124 to 516F-125. This 12-m interval is represented by dark red and dark gray calcareous volcanogenic sediments (10–30% $CaCO_3$), containing 0.15% C_{org}.

Unit 8 includes the veined and partly altered vesicular basalts of Cores 516F-125 to 516F-128.

Site 517 (water depth 2963 m)

The entirety of Site 517 is 50.9 m of Pliocene to Quaternary carbonates, which are rather monotonous in lithologic composition (Fig. 6). These foraminiferal-nannofossil oozes vary from a light yellow brown color in the upper portion to almost white in the lower parts of the section (see site chapter, Site 517, this volume). The $CaCO_3$ content ranges from 74 to 84%, and C_{org} is found only in trace amounts. By X-ray analyses, the carbonates are represented exclusively by calcite. There are only low concentrations of clay minerals, quartz, feldspars, and other terrigenous components.

Site 518 (water depth 3944 m)

Two units are distinguished in this hole (Fig. 7). The first (Cores 518-1 to 518-14), is 54 m of Miocene to Quaternary, light olive gray to pale brown foraminiferal-nannofossil oozes. Three layers of foraminiferal sand, ranging between 32 and 87 cm in thickness, occur in Cores 518-3 and 518-5 (see site chapter, Site 518, this volume). The bulk of the muds is calcite, with low illite, quartz, and plagioclase content. The sediments contain from 65 to 85% $CaCO_3$, and from 0.09 to 0.15% C_{org}.

The second unit (Cores 518-15 to 518-18) consists of terrigenous muds (Core 518-15) and marly nannofossil chalk of the Miocene. The unit thickness is 17.2 m. From top to bottom, the sediment color varies from dark reddish gray (terrigenous muds) to light reddish brown and yellowish brown. The chemical composition of these sediments is also nonuniform (Fig. 7); particularly, the $CaCO_3$ content fluctuates considerably. The sum of crystalline components is considerably decreased (64%); in the latter, for instance, illite and montmorillonite constitute the bulk of Sample 518-15-1, 130–135 cm. Quartz and plagioclase reach 8–9% each. On the whole, the sediments of Unit 2 contain more clay and clastic minerals than those of Unit 1. Montmorillonite (up to 15%), kaolinite, and chlorite, as well as illite, are found.

DISCUSSION

Sites 515, 516, 517, and 518 are situated in various geomorphologic and facies provinces (Fig. 1); each is characterized by different processes of Holocene sedimentation and by different Holocene sediment types.

Site 515 was drilled in the pelagic terrigenous oxidized muds (red clays) of the Brazil Basin. The composition of muds from Holes 515A and 515B resembles that of the deep-sea terrigenous muds of the ocean margins more than that of red deep-sea clays (Table 4). The muds of Site 515 contain considerably smaller amounts of such lithogenous elements as Cr, Ni, and V, but higher quantities of Cu than in terrigenous pelitic muds of the ocean margins. Compared to the muds from Cores 355-1 to 355-15 (Emelyanov, 1977), the sediments from Site 515 contain much more Ba, less V, and almost the same quantity of Zr. The geochemical data show that the conditions under which the area of Site 515 is located at the present existed during practically the whole period of the accumulation of recovered sediments, from the upper Eocene till the Holocene. In particular, the area is very close to the calcite compensation depth (CCD), where the calcareous components were to a considerable degree dissolved, and is relatively near the continent, where the accumulation rates of terrigenous matter are rather high. At present, the CCD in the southern part of the Brazil Basin is at nearly 4500–4600 m, and usually gray, terrigenous, noncalcareous muds are accumulating at even lesser depths.

Judging by the fact that the chemical composition of all the sediments recovered at Site 515 changed only very slightly, we can assume that, since the upper Eocene, this part of the Brazil Basin has changed only very slightly both vertically and with respect to the continent of South America. For a long time, the depths of this ocean area remained almost the same as at present (about 4.0–4.5 km). The absence of coarse-grained (sandy-aleuritic) and the presence of fine-grained (pelitic and aleuritic-pelitic) muds containing less than 10% of $CaCO_3$, increased amounts of amorphous SiO_2, and uniform quantities and proportions of the remaining chemical elements (occurring in the same proportions as those in terrigenous aleuritic-pelitic and pelitic muds of deep-sea marginal areas of the Atlantic Ocean) indicate accumulation under deep-sea conditions, relatively far from continents. The main source-area of the matter accumulating at Site 515 area is, therefore, a neighboring continent (in this case South America). This is confirmed by both the mineral composition of muds and the high content of such lithogenous elements as K, Li, and Rb. The high amounts of K and Na in sediments may specify that the main source of terrigenous sedimentary matter is the alkaline rocks, traps of South America.

The presence of sharply expressed maxima on the curves of some of the compounds and elements suggests fluctuations in the physical-chemical conditions of sedimentation. For instance, perhaps a cold spell in South America during the Miocene (Kennett and Brunner, 1973; Barker et al., 1976) or a shift northwards of the hydrofront (Antarctic divergence) toward the southern part of the Brazil Basin (Barker et al., 1976; McCoy and Zimmerman, 1977) resulted in increased accumulation of amorphous SiO_2. Enhanced Mn quantities in the lower portion of Hole 515A may be evidence of decreased sedimentation rates, as is the appearance of sharply oxidizing conditions in the upper portion of sediments. These deeper muds are probably most similar in composition to red deep-sea clays. Some subsidence of the bottom to the depths close to the CCD might also produce this decrease of sedimentation rates. Subsequently, Mn content became the same as that in typical gray terrigenous muds, and, in our opinion, the possibility of a volcanic source for the Mn in the lower parts of Hole 515A is excluded. The small amount of Fe (another ore component of hydrothermal exhalations) and the quantity of Mn could not increase, because the quantities of ash, in this case reflected in the high content of Ti, Cr, and V, would also be contained in sediments.

In contrast to Site 515, the chemical composition of sediments from Site 516 indicate that it apparently never sank below the CCD. At the same time, the ranges of element content in sediments from dissimilar geomorphologic areas are rather close. This is confirmed by the analysis of correlation graphs of some element pairs. Na and K abundance fluctuations in sediments of the Brazil Basin and the Rio Grande Rise correlate with each other satisfactorily despite their highly different relative quan-

Table 3. The ranges of contents of elements in sediments of the western central Atlantic (based on the data of *Glomar Challenger* Legs 39 and 72).

Hole	Content (%)								
	$CaCO_3$	C_{org}	$SiO_{2amorph}$	Ti	P	Fe	Mn	Na	K
355	0.00–89.12	0.15–0.66	—	0.03–0.67	0.02–0.06	1.18–7.32	0.02–0.76	0.88–1.88	0.54–2.77
		0.21–2.20	—	0.53–0.85	0.03–0.42	3.54–14.89	0.02–2.76	0.99–3.83	1.86–5.96
515A and 515B	0.00–22.51	0.10–0.30	0.40–1.40	0.39–1.07	0.04–0.09	2.64–5.62	0.03–0.79	1.39–2.84	1.56–3.19
		0.10–0.30	0.40–1.54	0.42–1.13	0.04–0.10	3.46–5.93	0.03–0.79	1.44–3.13	1.74–3.37
357	1.00–92.56	0.24–0.84	—	0.006–1.05	0.01–0.65	0.30–4.67	0.003–0.64	0.27–1.53	0.16–2.06
		0.28–6.99	—	0.09–1.25	0.01–2.29	1.74–33.02	0.03–1.80	0.96–11.69	0.41–5.89
516 and 516F	4.00–92.06	0.06–0.78	0.05–2.00	0.04–0.38	0.02–0.31	0.30–1.72	0.01–0.05	0.07–1.26	0.13–0.95
		0.09–2.28	0.26–10.62	0.40–1.41	0.20–0.58	2.63–8.55	0.03–2.19	0.33–9.84	1.01–4.52
517	74.05–84.55	0.09–0.18	0.15–0.25	0.10–0.15	0.02–0.03	0.80–1.60	0.03–0.08	1.12–1.51	0.33–0.63
		0.35–0.76	0.58–1.63	0.45–0.66	0.09–0.13	5.29–6.41	0.16–0.40	5.87–7.70	2.18–2.82
518	5.75–85.06	0.09–0.27	0.05–0.87	0.09–0.52	0.03–0.10	1.10–4.57	0.05–0.13	0.90–2.00	0.50–1.60
		0.14–0.71	0.09–2.46	0.47–0.70	0.09–0.11	4.37–8.24	0.17–0.38	1.77–7.87	2.16–3.04
353–358 and	0.00–92.56	0.06–1.35	0.05–2.00	0.006–1.07	0.01–0.65	0.30–7.32	0.003–0.79	0.07–2.84	0.13–3.19
515–518		0.09–6.99	0.09–10.62	0.09–1.41	0.01–2.29	1.74–33.02	0.02–2.76	0.33–11.69	0.41–5.96
Recent sediment	—	0.84	—	0.40	0.08	5.01	0.19	—	—
	—	1.42	—	0.47	0.08	5.34	0.20	—	—
Clays, shales	—	—	—	0.45	0.08	3.33	0.07	0.66	2.28

Note: The top line of data for each hole is for natural (dry) sediments; the bottom line is data on the carbonate-free basis. "Recent sediment" data are the average values for recent terrigenous pelitic muds (< 10% $CaCO_3$) of the Atlantic Ocean marginal areas (53 samples). "Clays, shales" data are the average values for clays and shales of the earth's crust (Vinogradov, 1962).

tities (Fig. 8). Na and K are present in considerably higher quantities in the Basin sediments (more than 1.5%) than in the sediments of the Rio Grande Rise. The content of Na and K differs sharply at Sites 516 and 515, reflecting the differences between the main lithologic types of sediments (the carbonates from Site 516 and the terrigenous mud and mudstone from Site 515). A comparison of the two graphs shows that the sediments of the Brazil Basin are more enriched in K for almost the same Na content at Sites 355 and 356 (Fig. 8).

For the Rio Grande Rise drill sites, the amount of Na decreases as the carbonate content increases. The maximum quantities of Na are found in sediments of the Brazil Basin in which $CaCO_3$ is usually less than 10%. In low-calcareous sediments (Sites 356 and 357), Na concentration generally ranges from 1.00 to 1.50%, whereas in high-carbonate ones (e.g., in limestones from Site 516) it generally does not exceed 1.00%.

Ti and Fe are directly correlated; Fe increases by 1% for each 0.1% increase in Ti (Fig. 9). The quantities of both these elements are greater in sediments of the Brazil Basin than in those of the Rio Grande Rise. On the whole, the correlation of Ti and Fe in sediments of these sites is almost the same as in Recent (upper Holocene) deposits of the Atlantic Ocean or the Mediterranean and Baltic seas. The sediments from Site 357, which are considerably enriched in Ti because of the pyroclastic matter admixture, are the only exception. This correspondence indicates that Fe and Ti are represented by the same minerals in sediments, probably various silicates (clay minerals), iron hydroxides, or clastic ferruginous minerals. Some trace elements, most importantly Cr and Ni, are also linked with the same minerals. The element pairs Cr and Fe and Cr and Ti correlate rather closely (Fig. 10). This leads us to assume that Fe, Ti, Cr, and Ni are connected with each other genetically, that the bulk of them are represented by the same clay and ferruginous minerals, and that they all are probably supplied from one and the same province.

The Zr and Ti correlation is somewhat weaker; however, increases of Zr content are most often accompanied by Ti enrichment. The maxima of these elements occur in sediments of the Rio Grande Rise.

The correlation between V and Ti is also weak. This lack of correspondence indicates that V enrichment is not the result of terrigenous or pyroclastic matter, but is due to some other sources. One possible source may be the accumulation of living plankton. The close correlation between V and C_{org} was confirmed many times when studying water suspension, phytoplankton, and Holocene bottom sediments (Blazhchishin and Emelyanov, 1977). At some stage of diagenesis and katagenesis, V, like the elements P, Ba, Zn, Cu, and Mo, was separated from organic matter and connected with various authigenic or terrigenous minerals.

Manganese correlates weakly with both Ti and Fe, one of the differences between deep-sea sediments and analogous sediment types of the marginal area or of internal seas. The latter sediments show almost perfect, direct correlation between these two pairs of elements (Emelyanov, 1975). The lack of correlation between the pairs Mn and Ti, and Mn and Fe in deep-sea areas of the ocean enables us to conclude that the bulk of Mn is represented not by silicate matter and ferruginous minerals, but by micronodules and fine particles of manganese hydroxides.

The correlation between Zn and Cu is not strong, indicating that these elements are connected with different minerals in the sediments. Cu varies widely in terrigenous muds of the Brazil Basin, where Zn makes up usually from 100 to 160 ppm, compared to calcareous oozes of the Rio Grande Rise, where Zn ranges between

Table 3. (Continued.)

Content (ppm)											
Cu	Zn	Ni	Co	Cr	Li	Rb	Ba	Zr	V	Mo	Sn
6–232	14–171	19–112	10–37	13–93	—	—	<200–350	40–250	52–870	<5–35	<6
21–245	14–255	52–298	15–106	45–138	—	—	<200–1838	63–374	100–883	<5–187	<6–<55
25–261	82–365	36–90	—	30–70	40–51	64–152	190–1313	51–230	37–300	<5–51	<6–15
27–277	84–390	37–93	—	30–74	40–79	81–154	190–1342	52–235	37–303	<5–52	<6–15
5–60	<4–231	<8–520	<4–65	7–513	—	—	<200–1055	<40–285	20–>1000	<5–>100	<6–11
18–284	17–610	14–902	<7–167	9–816	—	—	<269–4492	<54–551	33–>2800	<5–>772	<8–<62
8–20	16–149	14–300	—	4–76	8–31	4–20	<200–400	<40–610	<10–110	<5	<6
27–181	98–496	28–473	—	19–291	13–258	19–204	<211–698	<50–1064	<16–116	<5–<9	<7–<10
17–33	26–45	22–28	—	18–30	26–34	8–21	—	—	—	—	—
97–154	151–298	105–197	—	86–126	124–212	43–90	—	—	—	—	—
20–44	33–119	29–58	—	15–58	29–58	14–97	—	—	—	—	—
65–174	127–222	86–263	—	52–128	78–187	60–126	—	—	—	—	—
5–261	<4–365	<8–520	<4–65	4–513	8–51	4–152	190–1300	<40–610	<10–>1000	<5–>100	<6–15
18–284	14–610	14–902	<7–167	9–816	13–258	19–204	190–4492	<50–1064	<16–>2800	<5–>772	<6–<62
86	—	78	—	101	—	—	690	150	180	—	—
90	—	81	—	106	—	—	740	160	191	—	—
57	60	95	20	100	60	200	800	200	130	2	10

Table 4. Average content of elements (in %) in Site 515 muds, deep-sea terrigenous muds, and red deep-sea clays.

Element	Site 515 muds	Recent terrigenous pelitic muds[a]	Late Quaternary red clays of the Atlantic
Organic C	0.15	0.84	0.32
Fe	4.80	5.01	5.85
Mn	0.10	0.19	0.40
Ti	0.50	0.40	0.44
P	0.05	0.07	0.08

[a] From the Atlantic Ocean marginal areas (accounting for more than 70% of less-than-0.01-mm fraction).

30 and 160 ppm. Three samples from Site 515 are outliers: two contain extremely high quantities of Zn at normal Cu concentrations, and the third is Cu enriched but has a normal Zn concentration.

Ba content changes in different sediment types regardless of $CaCO_3$. The highest and lowest quantities of Ba were recorded for the terrigenous muds of the Brazil Basin.

The content of amorphous silica is considerably lower than in estimates recorded in the shipboard smear slide descriptions. As mentioned earlier (Emelyanov et al., 1978, p. 544), the chemical method records somewhat lesser amorphous SiO_2 content. The correlation factor averages 1.6. But even if the analytic data is multiplied by this coefficient, the amorphous SiO_2 content is usually less than 5% (maximum of 10.62% on a carbonate-free basis). Amorphous silica is primarily represented by diatom remains, sponge spicules, and radiolarians.

Organic carbon ranges from 0.06 to 0.90%, reaching a maximum in the carbonate sediments from Core 516F-78. If some samples with extremely high quantities of C_{org} (0.50–0.90%) are excluded, the remaining samples from all holes have very low contents of this component, generally between 0.15 and 0.20%.

The C_{org} and amorphous SiO_2 abundances are poorly correlated, because during sedimentation and diagenesis these two components, so closely connected with one another in the suspended matter of the upper active water column, are separated. Only the portion of organic matter most resistant to decay (the bulk is in a sorbed state or in the composition of biogenic carbonate matter) is retained in sediments (sedimentary rocks).

On the basis of the peculiarities of the chemical element distribution in the sedimentary section, the components and elements studied may be divided into three groups. The first group is lithogenous. It includes K, Li, Rb, Fe, Ti, Zr, Ni, Cr, Sn, and Na; within the pelitic fraction (less than 0.01 mm), these elements correlate well or satisfactorily with one another. Their main source is the continent of South America. The second group includes $CaCO_3$, amorphous SiO_2 and C_{org}; it is biogenic. The third group includes Zn, Cu, Ba, Mo, V, and Na; this group of elements correlates strongly neither with one another nor with the other chemical elements or components studied.

The source of the last group is both terrigenous and biogenic matter. In the course of sedimentation, diagenesis and katagenesis caused a number of changes. Any initial correlations formed in the course of sedimentation (e.g., with plankton) were lost, and the elements were included into the composition of one or another mineral or were sorbed by various particles.

CONCLUSION

Despite the location of Holes 515A and 515B in the marginal area of Recent red clay occurrence (Emelyanov et al., 1975), the chemical composition of sediments from these holes is more similar to typical deep-sea terrigenous muds than to red clays of the Atlantic Ocean. The increased content of biogenic components (amorphous SiO_2, Ba, Na, Cu) in upper Paleogene and Neogene sediments indicates that the southern part of the Brazil Basin was located in an area of increased bio-

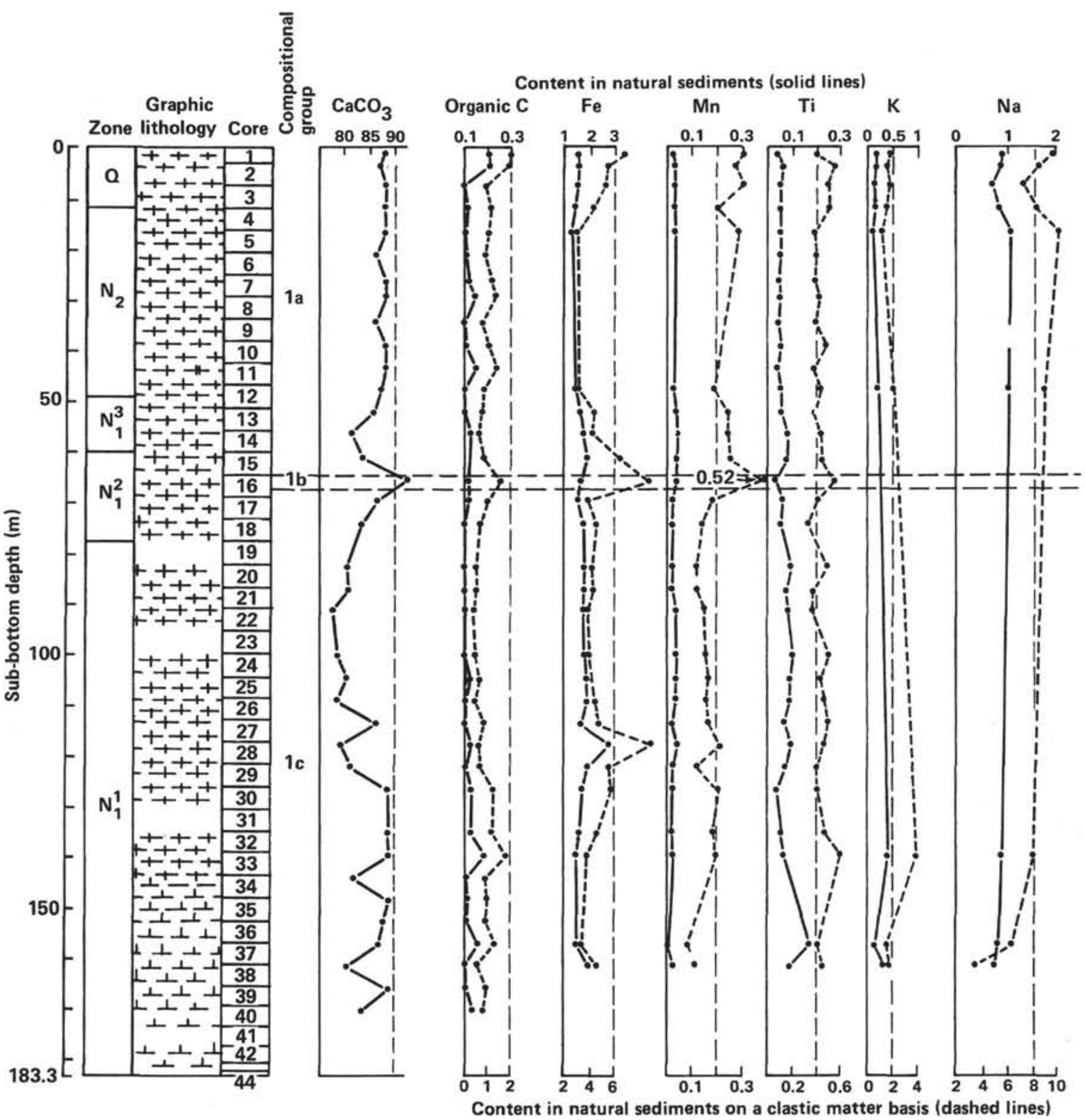


Figure 4. Lithologic composition of Hole 516 (water depth 1313 m) and distribution of chemical components and elements in sediments. Key for graphic lithology symbols is in Figure 2.

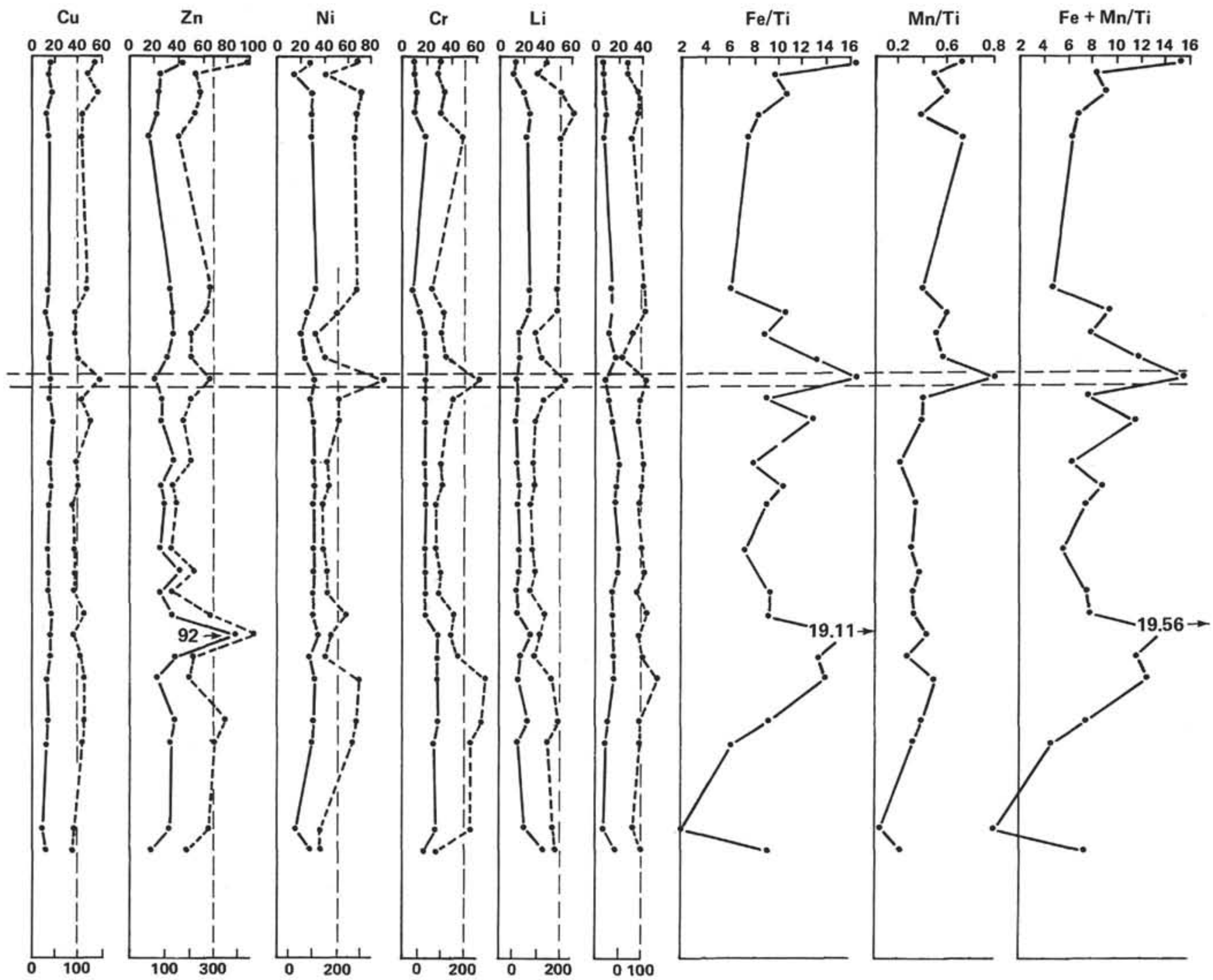
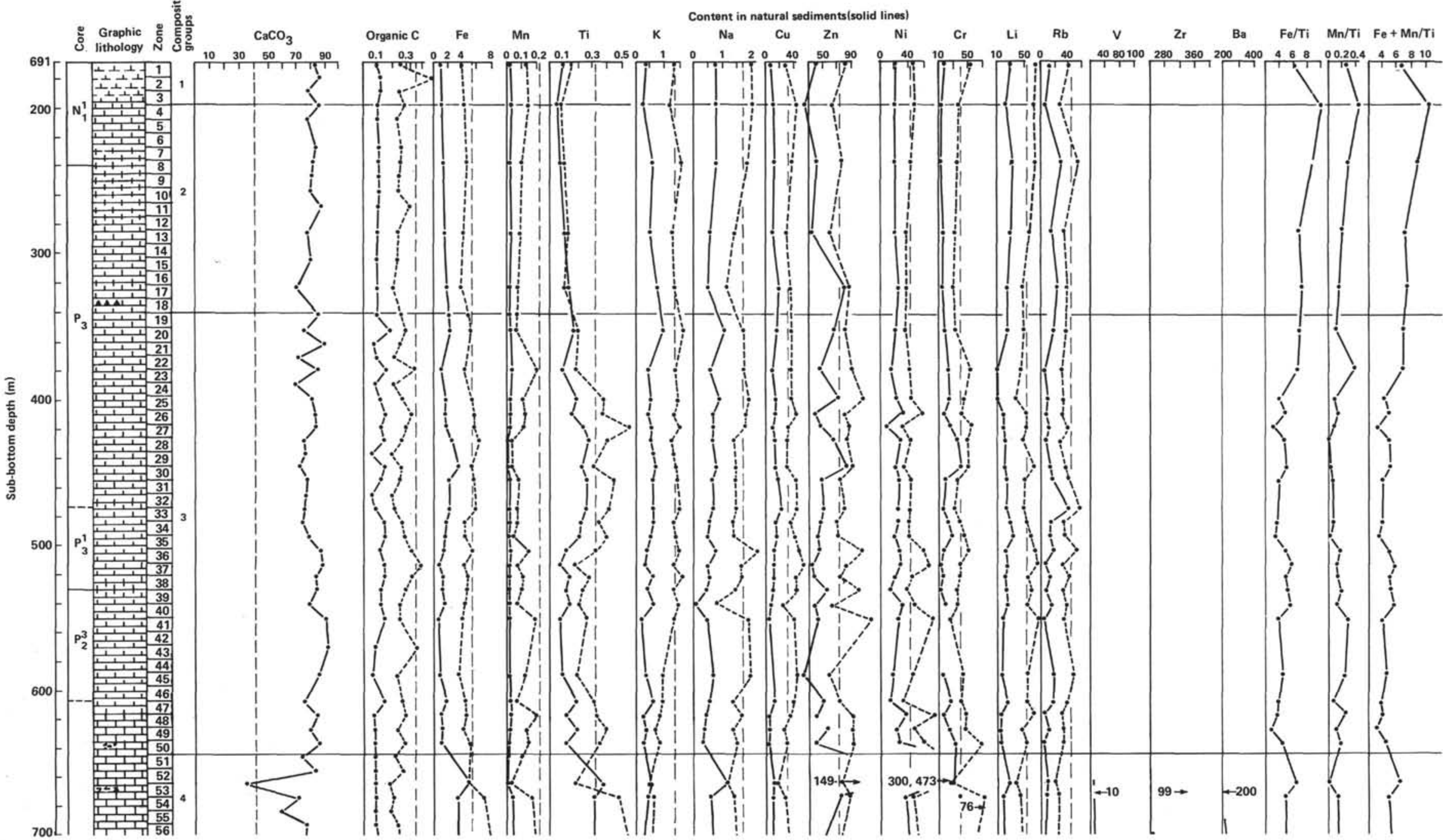


Figure 4. (Continued.)



Content in natural sediments(solid lines)
Core
Graphic lithology
Zone
Compositional groups
$CaCO_3$
Organic C
Fe
Mn
Ti
K
Na
Cu
Zn
Ni
Cr
Li
Rb
V
Zr
Ba
Fe/Ti
Mn/Ti
Fe + Mn/Ti
Sub-bottom depth (m)
691
200
300
400
500
600
700
N_1^1
P_3
P_3^1
P_2^3
149
300, 473
76
10
99
200

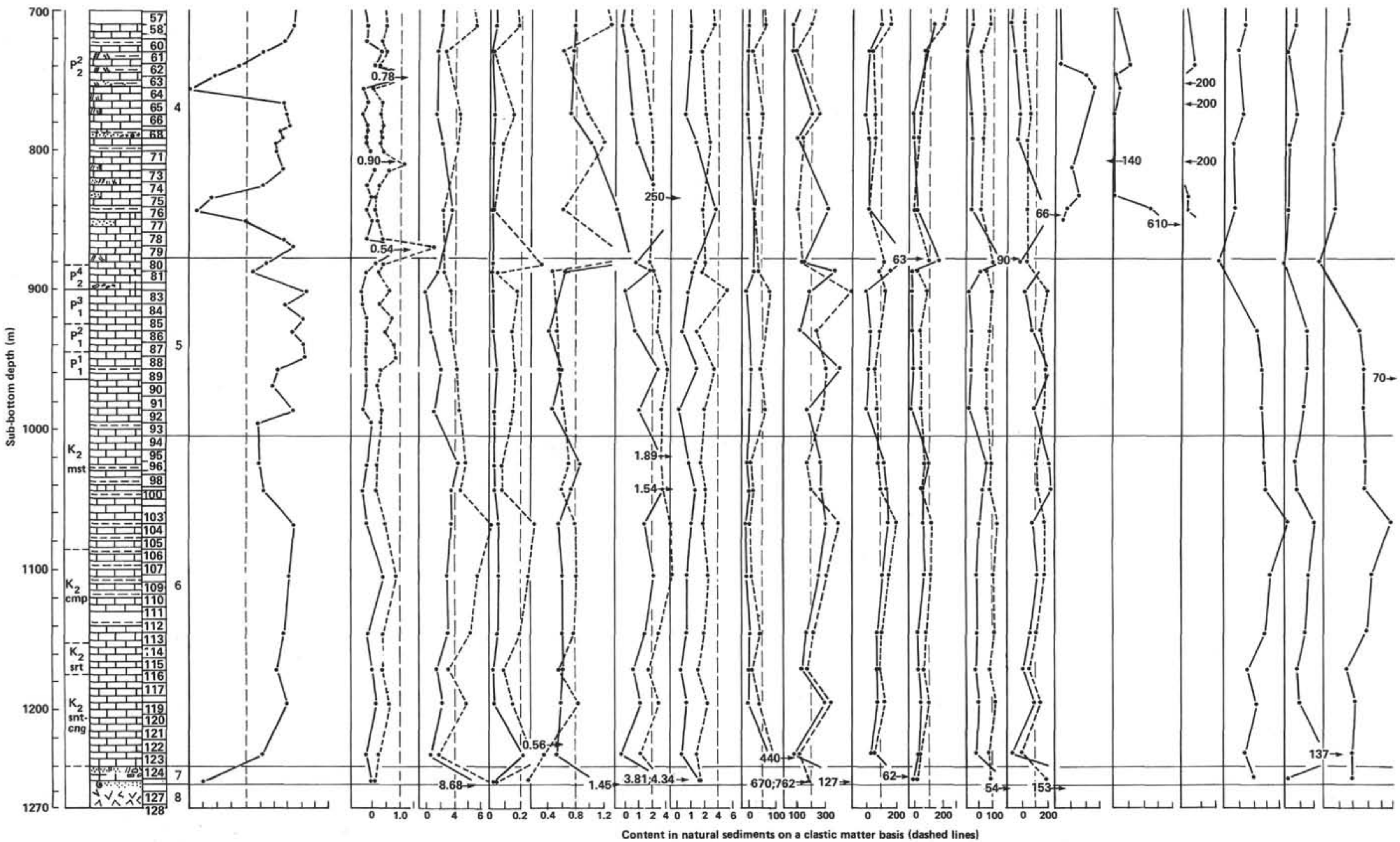


Figure 5. Lithologic composition of Hole 516F (water depth 1313 m) and distribution of chemical components and elements in sediments. Key for graphic lithology symbols is in Figure 2.

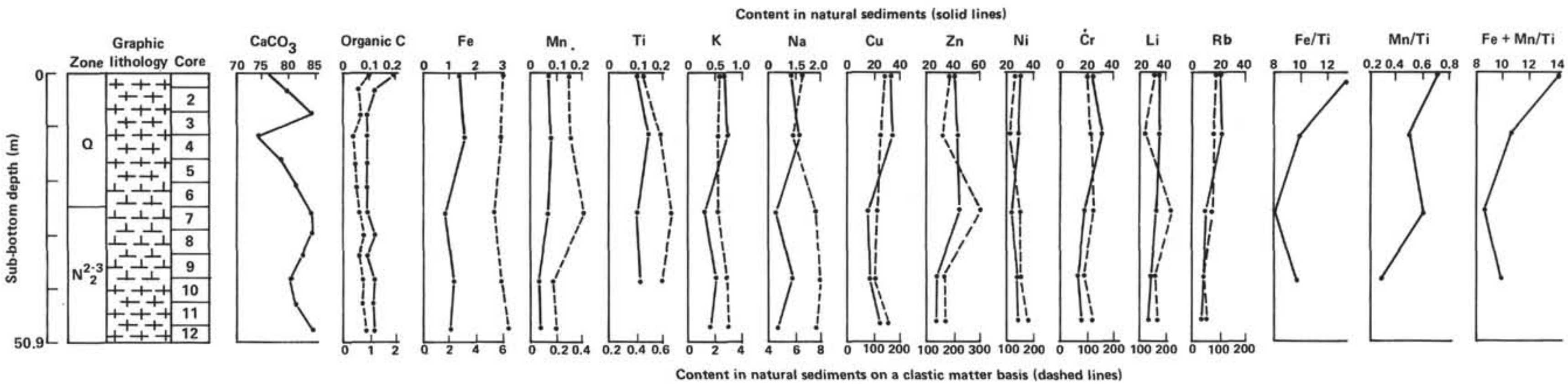


Figure 6. Lithologic composition of Hole 517 (water depth 2963 m) and distribution of chemical components and elements in sediments. Key for graphic lithology symbols is in Figure 2.

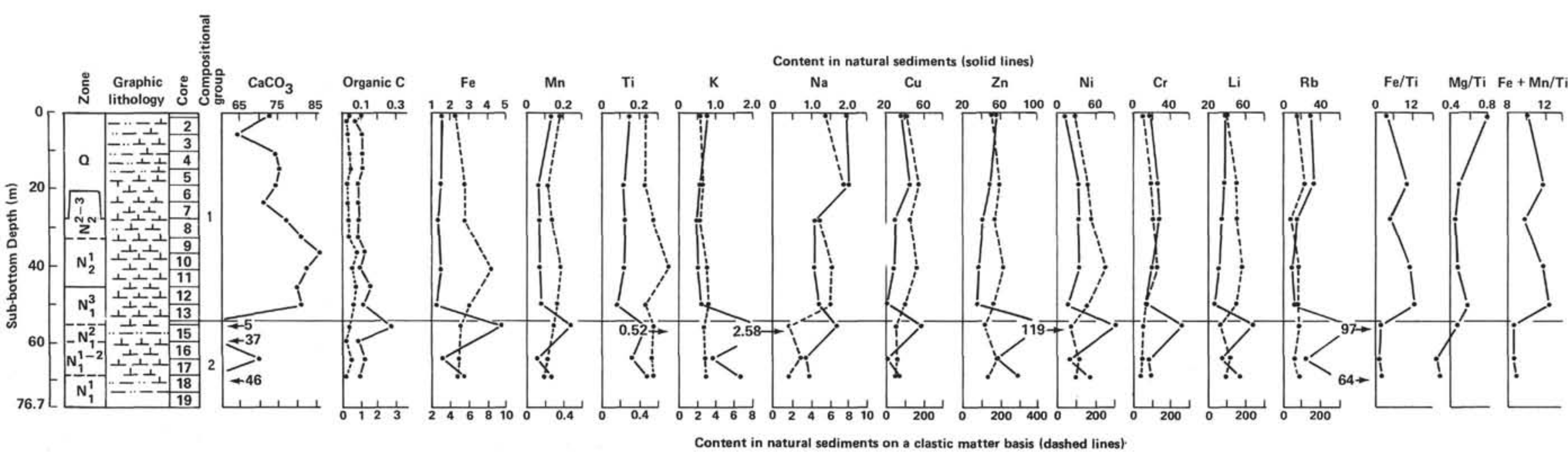


Figure 7. Lithologic composition of Hole 518 (water depth 3944 m) and distribution of chemical components and elements in sediments. Key for graphic lithology symbols is in Figure 2.

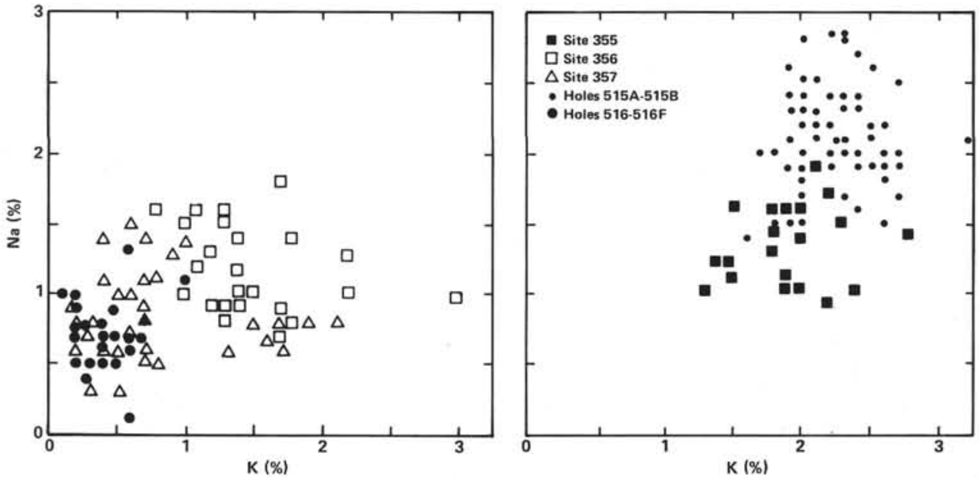


Figure 8. Correlation between Na and K.

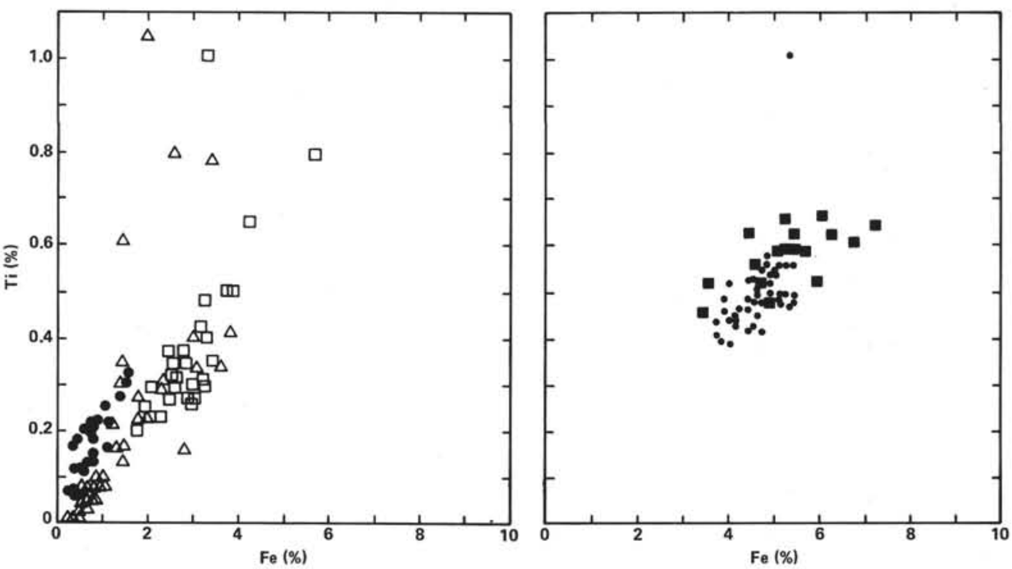


Figure 9. Correlation between Ti and Fe. See Figure 8 for symbols.

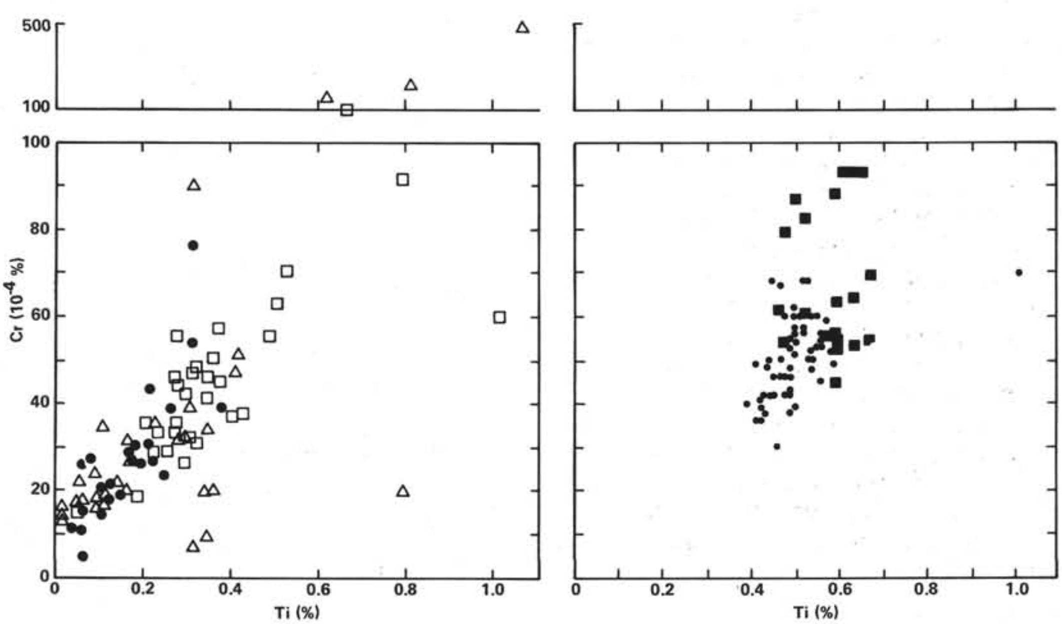


Figure 10. Correlation between Cr and Ti. See Figure 8 for symbols.

logic productivity and high sedimentation rates. Organisms with siliceous skeletons (diatoms) were prevalent among phytoplankton, and nannofossils were probably of secondary importance. More likely, the low content of $CaCO_3$ and the high content of Mn in the sediments may indicate that, after the late Paleogene, the CCD in the southern part of the Brazil Basin was somewhat lower, but the lysocline level was slightly higher, than the bottom; this resulted in only partial retention of the calcareous biogenic remains.

Considering the entire lithologic section recovered from Hole 515B, one may remark that, in the course of oceanic evolution, the chemical composition of these sediments changed to some extent. Through time, the amounts of some elements increased, others remained the same, and others greatly changed over short periods of time. The first group includes Fe, K, Na, Cu, Zn, Ni, Li, Rb, and Zr. These increase from bottom to top; it seems that, in the course of ocean evolution, still higher and higher quantities of clay and the terrigenous fine-dispersed matter with which these elements are connected will accumulate at Site 515. The second group includes $CaCO_3$, C_{org}, amorphous SiO_2, Ti, P, and V. Mn and Ba form the third group. Taking into account only Hole 515A, we find that the content of Fe, Ti, K, Zn, Zr, Ni, and V decreases somewhat from bottom to top, whereas Na continues to increase.

During the period from the late Eocene until the Holocene, the entire province of the Brazil Basin (Site 515) was characterized by the rather constant conditions of pelagic terrigenous sedimentation that took place mainly at the same depths as at present. Small changes in chemical composition are probably associated with four main changes: (1) the evolution of source terrains, mainly changes in the hydrography of South America; (2) minor alterations in physical-chemical conditions, perhaps linked with the Antarctic glaciation; (3) changes in hydrodynamic regime, which conditioned the transportation of sediments, their differentiation, and probably their sedimentation rates; and (4) the slight fluctuations of the ocean bottom level and the CCD.

The chemical composition of sediments from Holes 516 and 516F enables us to distinguish three main stages in the development of the Rio Grande Rise. The first covers the initial and shortest interval: volcanic breccia and low $CaCO_3$ sediments accumulated on basalts (the beginning of the Upper Cretaceous). The second stage is one of highly variable conditions of sedimentation covering the period from the Late Cretaceous until the middle Eocene. This record of variability is preserved in the accumulation of sediments of different chemical composition. The $CaCO_3$ contents range from 4 to 86%. Sharp variations are also observed in the content of C_{org}, Fe, Ti, K, Na, Li, Rb, and other elements. This variability suggests that in the period from the Late Cretaceous to the middle Eocene this portion of the ocean basin developed spasmodically, with sharp changes of sediment sources (both terrigenous and biogenic carbonate matter prevailed in turn); these changes were caused collectively and to varying degrees by changes in tectonic, physical-chemical, and hydrodynamic conditions.

A third stage in the development of the Rio Grande Rise (middle Eocene until Holocene) is characterized by the stability of sedimentation conditions that resulted in the formation of nannofossil oozes of 700-m thickness, all of which have a rather monotonous chemical composition. The ratios of various elements enable us to conclude that the main sediment sources were both biogenic and terrigenous. The trend of increasing relative abundance of the biogenic component ($CaCO_3$) on the one hand and that of lithogenous elements (K and Li) on the other persists from the middle Eocene until the Holocene. The portion of pyroclastic and volcaniclastic matter is insignificant.

The Rio Grande Rise sediments are most complete at Site 516 and apparently never subsided to depths that would have prohibited the accumulation of carbonate sediments. Previous sites drilled on the Rio Grande Rise have hiatuses in their sedimentary histories. These gaps are better linked with the activity of near-bottom currents (Maxwell et al., 1970).

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APPENDIX
Chemical Composition of Bottom Sediments, *Glomar Challenger* Leg 72

	Content, %									Content, ppm										
Core-section (interval in cm)	$CaCO_3$	C_{org}	SiO_2 amorph	Ti	P	Fe	Mn	Na	K	Cu	Zn	Ni	Cr	Li	Rb	Ba	Zr	V	Mo	Sn
Hole 515A																				
1-1, 130–135	8.50	0.21		0.47	0.06	5.16	0.39	2.82	2.22	85	113	50	67	57	118	380	97	53	<5	<6
2-1, 110–115	1.25	0.21	0.65	0.48	0.04	4.50	0.07	2.84	2.32	78	124	44	60	68	120	500	96	45	<5	<6
3-1, 40–45	7.50	0.18		0.45	0.05	4.60	0.06	2.32	2.06	62	106	48	68	60	106	440	85	36	<5	<6
4-1, 140–145	1.25	0.18		0.53	0.05	4.50	0.07	2.22	2.22	66	140	46	68	72	124	440	86	69	<5	<6
5-1, 40–45	0.75	0.24	0.50	0.52	0.04	4.50	0.07	2.36	2.36	56	120	48	56	68	130	350	74	55	<5	<6
6-1, 60–65	0.75	0.30		0.50	0.04	4.90	0.07	2.76	2.34	54	126	76	60	66	114	330	94	41	<5	<6
7-1, 60–65	5.25	0.27		0.56	0.06	4.82	0.12	2.40	2.27	86	365	57	54	74	100	380	99	61	<5	<6
8-1, 50–55	4.50	0.27		0.55	0.04	4.66	0.06	2.49	2.71	261	123	54	53	64	119	350	83	94	<5	<6
9-1, 50–55	1.25	0.27		0.51	0.05	4.55	0.07	2.63	2.46	104	130	70	60	67	124	500	94	36	<5	<6
10-1, 40–45	0	0.27	0.50	0.52	0.05	4.80	0.07	2.30	2.34	54	136	60	68	70	130	570	116	42	<5	<6
11-1, 50–55	0.75	0.21		0.48	0.06	5.40	0.12	2.68	2.41	92	122	68	56	59	120	450	71	37	<5	<6
12-1, 60–65	2.50	0.21		0.55	0.06	4.74	0.07	2.06	2.26	82	154	70	60	66	110	380	104	64	<5	<6
13-1, 40–45	3.98	0.25		0.59	0.05	5.62	0.11	1.87	2.21	65	131	55	49	66	108	360	120	89	8	<6
14-1, 60–65	0.75	0.15		0.54	0.08	4.97	0.41	2.03	2.22	96	141	79	48	69	109	390	140	73	<5	<6
16-1, 90–95	0.75	0.15		0.54	0.05	5.00	0.25	1.85	2.60	112	132	64	52	70	130	350	88	58	<5	<6
17-1, 50–55	1.25	0.15		0.56	0.06	5.19	0.29	2.04	2.30	90	129	59	56	72	111	290	78	56	<5	<6
18-1, 35–40	0	0.15	0.40	0.56	0.05	5.37	0.79	2.17	2.49	92	278	90	59	67	148	190	87	57	<5	<6
19-1, 50–55	4.77	0.22		0.60		5.46	0.21	2.00	2.66	74	144	76	52	74	122	390	160	100	8	<6
21-1, 90–95	5.32	0.19		0.56	0.06	5.13	0.30	2.00	2.36	91	131	67	53	65	112	270	110	90	<5	11
22-1, 50–55	0	0.15		0.50	0.07	5.16	0.22	1.97	2.43	94	136	63	51	66	130	240	96	53	<5	<6
23-1, 130–135	3.73	0.22		0.54	0.06	5.14	0.24	2.00	2.62	84	130	76	60	72	128	200	120	110	8	<6
24-1, 90–95	1.75	0.15		0.50	0.06	5.39	0.11	1.89	2.42	65	140	68	56	69	119	380	102	129	<5	9
25-1, 90–95	3.18	0.25	0.55	0.56	0.08	5.10	0.22	1.94	2.49	80	126	89	45	72	126	210	120	96	<5	<6
26-1, 100–105	2.11	0.19		0.58	0.07	4.80	0.22	1.86	2.66	74	126	76	52	74	116	280	160	90	9	<6
27-1, 110–115	0	0.19		0.56	0.05	5.20	0.22	1.78	2.64	77	132	77	45	76	144	340	180	130	7	<6
Hole 515B																				
1-1, 80–85	0	0.15		0.49	0.06	5.13	0.25	2.32	2.43	114	126	60	56	68	147	886	140	145	8	10
2-1, 80–85	0	0.15		0.50	0.06	5.07	0.33	2.09	2.52	76	136	77	54	72	146	430	90	300	10	12
3-1, 80–85	0.50	0.12		0.54	0.06	4.92	0.12	2.03	2.61	65	148	66	51	66	152	380	95	290	<5	12
4-1, 80–85	1.75	0.15	0.50	0.54	0.09	4.92	0.06	1.54	2.60	56	140	70	52	80	148	340	105	220	10	10
5-1, 80–85	2.00	0.12		0.54	0.08	5.11	0.09	1.88	2.54	82	143	63	50	75	133	550	115	108	<5	11
6-1, 50–55	2.64	0.16		0.50	0.06	4.98	0.21	1.70	2.72	74	134	90	62	84	120	430	190	130	12	<6
7-1, 50–55	1.00	0.15		0.50	0.05	5.00	0.17	2.15	2.60	52	139	68	57	76	152	1313	120	128	8	<6
8-1, 50–55	2.64	0.13	0.55	0.48	0.07	5.08	0.15	2.04	2.32	51	129	63	46	67	116	450	120	97	<5	<6
10-1, 50–55	3.75	0.15		0.44	0.06	4.12	0.14	2.34	1.99	91	121	52	48	59	93	870	116	146	10	<6
11-1, 50–55	8.50	0.15		0.39	0.06	4.00	0.16	2.40	1.94	54	122	48	40	62	110	833	110	100	9	<6
12-1, 80–85	0	0.12		0.46	0.04	3.92	0.04	2.43	2.15	67	114	62	30	65	105	790	107	87	<5	9
13-1, 80–85	0	0.15		0.42	0.05	4.40	0.05	2.51	2.13	64	120	58	41	59	105	460	76	110	8	12
14-1, 80–85	5.50	0.15	0.90	0.41	0.06	3.68	0.24	2.42	1.90	64	114	56	49	50	77	660	103	100	8	10
15-1, 80–85	1.25	0.15	1.40	0.44	0.05	3.70	0.09	2.62	1.90	50	108	48	50	54	82	890	107	205	12	12
16-1, 80–85	0.50	0.12	0.88	0.49	0.05	4.52	0.04	2.75	1.95	59	100	48	53	65	110	460	105	100	14	10
17-1, 110–115	0.75	0.15		0.47	0.05	4.24	0.06	2.34	2.06	66	120	36	50	54	86	1160	103	109	9	10
18-1, 110–115	0.75	0.15		0.45	0.04	4.56	0.05	2.54	2.00	60	106	38	46	56	94	490	78	140	11	11
19-1, 110–115	1.25	0.15		0.47	0.05	4.38	0.09	2.40	2.02	52	108	56	46	58	100	754	98	110	10	15
20-1, 110–115	1.25	0.15		0.49	0.05	4.80	0.05	2.48	2.04	64	140	82	42	58	102	446	98	110	10	15
21-1, 110–115	2.50	0.10	1.13	0.43	0.05	4.11	0.42	2.29	2.09	84	107	56	38	51	92	470	130	89	<5	<6
22-1, 80–85	6.75	0.18	1.20	0.41	0.05	3.69	0.17	1.98	2.03	58	107	48	36	45	83	500	140	71	<5	<6
23-1, 80–85	0.79	0.22		0.44	0.06	3.98	0.06	2.34	2.40	79	118	57	42	57	97	470	230	130	7	<6
25-1, 80–85	0	0.15		0.43	0.04	4.50	0.04	2.12	2.14	82	100	82	42	60	122	419	51	96	<5	<6
26-1, 80–85	1.86	0.19		0.49	0.04	4.44	0.05	2.06	2.18	65	123	73	43	64	115	420	130	130	<6	<6
27-1, 80–85	0	0.12	1.52	0.43	0.04	4.12	0.04	2.46	2.04	60	100	48	42	54	106	436	114	81	<5	<6
28-1, 70–75	0	0.15		0.45	0.05	4.12	0.04	2.20	2.04	68	100	52	42	58	108	420	123	90	<5	<6
29-1, 70–75	1.50	0.12	0.98	0.42	0.05	4.70	0.05	2.34	1.92	40	108	66	36	56	102	410	123	72	<5	<6
30-1, 70–75	1.32	0.13		0.50	0.04	4.60	0.04	2.08	2.08	83	106	65	39	59	105	400	160	130	<5	9
31-1, 70–75	0	0.12		0.42	0.05	3.76	0.10	2.23	2.08	48	110	52	39	48	86	340	133	99	<5	<6
32-1, 70–75	2.75	0.18		0.48	0.05	4.66	0.05	2.34	1.94	74	142	56	42	56	94	370	136	132	<5	<6
33-1, 50–55	6.18	0.15		0.40	0.05											376	130	87	<5	<6
34-1, 50–55	4.25	0.12	0.88	0.47	0.09											383	133	103	<5	<6
35-1, 50–55	8.23	0.16	0.98	0.52	0.06	4.04	0.60	1.94	1.85	50	111	59	57	52	90	396	116	101	<5	<6
36-1, 50–55	5.00	0.15		0.45	0.05											340	114	130	<5	<6
37-1, 50–55	5.00	0.15		0.48	0.07	3.80	0.21	1.92	1.95	36	141	59	42	48	110	250	95	113	<5	<6
38-1, 90–94	1.25	0.12		0.48	0.05	4.62	0.04	1.92	1.98	57	112	51	44	56	116	293	120	116	<5	<6
39-1, 90–94	0	0.15	0.80	0.50	0.05	5.16	0.07	2.10	1.88	82	122	66	50	60	106	233	126	142	<5	<6
40-1, 90–94	0	0.15		0.52	0.06	4.80	0.05	1.84	1.96	74	132	72	44	60	109	210	70	100	27	<6
41-1, 90–94	0	0.12	1.37	0.49	0.06	3.98	0.04	2.02	1.82	59	113	41	39	50	106	280	78	124	31	<6
43-1, 90–94	0	0.15		0.50	0.04	4.50	0.03	2.02	1.72	68	130	54	48	52	103	340	84	141	42	<6
44-1, 92–96	0.50	0.15		0.51	0.05	5.33	0.04	2.02	1.72	84	129	60	48	53	104	340	83	108	31	<6
45-1, 92–96	0	0.16	0.98	0.49		4.64	0.04	2.11	2.16	59	117	47	38	47	80	220	84	127	32	<6
46-1, 92–96	0	0.12		0.50		4.01	0.03	1.52	1.75	56	113	41	46	48	120	220	84	120	45	<6
47-1, 92–96	5.50	0.18		0.51												230	63	108	47	<6
48-1, 92–96	1.25	0.12		0.43		4.38	0.03	1.50	1.86	26	82	48	45	44	112	310	82	93	38	<6
49-1, 80–84	2.39	0.16		0.53		4.43	0.04	1.73	2.27	60	127	44	50	47	94	230	99	94	35	<6
50-1, 80–84	9.30	0.16		0.49		3.85	0.14	1.69	2.05	75	132	42	58	43	85	230	105	84	41	<6
51-1, 80–84	0.50	0.12	0.80	0.43		3.69	0.03	1.53	1.80	56	95	48	50	47	87	390	54	102	51	<6
53-1, 80–84	0	0.15		0.49		4.14	0.03	1.50	2.00	58	116	42	44	40	116	410	92	98	36	<6
54-1, 80–84	0	0.15		0.47		3.84	0.03	1.42	1.96	60	116	48	50	40	104	330	68	100	45	<6
55-1, 44–48	4.55	0.16	0.44	0.49		3.88	0.60	1.63	2.43	51	116	50	55	47	109	420	83	110	50	<6
56-1, 44–48	4.25	0.15	0.13	1.07		5.30	0.06	2.06	3.19	48	172	87	70	51	77	450	210	120	38	<6
57-1, 44–48	22.51	0.12		0.34		2.64	0.11	1.39	1.56	25	117	52	42	43	64					
Hole 516																				
1-1, 90–95	88.81	0.21	0.05	0.04	0.02	0.66	0.03	0.96	0.18	16	42	28	10	14	4	<200	<50	<10	<5	<6

Appendix. (Continued.)

Core-section (interval in cm)	Content, %									Content, ppm										
	$CaCO_3$	C_{org}	SiO_2 amorph	Ti	P	Fe	Mn	Na	K	Cu	Zn	Ni	Cr	Li	Rb	Ba	Zr	V	Mo	Sn
Hole 516 (Cont.)																				
2-1, 60–65	87.81	0.21		0.06		0.58	0.03	0.92	0.18	14	24	16	10	12	4	<200	<50	<10	<5	<6
3-1, 50–55	88.81	0.10		0.05		0.53	0.03	0.72	0.17	17	24	30	12	22	8					
4-1, 60–65	88.81	0.12	0.05	0.05	0.03	0.42	0.02	0.82	0.17	12	22	28	10	26	8	<200	<50	<10	<5	<6
5-1, 120–125	88.31	0.12		0.04		0.30	0.03	1.04	0.13	12	16	28	20	22	6	<200	<50	<10	<5	<6
6-1, 140–145	86.30	0.12	0.05	0.05	0.03											<200	<50	<10	<5	<6
7-1, 140–145	88.56	0.12		0.04												<200	<50	<10	<5	<6
8-1, 140–145	88.06	0.15	0.05	0.05	0.03											<200	<50	<10	<5	<6
9-1, 140–145	86.30	0.10		0.05												<200	<50	36	<5	12
10-1, 140–145	88.56	0.10		0.05												<200	<50	<10	<5	16
11-1, 140–145	88.31	0.15	0.05	0.04	0.03											<200	<50	<10	<5	19
12-1, 125–130	87.56	0.10		0.05		0.31	0.02	1.00	0.24	14	32	32	8	22	12	<200	<50	49	<5	17
13-1, 125–130	86.81	0.10	0.05	0.05	0.03	0.54	0.03			10	35	26	15	25	14					
14-1, 125–130	81.30	0.12		0.08		0.74	0.04			14	38	20	20	19	12	<200	<50	<10	<5	12
15-1, 115–120	83.05	0.12		0.07		0.92	0.04			14	32	22	20	19	18	<200	<50	<10	<5	12
16-1, 115–120	92.06	0.12	0.05	0.04	0.03	0.66	0.04			14	21	30	20	18	9	<200	<50	<10	<5	16
17-1, 115–120	86.30	0.12		0.05		0.46	0.02			14	26	26	20	18	12	<200	<50	<10	<5	17
18-1, 135–140	83.80	0.10		0.05		0.66	0.02			16	26	30	20	16	14	<200	<50	30	<5	<6
20-1, 135–140	80.30	0.10		0.09		0.74	0.02			14	37	30	20	17	20	<200	<50	23	<5	11
21-1, 135–140	80.30	0.10	0.25	0.07	0.04	0.74	0.02			14	25	30	20	18	18	<200	<50	16	<5	12
22-1, 130–135	77.55	0.10		0.08		0.74	0.03			13	29	30	20	18	18	<200	<50	<10	<5	<6
24-1, 130–135	78.55	0.10		0.10		0.74	0.03			12	25	30	20	19	20	<200	<50	29	<5	10
25-1, 130–135	80.05	0.12		0.08		0.84	0.03			12	41	30	20	19	20					
26-1, 110–115	78.80	0.10		0.09	0.05	0.84	0.03			12	25	30	20	17	16					
27-1, 110–115	86.30	0.10		0.06		0.56	0.02			14	34	30	20	18	15					
28-1, 45–50	78.80	0.12		0.09		1.72	0.04			13	92	34	30	25	15					
29-1, 145–150	81.30	0.10		0.07		0.94	0.02			14	38	26	30	19	16					
30-1, 115–120	88.56	0.12		0.04		0.56	0.02			12	21	30	30	18	16					
32-1, 115–120	88.06	0.12		0.05		0.46	0.02			12	38	30	30	22	10					
33-1, 135–140	88.06	0.18	0.25	0.06	0.06	0.38	0.02	0.85	0.42	11	33	28	25	17	8					
34-1, 135–140	81.30	0.10																		
35-1, 135–140	88.31	0.10																		
36-1, 90–95	87.56	0.10																		
37-1, 90–95	86.81	0.15		0.17		0.36	0.01	0.76	0.18	8	32	16	28	20	6					
38-1, 90–95	79.30	0.10	0.25	0.09	0.05	0.84	0.02	0.70	0.36	13	37	26	18	37	16	<200	73	16	<5	<6
39-1, 110–115	88.31	0.10																		
40-1, 110–115	83.30	0.12																		
Hole 516F																				
1-1, 60–65	83.30	0.10	0.05	0.08	0.05	0.50	0.02	0.78	0.34	8	40	20	18	27	12	<200	62	<10	<5	<6
2-1, 60–65	87.31	0.12																		
3-1, 90–95	77.80	0.12																		
4-1, 90–95	85.05	0.10	0.25	0.05		0.50	0.02	0.77	0.24	12	25	20	14	23	4	<200	61	<10	13	<6
5-1, 130–135	76.80	0.10																		
7-1, 110–115	82.30	0.10	0.25		0.06															
8-1, 110–115	81.05	0.10	0.15	0.07	0.05	0.62	0.02	0.80	0.57	12	42	20	14	32	28	<200	51	<10	<5	<6
9-1, 110–115	78.80	0.10																		
10-1, 140–145	78.06	0.10																		
11-1, 140–145	87.56	0.10																		
13-1, 140–145	77.55	0.09	0.10	0.10		0.70	0.02	0.59	0.47	12	33	20	18	29	16	<200	101	17	<5	<6
15-1, 40–45	78.30	0.09	0.37																	
17-1, 75–80	68.79	0.09	0.25	0.12	0.05	0.90	0.02	0.50	0.73	20	81	26	18	25	26	<200	91	11	<5	<6
19-1, 40–45	83.80	0.09																		
20-1, 15–20	72.80	0.18	0.25	0.16		1.14	0.02	1.09	0.95	19	67	22	20	25	20	<200	100	27	<5	<6
21-1, 80–85	87.81	0.06																		
22-1, 55–60	69.54	0.09																		
23-1, 5–10	84.30	0.15		0.08	0.05	0.54	0.03	0.60	0.36	10	44	16	26	10	6					
24-1, 55–60	68.54	0.09																		
25-1, 125–130	80.05	0.12	0.25	0.18	0.07	0.80	0.02	0.92	0.50	14	72	22	26	8	10	<200	130	18	<5	<6
26-1, 120–125	83.05	0.15		0.15		0.75	0.02	0.69	0.38	14	39	31	19	17	7					
27-1, 15–20	82.55	0.12	0.25	0.22		0.78	0.02	0.69	0.51	11	46	10	29	18	11	<200	100	43	<5	<6
28-1, 95–100	74.05	0.15		0.27		1.38	0.01	0.67	0.50	15	66	30	38	21	9					
29-1, 100–105	74.80	0.06																		
30-1, 105–110	71.55	0.15	0.15	0.22		1.17	0.01	0.83	0.67	16	85	22	43	20	13	<200	97	11	<5	<6
31-1, 70–75	76.30	0.12		0.25		1.07	0.02	0.68	0.65	20	50	26	23	23	19					
32-1, 100–105	76.05	0.06																		
33-1, 35–40	75.02	0.09	0.25	0.23		1.20	0.02	0.77	0.74	22	69	26	18	23	43	<200	108	14	13	>6
34-1, 70–75	74.30	0.15		0.22		0.90	0.02	0.62	0.58	18	48	26	26	26	14					
35-1, 145–150	77.80	0.15		0.21		0.79	0.01	0.54	0.50	18	42	20	30	31	14					
36-1, 60–65	86.30	0.12	0.55	0.11	0.06	0.57	0.02	0.74	0.38	13	46	26	20	21	19	<200	81	13	12	<6
37-1, 115–120	86.81	0.15		0.07		0.41	0.01	0.46	0.28	14	32	28	14	22	6					
38-1, 40–45	82.05	0.15		0.13		0.67	0.02	0.65	0.57	16	38	21	18	21	15					
39-1, 56–60	82.80	0.12		0.11		0.61	0.02	0.46	0.36	14	58	14	14	22	8	<200	90	12	<5	<6
40-1, 5–10	77.80	0.12		0.13		0.77	0.02	0.07	0.62	10	38	31	21	23	16					
41-1, 65–70	89.31	0.15		0.07		0.30	0.02	0.46	0.22	8	42	26	<4	18	6					
43-1, 40–45	90.81	0.09	0.37		0.04															
45-1, 15–20	84.80	0.06	1.68	0.08	0.04	0.38	0.02	0.70	0.37	14	22	20	19	16	19	<200	73	12	<5	<6
47-1, 5–10	76.30	0.15		0.19		0.81	0.02	0.63	0.61	18	51	15	30	25	19					
48-1, 80–85	86.05	0.09	0.25	0.11	0.04	0.45	0.03	0.51	0.31	9	41	40	20	20	7	<200	55	<10	<5	<6
49-1, 90–95	80.80	0.09		0.20		0.64	0.03	0.50	0.36	10	58	26	26	14	10	<200	150	27	<5	<6
50-1, 50–55	86.30	0.09		0.12		0.56	0.02	0.43	0.31	8	40	28	34	15	7					
51-1, 86–90	75.05	0.09																		
52-1, 56–60	84.80	0.09																		
53-1, 77–81	35.52	0.09		0.38		2.49	0.02	1.26	0.64	17	149	300	39	30	12	<200	99	<10	<5	<6

Appendix. (Continued.)

Core-section (interval in cm)	Content, %									Content, ppm										
	$CaCO_3$	C_{org}	SiO_2 amorph	Ti	P	Fe	Mn	Na	K	Cu	Zn	Ni	Cr	Li	Rb	Ba	Zr	V	Mo	Sn
Hole 516F (Cont.)																				
54-1, 30–34	72.30	0.09	1.30	0.32	0.08	1.65	0.05	0.73	0.48	15	76	38	76	20	10	<200	180	89	<5	<6
55-1, 91–95	58.79	0.09																		
56-1, 16–20	78.30	0.09																		
58-1, 54–58	76.30	0.12	0.37	0.31		1.65	0.05	0.77	0.30	16	47	44	53	22	9	<200	180	58	<5	<6
60-1, 61–65	69.29	0.12																		
61-1, 138–142	53.53	0.24	0.70	0.30	0.07	1.34	0.02	0.76	0.47	15	44	26	42	14	14					
62-2, 95–99	37.27	0.18														360	280	<10	<5	<6
63-1, 112–116	19.01	0.78														<200	240	89	<5	<6
64-1, 136–140	4.00	0.09														<200	250	110	<5	<6
65-1, 146–150	69.29	0.12																		
66-1, 72–76	71.55	0.09		0.28		1.39	0.05	0.57	0.63	16	74	20	16	14	23	<200	200	70	<5	87
67-1, 75–79	72.55	0.12																		
68-1, 72–76	66.04	0.12	0.55		0.04															
69-1, 124–128	68.04	0.12																		
70-1, 56–60	62.79	0.12	2.00	0.46	0.08	1.70	0.04	0.98	0.85	18	53	26	16	15	19					
71-1, 28–32	62.79	0.15																		
72-2, 50–54	23.76	0.90														<200	140	45	<5	<6
73-1, 101–105	67.79	0.18																		
74-2, 96–100	54.03	0.12																		
75-1, 120–124	16.26	0.15	0.37		0.15											280	240	61	<5	<6
76-2, 16–20	5.00	0.12	0.37	0.64		2.47	0.04	1.66	2.54	25	96	26	18	12	66	290	340	31	<5	<6
77-1, 98–102	41.53	0.15														400	610	22	<5	<6
78-4, 142–146	69.54	0.12																		
79-1, 138–142	75.30	0.54														<200	170	31	<5	<6
80-3, 46–50	54.78	0.18	1.12	1.22	0.18	1.98	0.02	0.95	0.95	370	59	63	59	50	24					
81-1, 122–126	46.52	0.12	0.50	0.28	0.31	1.50	0.03	0.86	1.34	25	106	57	18	34	52					
83-1, 18–22	85.80	0.09	0.25			0.53	0.03	0.70	0.46	12	68	20	14	14	28	<200	160	41	9	<6
84-1, 103–107	70.29	0.09																		
85-1, 55–59	83.05	0.12																		
86-1, 110–116	76.05	0.12	0.30	0.13	0.06	0.90	0.04	0.48	0.78	16	54	26	14	20	39	<200	150	37	<5	<6
87-1, 68–74	84.30	0.12																		
88-1, 31–35	84.80	0.12														<200	150	36	9	<6
89-1, 58–62	64.04	0.12	0.30	0.22	0.08	1.68	0.07	1.12	1.60	20	111	24	20	18	70	<200	170	44	<5	<6
90-1, 61–65	41.03	0.12																		
92-1, 71–75	76.30	0.09	0.30	0.15		1.14	0.04	0.43	0.90	16	64	20	14	14	42	<200	240	43	8	<6
93-1, 53–57	50.03	0.15																		
96-1, 63–67	50.03	0.12		0.36		2.86	0.05	0.69	1.89	11	83	47	40	43	61					
100-1, 138–142	54.03	0.09	0.25	0.29	0.03	2.28	0.05	0.92	1.84	14	84	50	32	36	64					
104-1, 36–40	75.30	0.12		0.20		2.28	0.08	0.75	1.08	9	92	52	32	30	40	<200	130	31	7	<6
108-1, 71–75	72.30	0.24	0.37	0.23	0.03	2.00	0.08	0.64	1.40	10	80	44	32	26	44	<200	200	62	<5	<6
113-1, 70–74	68.54	0.12	0.10	0.25		2.00	0.07	0.58	1.07	16	61	36	29	28	36	<200	160	62	<5	<6
116-1, 85–89	63.04	0.15		0.23		1.20	0.04	0.36	0.70	12	56	36	28	22	22	<200	140	38	<5	<6
119-1, 20–24	71.05	0.18	0.25	0.25		1.64	0.05	0.60	0.90	12	90	36	30	28	40					
123-1, 62–66	52.78	0.12	0.25	0.19		0.92	0.26	0.36	0.27	44	45	24	23	23	6					
125-1, 42–46	11.01	0.15	0.25	1.45	0.02	8.68	0.06	1.05	3.81	670	127	62	19	54	153					
Hole 517																				
1-1, 32–37	76.55	0.18		0.10	0.03	1.36	0.07	1.44	0.58	32	40	28	22	34	20	<200	130	74	<5	<6
2-1, 52–57	79.05	0.12																		
3-1, 52–57	84.55	0.09																		
4-1, 22–27	74.05	0.09	0.15	0.15		1.50	0.08	1.51	0.63	33	42	27	30	32	21	<200	<50	36	<5	<6
5-1, 102–107	78.30	0.09	0.22		0.02															
6-1, 122–127	81.55	0.09																		
7-1, 103–108	84.55	0.09	0.25	0.10		0.80	0.06	1.12	0.33	17	45	22	19	32	11	<200	<50	29	<5	<6
8-1, 103–108	84.05	0.12																		
9-1, 110–115	82.05	0.09																		
10-1, 110–115	80.30	0.12		0.11		1.06	0.03	1.43	0.50	18	28	27	16	28	8	<200	<50	18	<5	<6
11-1, 80–85	81.30	0.12																		
12-1, 130–135	84.05	0.12	0.22			1.00	0.03	1.16	0.44	24	26	28	18	26	8	<200	<50	20	<5	11
Hole 518																				
1-1, 33–38	65.79	0.12	0.25	0.16	0.03	1.48	0.13	1.97	0.78	39	54	29	19	37	27	<200	<50	29	<5	11
2-1, 110–115	72.30	0.09																		
3-1, 140–145	64.54	0.12	0.87																	
4-1, 130–135	74.04	0.12																		
5-1, 85–90	75.55	0.12	0.50																	
6-1, 85–90	74.55	0.09		0.12		1.38	0.06	2.00	0.62	44	50	42	26	38	32	<200	<50	29	<5	11
7-1, 90–95	71.05	0.09	0.22																	
8-1, 125–130	76.55	0.09	0.22	0.13		1.26	0.06	1.16	0.50	30	42	42	28	36	14	<200	<50	47	<5	9
9-1, 135–140	81.55	0.09																		
10-1, 30–35	85.06	0.12	0.22																	
11-1, 100–105	82.80	0.09		0.12		1.41	0.01	1.08	0.50	29	38	45	22	32	14	<200	506	<10	<5	<6
12-1, 100–105	79.05	0.15																		
13-1, 10–15	80.55	0.12	0.25	0.09		1.10	0.06	1.19	0.58	20	33	32	15	29	17	<200	506	29	<5	<6
15-1, 130–135	5.75	0.27	0.10	0.52	0.10	4.57	0.25	1.66	2.58	61	119	86	58	73	97					
16-1, 140–145	37.50	0.09																		
17-1, 95–100	69.02	0.12	0.75	0.16		1.40	0.05	0.90	0.82	20	58	37	18	40	25	<200	506	46	<5	<6
18-1, 135–140	46.03	0.09	0.05	0.29	0.05	2.56	0.10	0.99	1.60	37	82	58	28	58	64					
19-1, 140–145						1.50	0.14	4.00	3.60	28	273	15	12	400	1040					
21-1, 145–150						4.68	0.82	3.14	1.14	167	256	188	64	60	27					
21-1, 150–155						8.10	0.21	2.94	1.21	177	134	156	226	50	37					

Note: C_{org} = organic C; $SiO_{2\,amorph}$ = amorphous SiO_2.