5. MINERALOGY, GEOCHEMISTRY, AND PETROGRAPHY OF SEDIMENTS RECOVERED AT SITE 345, DSDP LEG 38

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INTRODUCTION

The mineralogy, geochemistry, and petrography of sediments recovered from Site 345 are discussed. Site 345 was located near the base of the Mohns Ridge near the western margin of the Lofoten Basin. The coring program was designed to penetrate horizontal (turbidite?) layers, which in turn abut against a folded transparent sediment sequence.[1] The latter, in turn overlie basement.

LITHOLOGIC DESCRIPTIONS

Series 1 (Pleistocene to early Miocene; Cores 1-1 to 6-4, Samples 241-246, depth 0-58 m)

The series boundary by the shipboard sedimentologist was established at Core 5-4. According to petrographic data, the boundary should be placed at a lower level. Sediments of Core 6-2 (Sample 246) are a clay graywacke genetically identical to those of Core 5.

Series 1 consists of very poorly sorted and clayey graywackes and silty sandy clays. The clastic content varies between 10%-20% and 50%. The clastic grains range in size from 0.5-0.6 mm to 0.02-0.01 mm. Clastic grains consist of irregular, acute-angled quartz, a few quartzite fragments, plagioclase, and less common mica and sparse glauconite grains. Also present are occasional pyroxene and amphibole fragments, single, short-column zircon grains (0.02-0.08 mm), as well as foraminifera shells. The clayey matrix is finely interspersed with carbonate (Sample 243).

An interbedding of typical clastic mixed-layer clay material (Samples 241, 243, 244) with more montmorillonitic clays (formed from volcanic glass, Samples 242, 245) is characteristic. Principal components of the clastic clays are alteration products of biotite, illite, and kaolinite. Diffraction patterns of the samples show (in the small-angle region) a broad "indented" reflection in the 10-14Å range (Table 1). This is evidence of differing degrees of hydration of montmorillonite interlayers. After glycerine saturation, the diffraction patterns record a broad peak from 14 to 19Å, which indicates that the montmorillonite component is virtually a mixed-layer phase of montmorillonite-vermiculite. The transformation of biotite through the vermiculite and mixed-layer phases is a widespread process in continental sedimentary rocks. This has been thoroughly investigated and is known to be characterized by diffraction effects similar to those just described (Kossovskaya et al., 1963). The micaceous component does not contain expandable layers and belongs to the illite group. The Mg-Fe chlorites often have imperfect brucite layers. Apparently, they are also a product of biotite transformation.

A reticular texture, characteristic in the montmorillonitization of volcanic glass, is typical of montmorillonitic clays. Often present are acute-angled quartz grains, amphiboles, and pyroxenes; the latter illustrate the exsolution "cock's combs." Phillipsite sometimes develops after glass fragments. The montmorillonites containing aluminum have a low iron content and may contain various absorbed cations. Sometimes glycerine saturated samples (Sample 246) have a diffraction pattern characterized by abnormally high values, $d_{(001)}$, of the small-angle reflection 19.8Å. This indicates a weak crystallization, a dispersed character of montmorillonite, or the presence of mixed-layer units.

The base of the series consists of a graywacke with an abundant clay matrix. The composition of the clay matrix is a montmorillonitic mixed-layer clay, with the montmorillonite being poorly crystallized.

Series 2 (late Oligocene or early Miocene; Cores 7-2 to 10-5, Samples 247-255, depth 65-139 m)

Series 2 nearly conforms to Subunit 2A of the shipboard designation. However, the upper boundary of the series is at the top of Core 7-1, and the lower boundary is at the base of Core 10-5 (Figure 1). This series should be set apart as an independent series inasmuch as the lithologic character (with typical siliceous-clay deposits) is not present elsewhere in the section. The underlying deposits of Series 3 and 4 consist of highly uniform clayey siltstones.

The series consists of siliceous clays, and more rarely clay diatomites, which are green-gray and have a fine-aggregate, sometimes reticular, texture. The sediments consist of a high-dispersed clay mass of a predominantly montmorillonitic composition, finely interspersed with siliceous microfossils including diatom fragments, Radiolaria, and occasional sponge spicules. Well-preserved forms are rather rare. Fragments of green-brown, more rarely colorless glasses (n = 1.52-1.55) are present. These are sometimes replaced by a fine aggregate of zeolites (phillipsite?). Lower in the sediment section, the admixture of clastic material increases including small quartz grains, rare fragments of fresh plagioclase, mica flakes, and single glauconite

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[1]For the purposes of this paper, the sediments have been grouped into "series" (Figure 1). The "series" do not necessarily correspond to "units" as defined by shipboard sedimentologists (see Site Report chapter, this volume). Also sediment terminology is that of the authors and may not correspond to shipboard designations. Sample numbers are those assigned by the authors for the investigations.

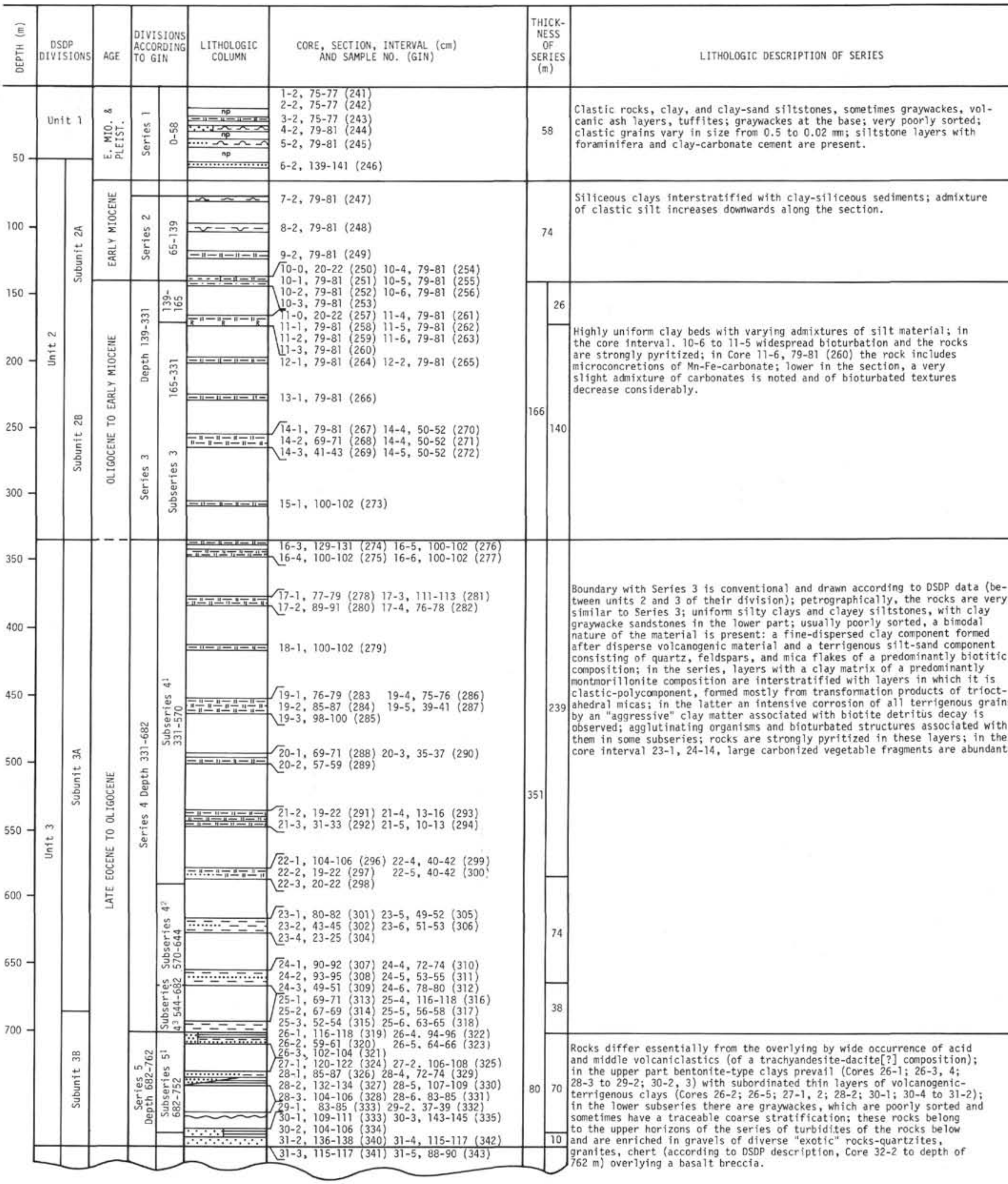

Figure 1. *Series designations and sediment characteristics, Site 345.*

grains. Zeolites are absent, and this can be apparently attributed either to the "share" contributed by fresh volcanic glass, or, perhaps, to a change in its composition (higher in the section there are more alkaline and basic [?] glasses which, in fact, enable zeolite to be formed).

A possible alteration of volcaniclastics is reflected in the character of montmorillonites, which changes

PETROGRAPHIC DESCRIPTION OF SUBSERIES AND LAYERS	ASSOCIATIONS OF CLAY AND AUTHIGENIC MINERALS
The composition of clastic material is quartz, plagioclases, micas of a predominantly biotitic composition, sometimes indented-dissolved pyroxene and amphibole grains, single grains of zircon and garnet; glass fragments are numerous; a varying composition of the clay matrix is typical: from clastic, associated with decay of trioctahedral micas, to volcanogenic, mostly represented by montmorillonite.	Alternation of a polycomponent association of clay minerals associated with biotite decay - a typical gamut of chlorite-vermiculite-montmorillonite minerals with relatively pure aluminum, slightly ferruginous predominantly 12Å (Na-K)-montmorillonites of a bentonite type.
Clay-siliceous rocks and clay diatomites consist of a fine-dispersed clay mass finely intersperesed with remains of silicon organisms, shreds of diatom and Radiolaria tests, more rarely sponge spicules; well-preserved forms are rare; a "reticular" texture is typical of the clay; it is characteristic of montmorillonite formed after volcanic glass; Phillipsite forms druse-like growths after some organic remains or substitutes for volcanic glass fragments.	The principal clay mineral is an aluminum, slightly ferruginous montmorillonite resistant to acid treatment; at the top of the subseries are Ca-Na or Ca-K montmorillonites (14-16Å), which are replaced below by Na-K montmorillonites (12Å); phillipsite associates with Ca-montmorillonite at the base of the subseries, its content decreases; mixed-layer smectite of montmorillonite (80%)-illite (20%).
Polycomponent-montmorillonite clays, often intensively pyritized: in the pyritized rocks the role of kaolinites is somewhat increased; an intensive development of bioturbated textures; clastogenic clay layers consisting mostly of trioctahedral micas decay products.	Principal mineral is an aluminum, slightly ferruginous predominantly Na-K (12Å) montmorillonite; abundant accumulations of globular pyrite.
In the top of the subseries there is an unusual Fe-montmorillonite rock with 0.02-0.05 mm sized rosettes of Fe-rhodochrosite or Mn-siderite; below the same polycomponent, montmorillonite clays are found as in subseries 3^1.	Fe-montmorillonite is present with Fe-Mn carbonates. Below, the clay matter is similar to subseries 3^1-composed of polycompnent-montmorillonitic (low-iron) largely K-montmorillonites, sometimes mixed-layer structures with a 15-20% hydromica component; an inferior quantity of 13-14Å Ca-K montmorillonites, usually associated with small amounts of phillipsite; traces of carbonates throughout the series.
Silty clays and clay siltstones; an alternation of clays of a polycomponent-montmorillonitic composition with a unfiorm occurrence of 14 and 12 Å montmorillonite and clastic polycomponent clays formed at the expense of detrital material of trioctahedral micas; in the predominantly montmorillonitic clays bipyramidal or irregular acute-angled quartz grains are present which are common for acid effusives, and there are more fragments of plagioclases and brown volcanic glasses with differing degrees of decay; bioturbated textures and globular pyrite accumulations are frequent. The same clay type but with a greater admixture of sandy material; the main component of the sand fraction is quartz (60-65%), feldspars (15-20%), glass fragments (7-8%), badly determinable aggregates (10%), mica flakes, (predominantly of biotite) (5%), single grains of accessory minerals, zircon, garnet; abundant remains of carbonized vegetable tissues and pyrite.	Alternating predominantly 14 and 12 Å montmorillonite (polycomponent-montmorillonite) clays and clastic polycomponent clays-decay products of trioctahedral hydromicas. The same composition as the overlying clays with an increased kaolinite content.
Alternating predominantly montmorillonitic clays with "reticular" texture and clastic polycomponent clays.	The same composition of clays as in subseries 4^1, with a greater amount of predominantly montmorillonitic clays.
Predominance of montmorillonite clays after altered volcanogenic glasses; an alternation is observed of the intensively birefringent montmorillonites and optically poorly crystallized, weakly polarizing, sometimes nearly isotopic ones; in some rocks, phenocrysts of plagioclases, bipyramidal quartz, large biotite plates are present; clastic clays occur as subordinate thin layers.	At the top, predominantly Na (12Å), at the base Ca (14-14.5Å) aluminum low-iron montmorillonites of bentonite type, resistant to acid treatment; subordinate thin layers of clays of the composition-montmorillonite-polycomponent biotite transformation products.
Graywackes, poorly sorted; the dominant component of the clastic material is "platform"-type quartz, with occurrence of intermediate and basic plagioclases and abundance of biotite. The matrix is a Ca-Na aluminum, slightly ferruginous montmorillonite and more rarely a mixture of montmorillonite and polycomponent decay products of trioctahedral micas; a bimodal character is a conspicuous-mixture of clastic matter supplied from continent and volcaniclastics.	

Figure 1. *(Continued).*

TABLE 1
Results of X-Ray Structural Analysis of Samples from Site 345, Leg 38

Depth (m)	Sample (Interval in cm)	GIN Sample	Size of Fraction	Zeolites	Montmorillonitic Mineral	Micaceous Mineral	Chlorite	Kaolinite	Other Mineral Components	Subseries	Age	Mineral Associations
1.5-3.0	1-2, 75-77	241			Mixed-layer montmorillonite-vermiculite (15-20%)	Illite 40-50%	Magnesial-ferruginous, unstable to heating 15-20%	5-10%			E. Mio. – Pliocene	Interbeds of clastogenic polycomponent clays (formed mostly at the expense of products of decomposition of biotite) and volcanogenic montmorillonitic clays
9.5-11.0	2-2, 75-77	242			30-40%	Hydromica with 20% montmorillonitic layers 25-30%	Decomposed while heating to 550° Magnesial-ferruginous 10-15%	5-10%				
19.0-20.5	3-2, 75-77	243			Mixed-layer montmorillonite-vermiculite (15-20%)	Illite 40-50%	Magnesial-ferruginous, unstable to heating 15-20%	5-10%				
28.5-30.0	4-2, 49-51	244			Mixed-layer montmorillonite-vermiculite (25-30%)	Illite 30-40%	Magnesial-ferruginous, unstable to heating 10-15%	5-10%	Quartz, feldspar, carbonates			
38.0-39.5	5-2, 79-81	245			30-40%	Hydromica with 20% of montmorillonitic layers 25-30%		5-10%				
57-58.5	6-2, 139-141	246			Poorly crystallized (25-30%)	Illite 25-30%						
	7-2, 79-81	247			Poorly crystallized (30-40%)	Illite 15-20%		Trace	Quartz		L. Olig.(?) – E. Mio.	Siliceous, mostly volcanogenic-montmorillonitic and mixed-layered hydromicaceous and montmorillonitic clays; above -Ca-K 14Å montmorillonite, below -12Å K; phillipsite tends mostly to 13-14Å montmorillonites
	8-2, 49-81	240			Montmorillonite (40-50%)	Illite 25-30%		Trace	Quartz, cristobalite			
	9-2, 79-81	249		Phillipsite				Trace	Quartz			
	10-0, 20-22	250			Montmorillonite, mixed layer phase	Illite 15-20%		Trace	Quartz, rhodochrosite			
	10-1, 79-81	251	Rock									
65-139	10-2, 79-81	252			Montmorillonite, mixed-layer phase montmorillonite-mica with 30% micaceous layers	Hydromica 15-20%		Trace Trace				
		252	0.001		Alumo-ferruginous 50-60%	Hydromica		Trace				
	10-3, 79-81	253			Mixed-layer montmorillonite-mica with 30% mica layers 60-65%			Trace				
	10-4, 79-81	254			Montmorillonite, stable to treatment in HCl 60-65%			Trace	Quartz, feldspar			

TABLE 1 – *Continued*

Depth (m)	Sample (Interval in cm)	GIN Sample	Size of Fraction	Zeolites	Montmorillonitic Mineral	Micaceous Mineral	Chlorite	Kaolinite	Other Mineral Components	Subseries	Age	Mineral Associations
	10-5, 79-81	255	Rock		Mixed-layer montmorillonite-mica with 35% micaceous beds 60-65%			Trace				
	10-6, 49-81	256										
	11-1, 79-81	257			40-50% Montmorillonite	Illite 25-30%			Quartz			
	11-1, 79-81	258	Rock									
	11-2, 79-81	259								31	E. Mio. or L. Oligocene	
139-165	11-3, 79-81	260			30-40% Heterogeneous as to degree of hydration of intra-layers	Illite 30-35%	Unstable to heating, 20-25%		Quartz, feldspar			Polycomponent 12Å (K-Na) montmorillonitic clays with somewhat higher kaolinite content
	11-4, 79-81	261			40-50% Montmorillonite							
	11-5, 79-81	262										
	11-6, 79-81	263	0.01		50-60% mixed-layer phase montmorillonite-illite with 30% unlabile layers			Trace				
	12-1, 79-81	264							Quartz, rhodochrosite			
	12-2, 79-81	265		Phillipsite			Unstable to heating 10-15%		Quartz			
	13-1, 79-81	266			50-60% Disordered mixed-layer phase montmorillonite-illite	Illite 20-25%						
165-331		266	0.001			Mixed-layer phase illite-montmorillonite with 30% labile layers	5-10%			32	Oligocene to E. Mio.?	
	14-1, 79-81	267				Illite 25-30%	Unstable to heating 10-15%					
	14-2, 69-71	268										Alternation of mostly polycomponent montmorillontic volcanogenic clays with plastogenic ones (products of changing biotite). Sometimes phillipsite. Presence of carbonates
	14-3, 41-43	269		Rock	30-40% Mixed-layer phase montmorillonite illite	Illite 30-35%	Unstable to heating 15-20%	Trace				
	14-3, 50-52	270		Phillipsite		Illite 30-40%						
		270			50-60% Mixed-layer phase montmorillonite-illite	Hydromica 20-25%	Unstable to heating 10-15%					
	15-1, 100-102	273	0.001		40-50% Mixed-layer phase montmorillonite-illite	Hydromica 15-20%	Unstable to heating 5-10%		Quartz			

TABLE 1 – *Continued*

Depth (m)	Sample (Interval in cm)	GIN Sample	Size of Fraction	Zeolites	Montmorillonitic Mineral	Micaceous Mineral	Chlorite	Kaolinite	Other Mineral Components	Subseries	Age	Mineral Associations
	16-5, 100-102	276	Rock									
	18-1, 100-102	279	Rock		30-40%	Illite 30-40%	Unstable to heating 20-25%	10-15%				
331-570		279	0.001		40-50% Mixed-layer phase mont-morillonite	Illite 25-30%	Unstable to heating 15-20%	Trace	Quartz	41		Alternation of volcanogenic polycomponent-montmorillonitic and clastic polycomponent clays (products of changing biotite)
	17-2, 85-91	280	Rock									
	19-2, 85-87	284	Rock		50-60% phase mont-morillonite-illite	Illite 20-25%	Unstable to heating 10-15%	Trace			Oligocene	
	20-2, 57-56	289	0.001		40-50% mixed-layer phase mont-morillonite-illite	Hydromica 25-30%	Unstable to heating 15-20%	5-10%				
	26-1, 116-118	319			40-50% Mont-morillonite	Illite 25-30%		5-10%				
	26-3, 102-104	321			90-95% Mont-morillonite				Quartz (little) carbon-ates			
	26-4, 94-96	322	Rock		30-40% Mont-morillonite	Illite 30-40%	Unstable to heating 25-30%					Ca and Na-K montmorillonitic volcanogenic, often almost monomineral slightly ferruginous-aluminic bentonitic type
682-762	28-1, 85-87	326		Phil-lip-site					Quartz (little)			
	28-4, 72-74	329										
	28-6, 93-95	331	Rock							51	L. Eocene	
	29-1, 83-85	333		Phil-lip-site	90-95%							
	30-1, 109-111	334	0.01		Montmorillonite							
	30-2, 104-106	336					Unstable to heating 2-5%					
	30-2, 104-106	337	Rock									
	30-5, 143-145	339										
752-762	31-4, 115-117	342			80-90% Montmorillonite	Illite 5-10%	Unstable to heating 5-10%			52		

deeper in the sediment section. In the diffraction pattern for Sample 247, the first basal reflection has $d_{(001)}$ = 14-16Å, and glycerine-saturated reflection is $d_{(001)}$ = 19Å. This is an indication that the material and the montmorillonite are poorly crystallized. There is also a likelihood of sorption of amorphous SiO_2. The abundance of amorphous material (uncrystallized glass or opal?) is also indicated on the diffraction pattern by a broad halo in the region of d from 4.5 to 3Å. Soda treatment of the sample substantially improves the resolution of the small-angle montmorillonite reflection. For samples 248-251, $d_{(001)}$ of montmorillonite is equal to 13.4-13.8Å. This is attributed to sorption, by montmorillonite interlayers, of Ca and Na and possibly K.

Lower in the section, $d_{(001)}$ montmorillonite reflection gradually falls to 12.6Å, and then to 12Å. This indicates an increasing share of Na and K in the general exchange complex. Analysis of the diffraction patterns for glycerine-saturated preparations shows that the montmorillonite component consists not only of montmorillonite, but also of mixed-layer montmorillonite-illite containing from 10% to 30% micaceous layers.

An admixture of a small amount of well-crystallized mica, kaolinite, quartz, and feldspars is present in all clays. Zeolites appear on X-ray patterns only in the upper 14Å. Ca-Na-montmorillonite clays have poor reflections at 7.5, 7.1, 3.95, 3.19Å. These may be typical of phillipsite.[2]

[2]Reflection d = 7.5Å may also belong to another type of zeolite. It is hoped to establish this during further special investigation of zeolites.

In contrast to clays typical for continental terrigenous units, the compositions of the less than 0.001 mm, 0.001-0.01 mm fractions, as well as the bulk composition are almost identical. This indicates that montmorillonite is the basic component of all size fractions and was formed in situ. It differs from typical pelagic Fe-montmorillonites by its resistance to an acid treatment. Judging from the chemical composition (Table 2, Sample 252), it can be assumed the montmorillonite developed from a volcanic glass less basic than tholeiitic basalts (of a trachyte-andesite composition?). This seems to be indicated by a rather low iron content (Fe_2O_3+FeO about 6%, Table 1). The content of K_2O and Na_2O in the bulk sample are approximately equal (Na_2O = 2.37%, K_2O = 2.13%). This is either a sign of an incomplete decomposition of glasses, or additional evidence confirming that montmorillonite was formed in the marine environment and not on the continent. Na is usually easily washed out during the montmorillonitization of volcaniclastics in fresh water basins.

Series 3 (Oligocene to early Miocene [?], Cores 10-6 to 15-6, Samples 256-273, depth 139-331 m)

This series corresponds to Subunit 2B of the shipboard designations. The sediments are highly uniform and are generally clays with a varying admixture of silt-sized material. Montmorillonitized ash layers are present. A great number of layers are bioturbated. Some layers are enriched in carbonaceous detritus and pyritized. The series has two subseries, 3_1 and 3_2.

Subseries 3_1 (Late Oligocene or Early Miocene, Cores 10-6 to 11-5, Samples 256-262, depth 140-165 m)

The subseries consists of highly uniform, predominantly montmorillonitic clays, with a constant but small admixture of terrigenous material with subordinate layers of silt-sized clastic clays. Bioturbation textures are typical. Numerous burrows and peculiar "loaves" are present. The "loaves" are oval, sometimes elongate-irregular structures (0.1-1 mm) and have agglutinized (?) rims, consisting of irregular small quartz grains, feldspar fragments, glasses, and sometimes zeolites (0.02-0.08 mm). These features may have a "vermiculite" texture (i.e., exfoliated) up to 1.5 mm long and about 0.06 μm thick. The internal nucleus consists of a rather pure, fine-aggregate of strongly birefringent clay material, as if "purged" of alien admixtures. Single specimens of these features are present in the lower part of the preceding series, but they have their maximum abundance in Subseries 3_1. The bioturbation textures are accompanied by large irregular accumulations of globular pyrite.

A typical example of clastic clay with numerous "loaves" and "agglutinate worms," strongly pyritized, is present in Sample 11-3, 79-81 cm (Sample 260). The X-ray pattern is typical of mixed-layer clay. Similar to Samples 241, 243, and 244, the diffraction pattern contains a broad maximum lying in the region of $d_{(001)}$ ranging from 11 to 14Å. The basal reflections of illite with $d_{(001)}$ = 10Å are clearly seen, and the basal reflections of kaolinite on the diffraction patterns of both the bulk sample and the less than 0.01 mm fraction are markedly intensive. Montmorillonite in the less than 0.01 mm fraction is represented by K-difference, as is suggested by the value of $d_{(001)}$ = 11.6Å. The iron content in the mineral structure is very low, which accounts for its resistance to HCl. The chemical composition of the sediment indicates a high Al_2O content recalculated for silicon-free substance (21.80%), which is in accord with the presence of kaolinite (Table 2). Abundant traces of intensive organic activity and high degree of pyritization, which often develops on organic remnants.

Subseries 3_2 (Oligocene, Cores 11-6 to 15-6, Samples 263-273, depth 165-295 m)

A bed of predominantly mixed-layer montmorillonitic clays with Mn-Fe-carbonates. In the subseries (Sample 11-6, 79-81 cm, Sample 263), a peculiar clay with microconcretions of manganosiderite or Fe-rhodochrosite is present. In the aggregate-polarizing clay mass, microconcretions of Mn-Fe-carbonate (0.02-0.05 mm) and having a rose-like form are densely scattered. In the central part of some of the microconcretions there are pyrite inclusions. The chemical composition (Table 2, Sample 263) is marked by a high iron content (Fe_2O = 9.24%, FeO = 2.15%) and an increased manganese content (Mn = 0.85%).[3]

Lower in the subseries, uniform sediments consist predominantly of montmorillonite clays with an admixture of silt-size quartz grains (often with an acute-angle or bipyramidal shape, a shape characteristic of acid extrusives), rare tablet-shaped fragments of intermediate and calcic plagioclases, brown palagonitized glasses, and mica flakes. There are occasional bioturbation textures, accumulations of globular pyrite, and leucoxene clots. The X-ray patterns resemble those of the less than 0.01 and 0.001 mm fraction. The sole difference is that the latter has a smaller admixture of micas, kaolinite, and quartz. Phillipsite reflections are fixed in some samples (Samples 264, 265, 266, 270).

Chemical characteristics of the sediments are similar to those of the clays of the upper portions of Subseries 3_1. They differ solely in having a greater SiO_2 content due to a great amount of terrigenous quartz (Table 1, Sample 266).

Series 4 (Oligocene to late Eocene [?], Cores 16-1 to 26-6)

The boundary of the series is unimportant as the sediments are so similar to Series 3 that it is unnecessary to assume any boundary between the series. These are highly uniform silty and sandy clays, clay siltstones, and sandstones. Agglutinized organisms, and likely traces of silt-eaters, probably developed the bioturbation in some interlayers. In some layers, there are abundant carbonized remains and pyrite. Three subseries are distinguished.

Subseries 4_1 (Core 16-22-6, Samples 274-300, depth 335-370 m)

Clays and clayey siltstones. The composition of the clays is a clastic mixed-layer clay associated with biotite alteration products, with layers of mixed-layer-montmorillonitic clays. Abundant clastic material of

[3]Recalculated in terms of silicon-free substance.

TABLE 2
Chemical Composition of Samples, Site 345

Age	Early Miocene		Oligocene to Early Miocene								Late Eocene to Oligocene													
Series	Series 2		Series 3								Series 4				Series 5									
Subseries			3_1		3_2						4_1		4_2		5_1		5_1		5_1		5_2			
No. of Sample	252	252[a]	260	260[a]	263	263[a]	266	266[a]	280	280[a]	302	302[a]	321	321[a]	329	329[a]	331	331[a]	341	341[a]
Components	Rock		Rock		Fraction <0.001 mm				Rock		Rock		Rock		Rock		Rock		Rock	
SiO_2	53.30	48.30	53.47	46.35	51.62	46.13	58.19	50.02	54.94	45.70	54.09	48.85	44.72	43.20	54.96	52.00	55.72	46.30	63.35	46.20
TiO_2	1.01	1.12	1.02	1.17	0.52	0.58	0.96	1.14	1.03	1.24	0.74	0.84	0.63	0.64	0.65	0.70	0.68	0.83	1.13	1.64
Al_2O_3	16.66	18.55	18.95	21.80	16.29	18.22	14.81	17.56	16.54	19.74	14.99	17.00	14.43	14.70	15.90	17.00	15.67	19.10	15.27	22.19
Fe_2O_3	5.39	6.00	3.16	3.64	8.25	9.24	4.38	5.20	5.36	6.44	9.13	10.36	5.65	5.75	3.84	4.11	4.21	5.12	3.16	4.59
FeO	0.92	1.20	1.30	1.50	1.92	2.15	1.07	1.27	2.34	2.81	1.33	1.51	0.42	0.43	0.81	0.87	0.47	0.57	1.59	2.31
CaO	0.59	0.66	0.38	0.44	1.48	1.66	0.52	0.62	0.69	0.83	1.02	1.5	8.33	8.48	1.82	1.95	3.27	2.64	0.87	1.26
MgO	2.11	2.34	1.98	2.28	1.72	1.92	2.11	2.50	1.89	2.27	1.56	1.77	1.80	1.82	2.36	2.52	2.42	2.97	1.63	2.36
MnO	0.04	0.04	0.04	0.05	0.76	0.85	0.03	0.04	0.03	0.04	0.02	0.02	1.15	1.17	0.12	0.13	0.15	0.18	0.05	0.07
Na_2O	2.37	2.64	1.99	2.29	0.57	0.64	2.25	2.67	1.69	2.03	1.46	1.65	1.69	1.72	2.18	2.33	1.84	2.24	1.06	1.54
K_2O	2.13	2.37	2.67	2.96	2.44	2.73	2.10	2.59	2.69	3.23	1.67	2.89	0.70	0.71	1.46	1.56	1.56	1.90	2.69	3.91
H_2O+	6.57	7.30	8.08	9.30	6.49	7.26	6.49	7.70	6.01	7.20	3.33	3.78	4.44	4.52	4.69	6.02	4.21	5.13	5.61	3.24
H_2O-	6.80	7.56	5.72	6.58	5.87	6.57	5.92	7.02	5.42	6.50	5.6	6.45	9.76	9.95	10.17	10.90	9.54	11.60	3.46	5.03
CO_2	0.07	0.08	0.24	0.28	1.21	1.36		–	0.12	0.14	0.17	0.19	6.45	6.55	0.25	0.27	0.72	0.88	–	–
C	0.40	0.45	0.13	0.15	0.34	0.38	0.26	0.31	0.41	0.49	–	–	–	–	0.06	0.06	–	–	–	–
P_2O_5	0.06	0.07	0.05	0.06	0.27	0.30	0.05	0.06	0.06	0.07	0.04	0.05	0.06	0.06	0.04	0.04	0.05	0.05	0.11	0.16
Cl	1.40	1.56	1.00	1.15	–	–	1.08	1.28	0.68	0.82	0.32	0.36	0.27	0.27	0.43	0.46	0.30	0.37	0.31	0.45
S_{Fe_2S}	–	–	–	–	–	–	–	–	–	–	37.0	4.19	–	–	–	–	0.09	0.11	0.10	0.15
SO_3	–	–	–	–	–	–	–	–	0.39	0.47	1.15	1.30	–	–	–	–	–	–	–	–
Σ	99.82	100.06	[illegible]	100.00	99.75	99.98	100.22	99.88	100.18	100.02	101.82	101.70	100.50	99.77	99.74	99.92	99.80	100.04	100.39	100.10
SiO_2 qw	8.50	–	12.16	–	9.28	–	13.04	–	15.84	–	12.54	–	0.98	–	5.20	–	16.66	–	30.60	–
SiO_2 am	1.40	–	1.05	–	1.15	–	2.80	–	1.05	–	1.05	–	1.26	–	1.06	–	1.05	–	0.98	–

Note: Sample 252 = 10-2, 79-81 cm, siliceous montmorillonitic clay; Sample 260 = 11-3, 79-81 cm, silty mixed-layer clay (products of decomposition of trioctahedral micas) with pyrite; Sample 263 = 11-6, 79-81 cm, ferrimontmorillonitic clay with micronodules, Fe-M-carbonate; Sample 266 = 13-1, 79-81 cm, silty clay, mostly montmorillonitic, with phillipsite; Sample 280 = 17-2, 89-91 cm, silty mixed-layer montmorillonitic clay with pyrite; Sample 302 = 23-2, 43-45 cm, silty mixed-layer clay; Sample 321 = 26-3, 102-104 cm, an interbed of slightly montmorillonitized glass, plagioclases are replaced by calcite; Sample 329 = 28-4, 72-74 cm, an interbed of montmorillonitized glass; Sample 331 = 28-6, 83-85 cm, bentonite-like clay; Sample 341 = 31-3, 115 117 cm, graywacke.

[a]Evaluated for nonsiliceous substance.

silt or sometimes fine sand size is comprised of quartz, tablet, or angular shaped grains of plagioclase (predominantly of an intermediate or calcic composition, seldom albite), albite-oligoclase, and sporadic single, fragmentary microcline grains. There is a considerable amount of variously altered and fresh, single green-brown fragments of volcanic glasses ($n \sim 1.53$-1.55), and biotite flakes with differing degree of alteration. Micaceous minerals are so abundant, that the clay material has a pronounced mixed-layer composition. This is usually formed during decomposition of trioctahedral micas, with approximately equal contents of montmorillonite, hydromica, and a small amount of kaolinite (Sample 276). In some samples, it is not the bulk sample but even the less than 0.001 mm fraction that is clastic. In Cores 16-3 to 17-2, intensively developed bioturbation reappears, with agglutinized organic remains, small additions of pyrite, and leucoxene clots.

The altered nature of the clays, and, in particular, the biotite micas, is reflected in the chemical composition (Table 2, Sample 280). The Al_2O_3 content increases, and K_2O (3.23%) exceeds Na_2O by 1.5 times (2.03%). Lower in the series silty clays reappear, but there are few agglutinized organic remains.

Subseries 4_2 (Cores 23 to 24-4, Samples 301-310, depth 571-641 m)

The siltstone contains clays of a mixed-layer composition and abundant carbonized vegetable remains. The carbonized material has a perfectly preserved cellulose structure. The rocks are strongly pyritized. The subseries seems to have been formed under conditions dominated by a high terrigenous influx.

Subseries 4_3 (Cores 24-25-6, Samples 307-318, depth 641-683 m)

The composition is similar to Subseries 3_1. Bioturbation textures were observed in many samples.

Series 5 (Cores 26-1 to 32-2, depth 683-762 m)

This part of the sediment section should be treated as an independent series. There is a prevalence of volcanogenic material and frequent interlayers of glasses more or less reworked into a slightly ferruginous-aluminum montmorillonite. Two subseries are clearly distinguished.

Subseries 5_1 (Cores 26-1 to 31-2, Samples 319-340, depth 683-752 m)

A subseries of specific, nearly monomineralic, montmorillonite clays developed after volcanic glasses. An alternation is observed of montmorillonites which are intensively polarized in yellow-orange light, with almost isotropic optically slightly crystallized ones. No difference of X-ray structures of the minerals is observed. All the montmorillonites belong to the aluminum low-iron difference and seem to have been formed at the expense of volcanic products of a rather acid and apparently alkaline trachyte-andesite composition. Idiomorphic inclusions of plagioclases and large biotite plates are present in some samples. Plagioclases are sometimes replaced by calcite or manganocalcite, which is indicated by a higher Mn content in all samples (Table 1, Samples 321, 329, 331).

Subseries 5_2 (Cores 31-3 to 32-3, Samples 341, 342-343)

Graywackes forming the upper part of the layers make up the base of this sedimentary series. According to the Site Report (this volume), beneath the graywackes, rocks are present containing rounded "exotic" pebbles of quartzite, granites, and limestones.

A dual nature of the components is conspicuous in the graywackes. The sand fraction is characterized by a high quartz content. According to Simanovich (personal communication) the quartz association of Sample 342 consists of: metamorphic quartz = 65%, quartz of "ancient" granitoids = 8%, quartz of "young" granitoids = 6%, and vein quartz = 21%.

The distribution pattern indicates a typical quartz association of quartz of crystalline schists and sandy rocks of platforms. Many grains are well rounded, and regeneration rims are frequent. This indicates that a part of the quartz was supplied from a sedimentary platform. The clay component has a nearly monomineral montmorillonite composition and is undiscernible from montmorillonite clays in the overlying subseries, which are bentonites (Sample 342).

PRINCIPAL RESULTS AND CONCLUSIONS

1. Five series have been distinguished on the basis of mineralogic-petrographic features.

2. Series 1 is characterized by the conspicuously "polygenetic" (bimodal) nature of the sediments, which has been derived from terrigenous and volcanic sources.

The composition of the clastic quartz (Simanovich, personal communication) indicates the presence of a typical association of quartz from ancient metamorphic rocks of shields and sedimentary sandstones. This quartz association is genetically related to the clastic polycomponent nature of the clays and the matrix graywacke, which are for the most part alteration products of biotite micas. Noteworthy is the small role of chlorite in biotite transformation products. Montmorillonitization of biotite, passing through a stage of mobile chlorite-vermiculites, with an isolation of an independent phase of dioctahedral hydromica (illite) could have begun on the continent and ended as a result of diagenesis. It appears that the clastic material was supplied largely as a result of erosion of pre-Cambrian crystalline rocks, particularly quartz-biotite schists, and granitoids. At the same time sedimentary and metasedimentary rocks were being eroded, which is evidenced by regeneration rim on some rounded quartz grains. Therefore, quartz and trioctahedral micas are "leading" components representing a continental supply. It should be pointed out, however, that a part of biotite might not have a terrigenous origin, but a volcanogenic origin. The latter is associated with the destruction of a series of alkaline rocks ranging from ankaramite to trachybasalts and trachytes rich in phlogopite, and widespread in the northern part of the Jan-Mayen Ridge (Flower, 1969). The Bjurenberg volcano in this part of Jan-Mayen Island has a late Pleistocene age.

Volcanogenic material is represented by montmorillonite which is present in the sediments clay matrix and less frequently as independent layers.

3. Series 2 differs drastically from the overlying and from underlying deposits and is composed of siliceous-clay sediment. The upper portion contains very little admixture of terrigenous material. The deposition of the Series 2 sediments during the Miocene represents a period of a high pelagic input. The main clay mineral is volcanogenic montmorillonite developed by alteration of the clastic glasses with a middle trachy (?) - andesite-dacite- composition. In contrast to typical pelagic Fe-montmorillonites recovered at Hole 337, these "middle" montmorillonites are resistant to acid treatment.

4. In the very thick and uniform series embracing Series 3 and 4, alternating clayey siltstones and clays are present, which have varying ratios of terrigenous to volcanogenic components.

In the upper part of Series 3 (Oligocene-Miocene) there is an interlayer of a peculiar Fe-montmorillonite clay with a Fe-rhodochrosite and Mn-siderite. The development of this rather "exotic" sediment alien to surrounding deposits in its chemical composition, is probably related to the afflux of hydrothermal Fe-Mn solutions.

The interbedding in these two series of subseries having bioturbation textures and enriched in vegetable detritus, seems to indicate stages of intensified "continentality" of the basin.

5. Series 5 is characterized by a wide-scale development of montmorillonite clays of a bentonite type at the top forming a separate subseries and at the base, the matrix of graywackes. The graywackes are polygenetic. Clastics are represented by a typical association of quartz from metamorphic and sedimentary platform complexes. Identical in nature to the upper Subseries 5_1, the subseries of bentonite-like clays seems to have been formed at the expense of sufficiently intermediate alkaline hyaloclastics (trachyandesites). This is attested to both by chemical and by petrographic composition, which indicates a comparatively slight montmorillonitization. Therefore, after the alkaline basalt volcanism that preceded the accumulation of the sedimentary series, the area of Site 345 throughout the entire Oligocene, Miocene, and Pleistocene (?) was an arena of middle and, in all likelihood, alkaline volcanism.

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