11. LITHOLOGIC-MINERALOGIC STUDIES OF THE SEDIMENTARY DEPOSITS FROM HOLE 350, DSDP LEG 38

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INTRODUCTION

Hole 350 was drilled on the edge of one submarine ridge situated to the east of the Jan-Mayen Ridge. It is hoped that the study of the sedimentary deposits covering acoustic basement will lead to a clarification of the following points: (1) the structure and tectonics of the ridges situated to the west of the Norwegian Basin correlate with the basic part of the Jan-Mayen Ridge, and (2) pecularities in the evolution of these ridges.

The oldest sedimentary rocks, recovered at a depth of 361 meters, are siltstone argillites. Basement recovered at a depth of 361.7 meters is either a basaltic breccia or doleritic basalt.

The sequence of sedimentary, volcanogenic formations can be subdivided into three main lithologic series. On the basis of the detailed microscopic analysis of the cores and X-ray data from the fine fraction (<0.001 mm), the three main lithologic series are divided into smaller units, subseries and members (Table 1).[1]

DESCRIPTIONS OF SERIES, SUBSERIES, AND MEMBERS

Series 1 (Pleistocene and Plio or Pleistocene, 0-55.5 m)

Sandy sediments with different admixtures of volcanic ash and foraminiferal components. Volcanic ashes are present as separate layers (Section 1-3), and lithified ashes were observed in Section 2-5. Foraminifers are typical for intervals within Sections 1-3 and 2-1. The deposits are thought to be glacial marine.

Subseries IA (Pleistocene, 0-8 m, Sections 1-1 to 1-6)

It is composed of two members: 1-A-1, clayey sandstones and siltstones with foraminifers (0-3 m), and 1A-II a hyalopelitic, palagonitized tuff with a small admixture of silt particles, foraminifer shells, and diatom tests (Section 3-6 [?]).

Member 1A-I (upper Pleistocene, 0-3.0 m, Section 1-1 to 1-2) consists of sandy-silty clays with foraminifer (20%). The clay matrix (60%) is represented by coarse aggregates, with some chlorite-glauconite forms.

[1]For the purposes of this paper, the sediments have been grouped into "series and subseries" (Table 1). The "series or subseries" do not necessarily correspond to "units or subunits" 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. The X-ray structural studies were carried out by V.A. Driz, head of Physical methods of Investigation, Geological Institute, USSR Acad. Sci.

The sandy-silty particles (20%) are chiefly angular quartz grains, calcic feldspars, and albite. There are also rounded fragments of deeply oxidized basaltic glasses and pyroxene grains. Oxidized glauconite and iron hydroxide grains are also present.

The clay fraction (<0.001 mm) is represented by a mixture of: montmorillonite (30%), illite (40%), chlorite (20%), with a probable admixture of kaolinite (10%). The montmorillonite, basically iron-bearing, contains Ca-Mg in the interlayers. It is a heterogenic mixed-layer clay, with alternating vermiculite and montmorillonite packets. Samples treated with glycerine expand to 16.8Å. The chlorite (Fe-Mg) is defective and upon heating, it constricts to 13.3Å.

Member 1A-II (lower Pleistocene [?], 3.0-8.0 m, Cores 1-3 to 1.6) is a tuff, hyalopelitic, with a low silt content and with foraminifers. The matrix (60%) is represented by a yellowish-brown hyalopelitic substance, which is nearly isotropic, and partically palagonitized. It contains silty debris of brown, often fresh basaltic glass. The debris is often replaced by the matrix.

The deposits contain silt particles of quartz (10%), some scattered goethite particles (10%), foraminifer shells (10%), and diatom detritus (10%).

Subseries 1B (Upper Plio-Pleistocene, 8.0-30.0 m, Sections 1-6 to 2-2)

Its lower part (Sections 2-1 and 2-2) is composed of silty clay, with the lowermost beds composed of sandy clay. There are scarce foraminifers, and terrigenous glauconite particles. The clay matrix (up to 60%-70%) contains brown basaltic glass debris, with an admixture of hematitized basaltic tephra (up to 15%). In the main part of the sediment, detrital sandy-silty grains are present, consisting of quartz, and to a smaller extent, potash feldspars, and acid plagioclases. Sandy-silty particles make up to 50% of the lower part of the interval. Of interest is the well-developed corrosion of quartz and feldspars.

The clay minerals (Sample 2-1, CC) are chiefly montmorillonite (70%) (ferrous-aluminic variety), with a higher content of Fe in the octahedral layer, and Ca dominating in the interlayer interval. The montmorillonite is represented by two phases, i.e., montmorillonite proper and a mica-replacement product. Hydromicas (20%) are mixed layered with 20% montmorillonite. Chlorite (10%) is defective and ferromagnesial.

Subseries 1C (Lower Plio-Pleistocene, 30.0-55.5 m, Sections 2-3 to 3-0)

The upper part of the interval (Samples 2-3A, 100-102 cm; 2-4A, 80-84 cm; 2-5A, 110-112 cm) consists of

TABLE 1
Results of X-Ray Structural Analysis of Samples of Hole 350

Depth (m)	Sample (Interval in cm)	No. of Sample (GIN)	Size of Fraction (mm)	Zeolites	Montmorillonitic Mineral	Micaceous Mineral	Chlorite	Kaolinite	Other Elements	Member	Age	Mineral Associations
1.5	1-1, CC	–	< 0.001	–	Mixed-layer montmorillonite-vermiculite; montmorillonite ferrous, Mg-Ca exchangeable ions (30-40%)	Illite (40%)	Chlorite, defective, ferromagnesial (20%)	–	–	1A-I	Pleistocene	Clays (60%) sandy, silty with forams (20%) sandy-silty fragments; angular grains of quartz, K-feldspars, albite, oxidized basalt glass, glauconites
3.0	1-2, CC	–	< 0.001	–	Montmorillonite mixed-layer montmorillonite-vermiculite, ferrous aluminum, Mg-Ca exchangeable ions (30%)	Illite (40%)	Chlorite, defective, ferromagnesial (20%)	Kaolinite (10%)	–			
28.5	2-1, CC	–	< 0.001	–	Montmorillonite ferrous-aluminum type with Ca as exchangeable cation; composed of two phases: montmorillonite properly and mixed layer: montmorillonite-mica (70%)	Hydromica with 20% montmorillonite layers (20%)	Chlorite defective (10%)	–		1B	Plio or Pleistocene	Clay silty with rare forams and grains of clastic glauconite
37.0	3-1	–	< 0.001	–	Mixed-layer montmorillonite essentially ferrous, contains to 30% of mica layers; exchangeable cations mainly Na, lesser Mg, Ca (>70%)	Illite, Al form (15%)	–	–	Abundance of glass fine fragments	2A	Middle Miocene	Predomination of tuffs crystals, clastic with admixtures (⩽ 3%) of terrigenous grain, main part of rock composed of fine-grained ash of basaltic glass, fragments of tephra and pyroxenes; clay minerals – products of alteration of basalt ash
38.5	3-2	–	< 0.001	–	Mixed-layer montmorillonite, irregular alternations of montmorillonite and mica layers	–	–	–	Notable amounts of glass and amorphous phase			
40.0	3-3	–	< 0.001	–	Mixed-layer montmorillonite-illite; montmorillonite highly ferrous, Na form	–	–	–	–			

85.0	1, CC	–	< 0.001	Traces (~1%-2%)	Montmorillonite, Fe-Al species, Na form pure, without mixed-layer components	–	–	–	–	2B-I	Undated	Compacted vitroclastic pyrite-silty basaltic fragments deeply palagonitized and altered to montmorillonite-hydromica mass – impregnated by manganese oxides
87.0	2, CC	–	< 0.001	–	Mixed-layer montmorillonite-illite, essentially ferrous; predominant part of the sample	–	–	–	–			
114.0	5-1, CC	–	< 0.001	–	Mixture of two components: montmorillonite ferrous, and mixed-layer phase montmorillonite-illite (90%)	Illite (10%)	–	–	–			
115.5	5-1, CC	–	< 0.001	–	Mixed-layer montmorillonite-illite (20%); montmorillonite Fe-Al, Na form (80%)	Hydromica with 20% montmorillonite layers (15%)	–	Kaolinite (5%)	–	2B-I		
142.5	6-1, CC	–	< 0.001	–	Mixed-layer montmorillonite-illite (10%-20%); montmorillonite essentially Al form (60%)	Hydromica with 20% montmorillonite layers (25%)	–	Kaolinite	–	2B-II	Undated	Sedimentary microtuffa-breccia composed of hyalopelitic basalt tuff, impregnated by manganese oxides; patches of zeolites
144.0	6-2, CC	–	< 0.001	–	Mixed-layer montmorillonite with 20% of illite, Mg, Ca, Na-exchangeable cations (60%)	Hydromica with 20% montmorillonite layers (25%)	Chlorite (15%)	–	–			
171.0	7-1, CC	–	< 0.001	–	Mixed-layer montmorillonite with small amount of illite K-Mg-Ca form (60%)	Hydromica with 20% montmorillonite layers (25%)	–	Kaolinite (15%)	–	2C	Oligocene (?)	Clay hyalopelitic tuffeceous with admixtures of terrigenous sandy-silty-grains of quartz, zeolites present
199.5	1, CC	–	< 0.001	–	Montmorillonite Al-Fe type, with small quantity of illite layers (60%)	Hydromica with 25% montmorillonite layers (25%)	Chlorite defective (13%)	Kaolinite (2%)	–	2D	Oligocene	Clay tuffaceous with admixture (30%-40%) of clastic quartz, mica; clay are present by fine grained basalt glass, altered, zeolitized
227.50–227.52	9-1, 100-102	–	< 0.001	–	Montmorillonite essentially ferrous, Ca form (65%)	Hydromica, Al form, with 20% montmorillonite layers (20%)	–	Kaolinite (15%)	–	3A-I		Clays tuffaceous enriched by dispersed organic matter, the matrix of tuffaceous

TABLE 1 – *Continued*

Depth (m)	Sample (Interval in cm)	No. of Sample (GIN)	Size of Fraction (mm)	Zeolites	Montmorillonitic Mineral	Micaceous Mineral	Chlorite	Kaolinite	Other Elements	Member	Age	Mineral Associations
227.19–227.21	9-2, 19-21	—	< 0.001	—	Montmorillonite essentially ferrous, Ca-Mg form mixed layer, with inter-layers of illite (80%)	Hydromica with small amount of montmorillonite layers (10%)	—	Kaolinite (10%)	—	3A-I	Oligocene	clays consists of hyalo-detritous altered into montmorillonite-hydromica product, zeolitized.
343.00–343.02	13-2, 100-102	—	0.001	—	Montmorillonite essentially ferrous, the interlayer space are probably occupied by Fe (70%)	Hydromica with small amounts of montmorillonite layers (5%-10%)	—	Kaolinite (20%)	—	3B	L. Eocene	Clays tuffaceous silty with admixture (to 5%-10%) of organic matter composed of two main components: (a) hyalopelitic basic material altered into clay (b) terrigenous grains of quartz acid feldspars, mica, biotite. Globules of pyrite are widely developed, as well as carbonate
361.36–	14-2, 36-38	—	0.001	—	Montmorillonite, Fe-Al (70%)	Hydromica with small amounts of montmorillonite layers (5%-10%)	—	Kaolinite (20%)				

silty clays (30%), which are essentially a tuffite. The clay matrix is represented by a weakly birefringent material, with an olive-yellow color. Glass relics are obvious under high magnification. Also present are oxidized basaltic tephra particles. Towards the top of the interval, the tuffaceous nature increases (Section 2-3). Below (Section 2-4), the detrital, sandy silty grains make up to 45% of the rock. Quartz particles prevail along with microquartzites and plagioclase fragments.

Series 2 (Miocene and Oligocene, 55.5-226.5 m, Sections 3-1 to 9-0)

Unconsolidated deposits alternate with lithified ones. Volcanic ashes are present as distinct layers (Section 3-1) and as admixtures. The series is composed mainly of hyalopelitic tuffite clays and silts. In its lower part (Section 5-1 and downward) it is relatively fine grained and contains some bioturbation features. The lowermost beds of the series reveal the first appearance of turbidites, which increase in number down section.

Subseries 2A (Middle Miocene, 55.5-84.0 m, Sections 3-1 to 4-0)

The interval is dominated by hyalocrystalloclastic tuffs with an insignificant amount (3%) of terrigenous admixtures. The groundmass (70%) is represented by fine silt and clay particles of basaltic glass, which are altered, palagonitized, and converted to clay. Coarse silty, brown basaltic glasses, oxidized tephra debris, and fragments of pyroxene and amphiboles make up to 25%. An admixture of diatoms and Radiolaria (about 5%-7%) is typical. Rare glauconite grains are also present.

The clay minerals (Sections 3-1, 3-2, 3-3) are dominated by ferrous-montmorillonite, a product of the submarine alteration of basalt glass. In lower beds (Section 3-3) of the interval, montmorillonite with glass is the main component; at the top (Section 3-1), montmorillonite is mixed layered and contains up to 30% mica layers. An AL-illite admixture makes up 15%, with exchange cations of Na, Mg, and Ca. Below Section 3-3, there is a Na-montmorillonite. It is mixed layered and contains hydromica packets. Products of submarine alteration are quite typical.

Subseries 2B (Middle Miocene and Older, 84.0-169.5 m, Sections 4-1 to 7-0)

The interval is divided into two members: 2B-I; 2B-II. The upper member (2B-I) is hyalopelitic basaltic tuffs, essentially palagonitized. With submarine alteration, they have changed into montmorillonitic products. On the whole, the rocks have a characteristic microbreccia structure, the size of debris varying from 0.08 to 2-3 mm. The hyalopelitic tuff fragments are often cemented with manganese hydroxides, which also developed as irregular, sometimes veined, intrusions (up to 30%). The well-developed sedimentary microbreccias resulted from biotrubation of the consolidating sediment. Zeolites are well developed. The lower member (2B-II) differs from the upper by its basaltic volcaniclastic material (up to 30%). Zeolitization is rather intensive.

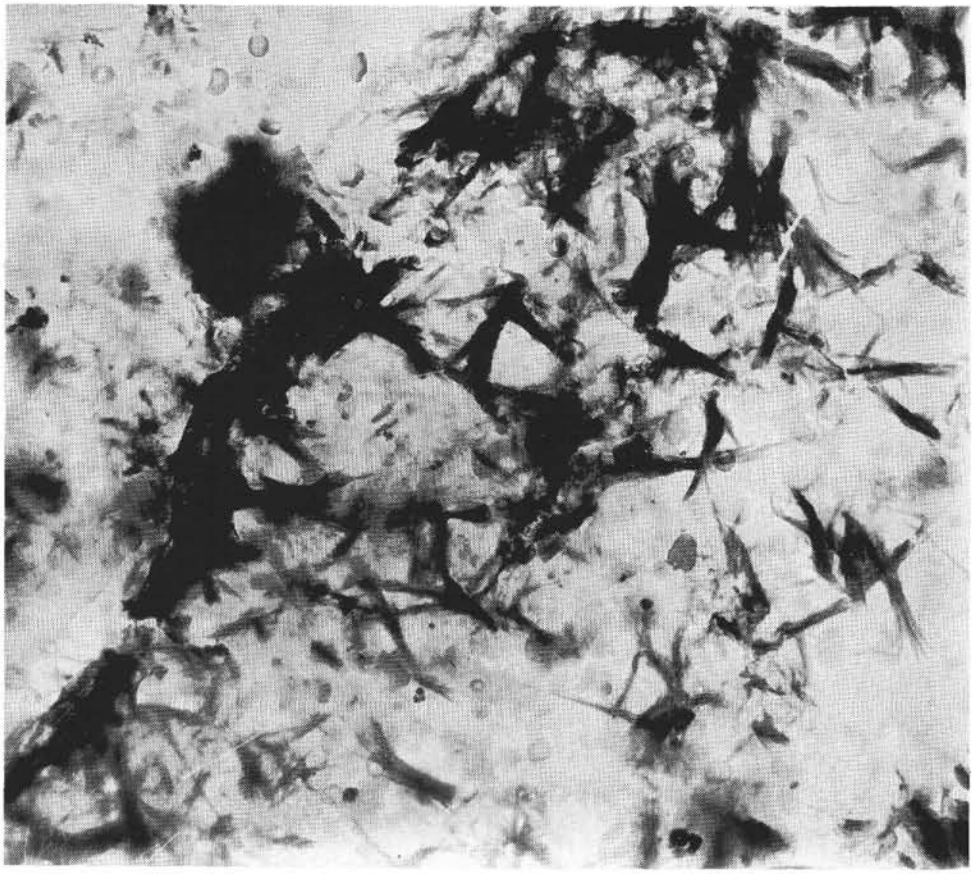

Figure 1. *Montmorillonite, essentially ferrous, Na form, developed from a hyalopelitic basaltic tuff. The particles have an interesting needle and rod-like habit. Fraction <0.001 mm, Sample 350-1, CC, magnification ×18,000 (SEM photo).*

Member 2B-I (middle Miocene and older, 84.0-141.0 m, Sections 4-1 to 6-0) is dominated by sedimentary microbreccias of hyalopelitic tuff. The rock, irregularly consists of angular debris (0.08-1.6 mm; average of 0.8-1.0 mm) composed of aggregated particles of consolidated vitroclastic detritus of clay or fine silt. It is deeply palogonitized, and altered into a montmorillonite-hydromicaceous mass. Black, earthy intrusions of manganese hydroxides are observed in the peripheries and within the debris. The hydroxides are mainly present as cement in the interstices between fragments. However, they do appear as a cohesive mass (Sections 4-1, 5-1, 5-2). There are also fragments of palagonitized hyaloclastite, fresh green basalt glass, and pyroxenes. Tabular crystals of zeolites are present in some areas. These microbreccias have, most probably, a bioturbation origin. Later, due to the circulation of metal-bearing solutions, they were impregnated with manganese hydroxides.

The clay minerals (Section 4-1) contain montmorillonite (evidently aluminic), with a subordinate presence of Fe in the octahedral layer. The interlayer complex is dominated by Na. Some traces of zeolite (1%) have been found. Section 4-2 contains a pure montmorillonite phase, which is mixed layered (with hydromica packets, 20%). The interlayer complex is dominated by Mg. In Section 5-1, the main phase is ferrous montmorillonite (70%). There is a notable mixed-layer phase of montmorillonite, hydromica (15%), an admixture of illite (10%), and small amounts of chlorite and kaolinite. In Section 5-2, the clays are dominated by ferrous-aluminic, mixed-layered montmorillonite (80%) containing up to 20% micaceous layers. There is also hydromica (10%) with up to 20% expandable montmorillonite layers. The kaolinite admixture is 10%. The montmorillonite, hydromica, and illite are all products of the submarine alteration of thin basaltic glass.

Member 2B-II (middle Miocene or older, 141.0-169.5 m, Sections 6-1 to 7-0) is composed of a hyalopelitic tuffite represented by thin silt-clay particles of basic glass considerably altered into montmorillonite-hydromicaceous minerals. There is an insignificant admixture (2%-5%) of terrigenous silt-size particles of quartz, feldspars, muscovite flakes, and rare fragments of palagonite glass.

The lower part of the interval (Section 6-2) is composed of a sedimentary tuffite microbreccia. The matrix (40%) is composed of a hyalopelitic basaltic tuff, which is pigmented and impregnated with manganese hydroxides. The same sections show numerous zeolite extrusions. The roundmass contains sand-silt size volcaniclastic debris (30%), as ell as fragments of palagonite and hyaloclastites. Small pieces of the

Figure 2. *Aluminic-ferric montmorillonite, Na form, developed upon hyalopelitic tuff. Noticeable is the needle-fibrous habit of the authigenic minerals. Fraction <0.001 mm, Sample 350-4-1, CC, magnification ×18,000 (SEM photo).*

matrix have a microphytic andesitic structure. Typical here is large (up to 2 mm) angular debris of hyalopelitic tuff, with fragments of colorless glass and zeolites.

Compared to the overlying subseries, these deposits are noted for their relatively intensive zeolitization. The clay minerals (Section 6-1) consist of montmorillonite (70%), which is predominantly aluminic with an insignificant ferrous admixture; its exchange complex mainly contains Ca and Mg. The mixed-layer phase is represented by few hydromicaceous packets. Hydromica is present as an independent phase (up to 25%), containing about 25% expandable montmorillonite layers. Kaolinite makes up about 5%. Section 6-2 contains ferrous montmorillonite (70%); the exchange complex shows Mg, Ca, Na; the clay is mixed layered and contains nearly 20% mica packets. Hydromica (25%) comprises about 20% montmorillonite layers. The chlorite content is 5%.

Subseries 2C (Oligocene[?], 169.5-195.0 m, Sections 7-1 to 8-0)

The clay here is a hyalopelitic tuffite, with an admixture of terrigenous silty-sandy particles of quartz (10%). The ground mass is represented by altered, fine detritus of basaltic glass replaced by a weakly polarizing clay substance. Also present are mica flakes and chlorite-like minerals. Zeolites are widely developed, and the clay matrix, they form nest-like clusters. There is sandy-silty debris (10%) of green basaltic glass, and palagonite. Tephra fragments, deeply impregnated with manganese hydroxides, are also present (5%).

The clay minerals are chiefly montmorillonite (65%) evidently aluminic. The exchange cations show a dominance of K, Mg, Ca. The hydromica (25%) includes expandable montmorillonite packets (20%); the kaolinite content is about 10%.

Subseries 2D (Oligocene [?], 198.0-226.5 m, Sections 8-1 to 9-0)

Tuffite clays dominate with an obvious content (30%-40%) of fine silt, terrigenous particles, including quartz and rod-like mica fragments. The clay matrix is represented by altered (zeolitized) hyalopelitic basaltic glass. Black, coalified organic remains (5%), pyrite globules and aggregated (5%) often altered to hydroxides, are scattered throughout. To a large extent, the beds have a typical microbreccia structure (Samples 8-2, 40-42 cm; 8-3, 49-51 cm). Irregularly rounded and angular particles of tuffite clay and hyaloclastite fragments (up to 2-3 mm) are often found within the olive-gray clay matrix. Often, peripheries of the organic debris are bordered with micrograined pyrite. Both the debris and the matrix are intensively zeolitized. The breccia structure is probably a consequence of bioturbation.

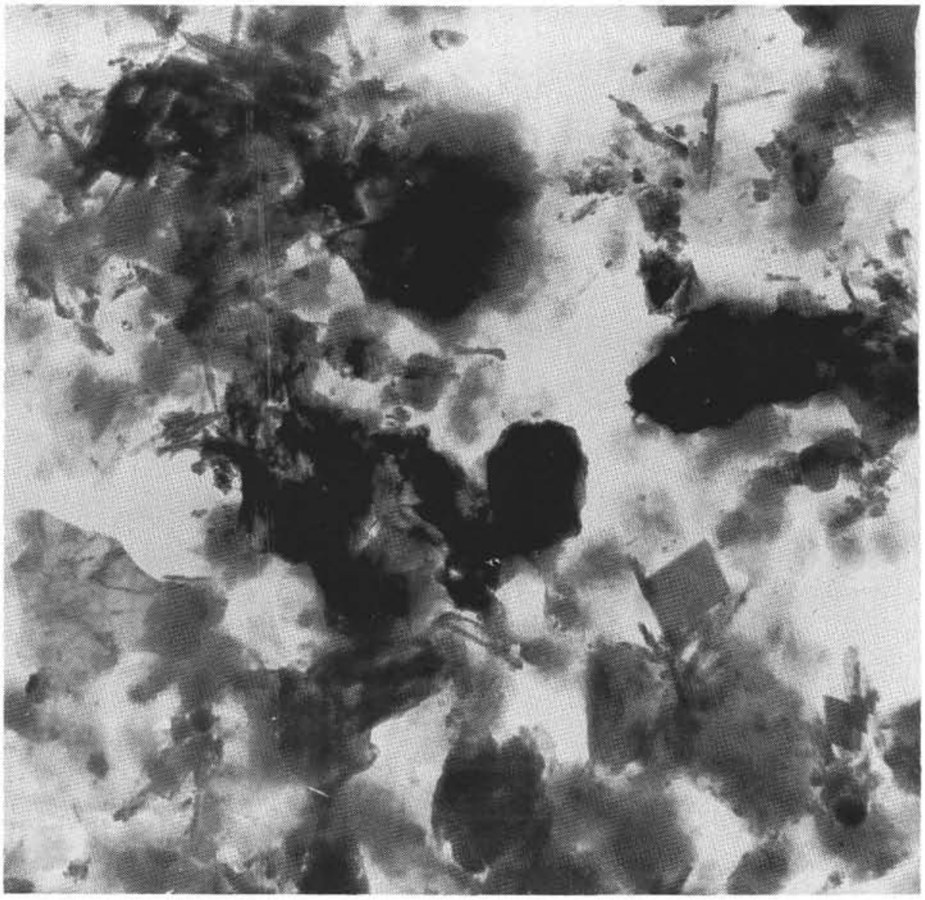

Figure 3. *Aggregates of needle-like particles of montmorillonite, which is ferrous-aluminic, of Na form, mixed layered. Also present are hydromica particles and zeolite crystals. Clay minerals developed upon a basic hyalopelite. Fraction <0.001 mm, Sample 350-5-2, CC, magnification ×18,000 (SEM photo).*

The clay minerals (Section 8-1) have been identified as: (1) montmorillonite (60%) which is aluminic-ferrous, weakly mixed-layered, and containing a few hydromicaceous packets (15%); and (2) hydromica (25%) weakly mixed layered, and containing about 25% expandable montmorillonite layers. Chlorite is defective (13%), and kaolinite comprises about 2%.

Rocks making up Subseries 2D differ from the overlying subseries by their terrigenous silty admixtures (15%) (Sample 8-1A, 134-136 cm). It is possible that the rocks in Subseries 2D are transitional.

Series 3 (Oligocene and late Eocene, 226.5-364 m, Cores 9-1 to 14-2)

The deposits are dominated by lithified sediments, in particular, by siltstone argillites, argillites, limestones, breccias, and some sandstones (in turbidite deposits). Turbidites are very numerous and increase towards the base of the series, in particular, in Cores 13 and 14. In these intervals, they illustrate turbidite-like structures, along with sediments, which are regarded as being deposited from the margins of suspended flows, i.e., from areas of accumulated sand. Near the basal contact, the sediments are strongly lithified breccias.

Besides interlayers of volcanic ash and limestone, this series also shows abundant bioturbation of fine-grained materials and contains significant quantities of pyrite.

Subseries 3A (Oligocene[?], 226.5-293.0 m, Sections 9-1 to 11-6)

The rocks are dominated by tuffite clays enriched in scattered coalified organics (10%), and microglobular accumulations of pyrite. The matrix of the fine-grained material is represented by hyalopelite hyaloaleurite with a basaltic composition, which has been altered into a montmorillonite-hydromicaceous material. There is a terrigenous admixture of rod-like particles of altered muscovite and biotite. Hyaloclastic tuffs are present as separate layers (Sections 9-2; 10-3A, 10-12), they are palagonitized and partially carbonized. The upper member (3A-I) contains bioturbation breccias. The underlying beds (member 3A-II) are mostly thin micro-laminated.

Member 3A-I (Oligocene[?], 226.5-264.5 m, Sections 9-1 to 10-6) contains abundant tuffite clays enriched in scattered organics. The matrix of the tuffite clays is represented by fine hyalodetritus (clay-silt), altered into a weakly polarizing montmorillonite-hydromicaceous mass. There are relics of basaltic and, less frequently,

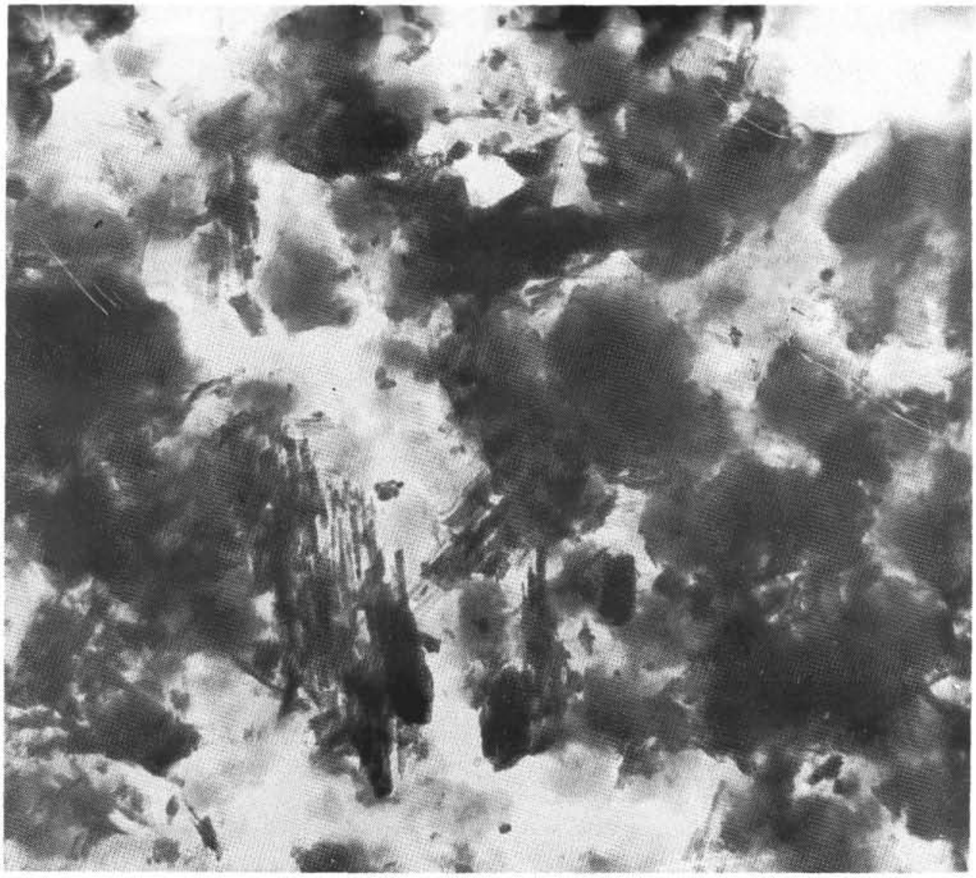

Figure 4. *Aggregates of needle-like particles of montmorilonite which is ferrous-aluminic, Na form, mixed layered. Noted are particles of hydromica. Clay minerals are developed from a basic hyalopelite. Fraction <0.001 mm, Sample 350-5-2, CC, magnification ×18,000 (SEM photo).*

acid glass, which have been replaced by the matrix, which as a rule is intensively zeolitized. The alteration of glass into hydromicaceous-montmorillonite is usually observed along the peripheries of fragments, along cracks, and parting contacts. The rocks contain a higher amount (up to 10%) of coalified plant fragments, and finely scatter humus substances. These give the rock a brownish color. Besides the organics, the hyalopelitic clays contain microglobular intrusions of pyrite, which occasionally form aggregates (up to 2-3 mm). Also present are concretion of gypsum crystals within the clay mass.

On the whole, the rocks of the member have a typical microbreccia structure. There are irregularly rounded fragments (up to 2-3 mm) which include large gravel debris of light green hyalopelitic tuffs and palagonitized hyalocalstites. These are usually cemented with a brownish poorly coaly clay. The breccia structure is of bioturbational origin. The member (Sections 9-2, 10-3A, 10-12) contains beds of basaltic tuffs composed of glass fragments (70%) of a sandy-silt size, which are intensively palagonitized and altered into montmorillonite, hydromicaceous and partially carbonate products. It should be noted that these tuffs also contain some scattered coaly substances, as well as small pyrite intrusions.

The clay minerals (Sample 9-1, 100-102 cm) contain ferrous montmorillonite (70%) of Ca form, without any admixture of mixed-layered packets. Hydromica (15%) is an aluminic form containing 20% expandable montmorillonite phase. Kaolinite makes up to 15%. Sample 9-2, 19-21 cm contains ferrous montmorillonite (80%), basically mixed layered, including up to 25% hydromicaceous packets. The absorbed complex shows the domination of Ca-Mg. The hydromica content is 10%, kaolinite up to 10%.

Products of the submarine alteration of hyalopelites distinctly prevail in this member, as compared to the other clay minerals. Authigenic montmorillonites are present in the Ca form, sometimes in the Ca-Mg form. The increased content of kaolinite (up to 15%) reflects the increased influence of the continental drainage.

Member 3A-II (Oligocene[?], 264.5-293.0 m, Sections 10-6 to 11-6) contains a clay tuffite with a relatively higher content of scattered coalified organics (15%) and pyrite microglobules. There is an admixture (10%) of terrigenous silty grains of quartz, muscovite particles, biotite, and feldspars. The matrix (up to 70%-80%) is represented by thoroughly altered hyalopelitic material, which contains decomposed glass relics (both brown and green) and palagonitized particles (up to 10%. Typical here are scattered globules and aggregates of pyrite. Thin sections also show some linear microlaminations. The basic clay mineral is montmorillonite, but there are considerable amounts of hydromica (mixed layers), kaolinite, and chlorite.

Subseries 3B (Late Eocene[?], 293.0-364.0 m, Sections 13-1 to 14-2)

This subseries is almost entirely composed of tuffitic and silty clays with a rather significant admixture of coalified remains. The matrix is composed of two main elements: (1) by a hyalopelite, hyaloaleurite material (up to 60%-70%). This material has been altered into a clay. There are some relics of glass, debris of hyaloclastites, and palagonites; and (2) by terrigenous, silty particles of quartz, altered and, less frequently, fresh alkaline feldspars; and rod-like particles of hydromica and altered biotite. Coalified plant fossils (10%) are scattered throughout, and cause a brownish humus pigmentation. Also finely scattered is microglobular pyrite. The lower parts of the interval (Sections 13-1, 13-2) reveal a considerably greater number of brown and green volcanic glass particles, together with debris of sand-sized hyalopelitic tuff and palagonite.

The clay is comprised of some spotty aggregates of coarse-crystalline carbonate (2-5%), pigmented by finely scattered organics (Sections 13-3, 59-61 cm; 14-1; 14-2).

The lower half of the interval shows some bioturbation features. The base of the subseries contains increasing amounts of basic glass debris and palagonite tuffs (silt-size), which dominate over the brown tuffite clays enriched with organics.

The clay minerals contain montmorillonite (70%) (aluminic). Its exchange complex seems to contain Fe. The kaolinite content is 20%. The hydromica (up to 10%) is a mixed-layered clay and includes expandable montmorillonite packets.

At a depth of 361.7 meters the boundary between the sedimentary sequence and the underlying volcanic rocks was present. According to the shipboard descriptions, directly above the contact, there are breccias of poorly lithified clay with angular fragments of altered basalt and chert. Rocks of Sample 14-2, 40-42 cm contain barite crystals (0.1-1.0 cm) and pyrite concretions (0.3-0.5 cm). At a depth of 379.4 meters (Section 16-1), there is a basaltic breccia gradually replaced by a massive basalt (down to Section 16-3).

SEDIMENTATION HISTORY

On the basis of lithologic and mineralogic studies of the rocks from the sedimentary sequence cored in Hole 350, the sedimentation history can be divided into four major stages.

1) Late Eocene and Oligocene (?) (sediments of Series 3, Subseries 2D).

2) Oligocene and middle Miocene (sediments of Subseries 2A-2C).

3) Plio-Pleistocene (?) (sediments of Subseries IB-IC).

4) Pleistocene (sediments of Subseries IA).

Each sedimentation stage can be divided into some more detailed intervals, characterized by their own specific features of sedimentation. It should be emphasized that the deposits on the ridge are, on the whole, of the mid-oceanic type. They are characterized by obviously dominating products of basaltic volcanism. During Eocene-Miocene hyalopelites-hyaloaleurites of basic composition were the significant components. These subsequently underwent submarine alteration into montmorillonite-hydramicaceous products, often with a large amount of zeolites.

Late Eocene and Oligocene

During this time deposits making up Series 3, Subseries 2D accumulated with a total thickness of 166 meters. At the contact between this series and the rocks of acoustic basement, there is a breccia composed of fragments of relatively lithified siltstone argillites and altered basalts. The breccia contains barite crystals and pyrite concretions. Such formations can be interpreted as manifestations of hydrothermal mineralization.

The breccia is overlain by tuffitic silty clays (about 30%-40%) admixed with coalified remains and globular pyrite aggregates. The clays are products of the submarine alteration of the basic hyalopelitic-hyaloaleuritic material. Whereas at the beginning of this sedimentation stage there were authigenic montmorillonite-hyromicaceous minerals and terrigenous components, later, particles of hydromicas, kaolinite, and clastic quartz were deposited.

The lower Eocene-lower Oligocene deposits are typically turbidites and are characterized by widely developed microbreccia structures of bioturbational origin. Towards the top of this interval, the amount of terrigenous components and coalified humusified plant detritus increases considerably. No marine fossils were observed in these deposits. It seems possible to believe that these deposits were accumulating during Eocene-lower Oligocene within the limits of a rather confined intracontinental (Mediterranean) type basin with associated basic volcanic activity, both submarine and on Jan-Mayen Island. Thin plant detritus and fine-sand silty terrigenous products from eroded acid granitoid rocks entered the basin from comparatively close land sources. The increased amount of organics facilitated the diagenesis of pyrite concretions. On the basis of the data, the sediments cannot be regarded as typical of an open ocean basin.

Oligocene and Middle Miocene

During this period, clayey tuffite deposits of basic composition (Subseries 2C, 2B, 2A, 142 m thick) accumulated in the region. These deposits are composed of hyalopelitic, hyaloaleurolitic volcaniclastic materials, mainly of basaltic composition. These materials alterated into ferrous-montmorillonite products admixed with hydromicas. The sediments are largely microbrecciated by bioturbation, and reveal a high degree of zeolitization. The upper horizons have a high content of manganese hydroxides, which cements the microbreccia fragments and is present as spotty intrusions. It is interesting to note that remains of siliceous marine organisms (diatoms, Radiolaria) are found only in the top of the interval (Subseries 2A, Core 3).

It is possible to conclude that the volcanic activity, beginning in Eocene, became much more intense by upper Miocene. Predominantly fine hyalopelitic and, to a smaller extent, hyaloaleurolitic sediments accumulated in the relatively limited basin. The basaltic vitroclastic material most likely resulted from submarine and island volcanism. Large amounts of hyaloclastite fragments, intercalations of intensive zeolitigation and distinctive metal-bearing sediments represented manganese hydroxides (which are also found on the adjacent Icelandic Plateau) all testify to manifestations of submarine hydrothermal activity. It is likely that it was only at the end of the Miocene that the sedimentation basin became an open sea, as the ashy basic tuffs contain some diatom and radiolarian remains.

Plio-Pleistocene Stage

This can be divided into two periods: (1) the time when Subseries 1C (lower "Glacial" Plio-Pleistocene; 25.5 m thick) was accumulating. During this time, hyalopelitic clays were deposited admixed (30%-40%) with terrigenous silty material represented by grains of quartz, microquartzites, and alkaline feldspars. The hyalopelitic clays are composed of ferrous montmorillonite developed from basic glass under submarine conditions; (2) the time with Subseries 1B (upper Glacial Plio-Pleistocene, 22 m thick) was accumulating. During this time, aleurolitic clays with foraminifers and grains of terrigenous glauconite were deposited. Also typical, are fragments of brown basaltic glass. Deposits such as this are widely distributed in the northern Atlantic region. Basic volcanism which continued until lower Plio-Pleistocene greatly diminished, and the dominate sediment component became terrigenous.

Pleistocene Stage

Two members were accumulating during this time: (1) Member 1A-II (lower Pleistocene, 5 m thick) which contains hyalopelitic ashes composed of finely detrital basaltic glass with fragments of palagonites, and admixtures of terrigenous quartz and foraminifers. The time of sedimentation of this member probably coincided with the time of the most intense basic volcanic activity on islands of the northern Atlantic; (2) Member 1A-I (upper Pleistocene, 3 m thick) corresponds to the time when "Recent" deposits were accumulating. They are represented by clayey sandy-silty sediments abundant in terrigenous components.