13. ALTERATION OF SEDIMENTS IN LOWER PART OF HOLE 286[1]

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ABSTRACT

About 100 cm of altered rock from Core 286-35-1 constitute the oldest sediments obtained from the New Hebrides Basin. They rest on underlying basalt flows and differ from overlying sediments in being orange pink rather than greenish gray and soft to semilithified rather than strongly lithified. Mineralogic changes that have occurred, assuming that the original composition of the altered zone was similar to that of the unaltered sediments, include: (1) increase in abundance of montmorillonite, and decrease in amounts of feldspar and volcanic glass; (2) elimination of calcite; (3) introduction or remobilization of iron and manganese to form earthy nodules. These changes are thought to be the result of rapid weathering of unstable feldspars and volcanic glass produced by reaction with warm, slightly acidic waters that emanated from gabbro that intruded the pillow basalt.

INTRODUCTION

The lowest sedimentary rocks in Hole 286, lying immediately above basalt flows, are altered and show striking changes in color and hardness as compared with overlying sedimentary rocks of comparable grain size. The color changes from greenish gray to orange pink and the hardness from strongly lithified (requiring diamond sawing) to soft or semilithified in the altered zone. Sedimentary structures within these altered rocks are similar, however, to those in overlying rocks. Our tentative conclusions on shipboard were that these changes resulted from postdepositional alteration of volcanogenic sediments similar in initial character to the overlying unaltered portion. We also concluded that the underlying basalt predated deposition of the sediments and thus represented the basement of the New Hebrides Basin. Hole 286 bottomed in gabbro that clearly intruded the basalt. Evidence for intrusion includes: (1) the margin of the gabbro is chilled; (2) thin dikes of volcanic glass and dolomite that cut the basalt may have emanated from the gabbro; and (3) the development of extremely large variolites (up to 2 cm in diameter) within the basalt suggests reheating. It seemed possible that the alteration of the sediments lying just above the basalt also could have resulted from hydrothermal activity stemming from intrusion of the gabbro. To confirm this inference, a detailed study of the sediments within and above the altered zone was undertaken in order to specify what mineralogic changes might have taken place. Resolution of the origin of this altered zone is important in interpreting the early history of deposition in the New Hebrides Basin and establishing the nature of the sediment-basalt contact.

STRATIGRAPHIC SUMMARY

Hole 286 penetrated 706 meters of rock with recovery of 41 cores; 649 meters of sediments and 43 meters of basalt and gabbro were sampled. Three major sedimentary units were recognized, the lowest of which comprises 452 meters of vitric siltstone, vitric sandstone, and volcanic conglomerate. The lowest core of this unit contains about 100 centimeters plus core catcher of highly altered sedimentary rock that rests on basaltic basement (Figure 1). This part of the core is barren of fossils, but fossils from the unaltered sediments in Core 33 indicate a middle Eocene age (nanno zone of *Reticulofenestra umbilica*).

MINERALOGIC CHANGES

The conglomerate, sandstone, and siltstone above the altered zone consist almost entirely of volcanically derived sediments together with minor amounts of pelagic organisms. Conglomerate clasts exhibit textures ranging from holohyaline to holocrystalline. Most fragments are porphyritic, microporphyritic, or vitrophyric. In general, the clasts with porphyritic textures contain plagioclase phenocrysts ranging from sodic labradorite to calcic andesine embedded in a glassy or crystalline matrix. The crystalline clasts are hyperstheneaugite andesites, or less commonly hornblende or basaltic andesites. Highly vesicular clasts are also present that have a similar phenocryst content and probably a similar composition.

The fine to very fine sands and siltstones above the altered zone contain virtually the same volcanic debris as the conglomeratic fraction; however, the sands and siltstones are more altered. Smear slides and X-ray diffraction studies (Table 1) of samples from Cores 17 to 34 indicate that some of the glassy clasts in the finer grained siltstones have altered to montmorillonite, but the clay fraction is usually less than 20 percent of the bulk mineralogy.

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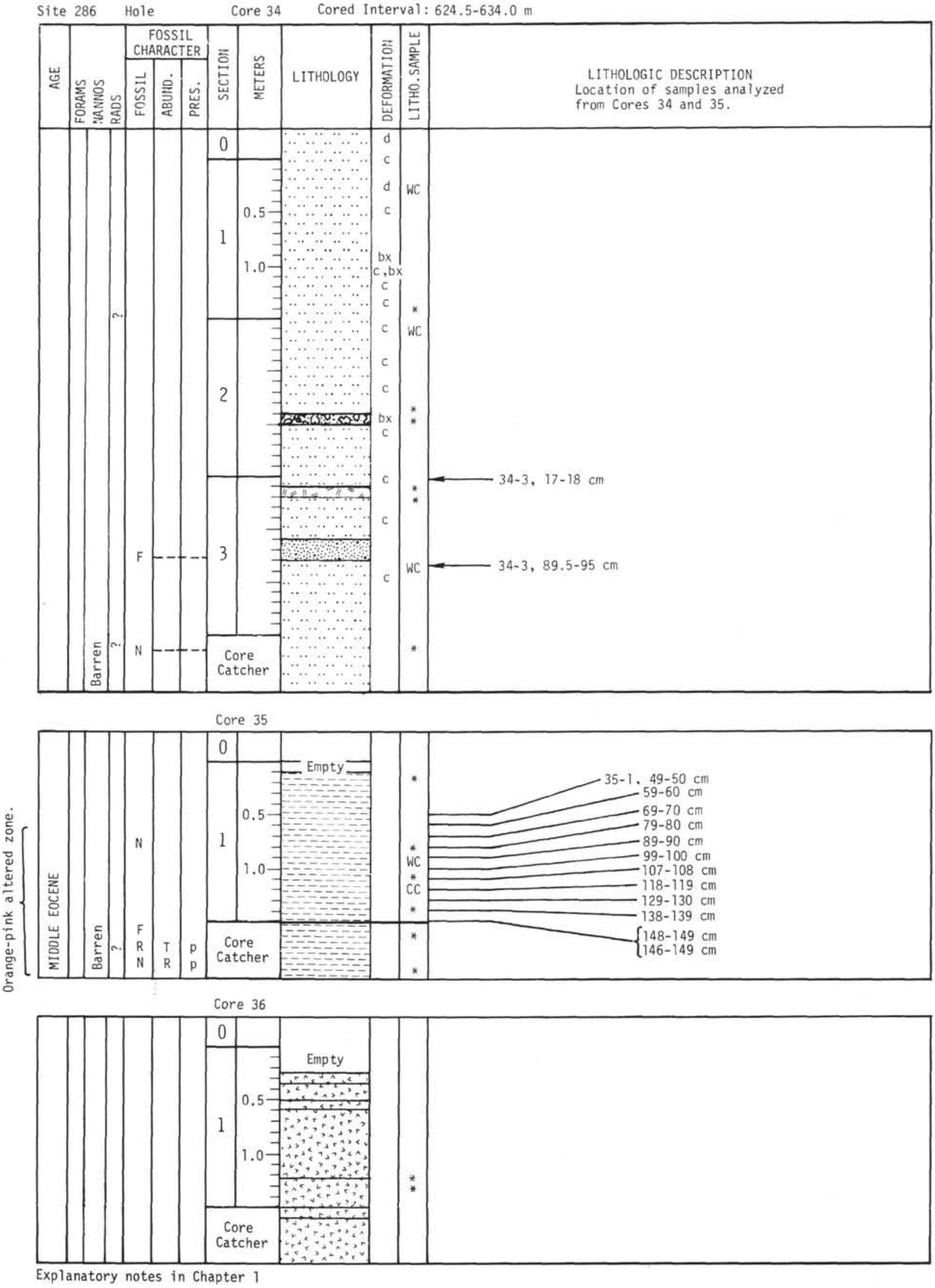

Figure 1. *Location of samples analyzed from Cores 286-34 and 286-36.*

TABLE 1[a]
Smear Slide and S-Ray Diffraction Studies

Sample (Interval in cm)	Color	Lithologic Description	Plagioclase	Quartz	Cristobalite	Calcite	Montmorillonite	Clinoptilolite
17-4, 83-84	5GY4/1	Dark greenish-gray siltstone	70	5	13	1	11	–
19-1, 137-139	5Y4/1	Olive-gray sandstone	64	2	9	13	12	–
23-2, 113-116	5GY4/1	Dark greenish-gray siltstone	58	1	6	25	10	–
25-2, 63-68	5Y4/1	Olive-gray microlaminated siltstone	61	3	T	19	17	–
29-4, 38.5-40.5	5Y4/1	Olive-gray siltstone	83	<1	T	–	17	–
34-3, 17-18	N7	Light-gray glass shard ash or siltstone	46	<1	T	–	54	–
34-3, 89.5-95	5GY4/1	Dark greenish-gray mottled siltstone	77	<1	T	–	23	<1
35-1, 49-50	5Y6/1	Light olive-gray mottled siltstone	77	<1	T	–	23	<1
35-1, 59-60	5Y6/1	Light olive-gray mottled siltstone	81	<1	T	–	16	3
35-1, 69-70	5YR7/2	Grayish-orange-pink siltstone	59	<1	T	–	32	9
35-1, 79-80	5YR8/4	Moderate orange-pink altered siltstone	27	2	T	–	71	–
35-1, 89-90	5YR8/4	Moderate orange-pink altered siltstone	35	<1	T	–	65	–
35-1, 99-100	5YR8/4	Moderate orange-pink altered siltstone	30	2	7	–	60	1
35-1, 107-108	5YR8/4	Moderate orange-pink altered siltstone	43	2	T	–	49	6
35-1, 118-119	5YR8/4	Moderate orange-pink altered siltstone	23	5	6	–	66	–
35-1, 129-130	5YR8/4	Moderate orange-pink altered siltstone	8	6	11	–	74	1
35-1, 138-139	5YR8/4	Moderate orange-pink altered siltstone	33	7	2	–	57	1
35-1, 148-149	5YR8/1	Pinkish-gray altered siltstone	53	3	T	–	43	1
35-1, 146-149	5YR8/1	Pinkish-gray altered siltstone	62	8	2	–	27	1

[a] Composition, in percent, of crystalline components.

A characteristic feature of the sands and siltstones is the presence of subhedral crystallites of water clear andesine (An_{35}) and trace amounts of subhedral green augite. Trace amounts of light brown to amber glass shards are ubiquitous in the coarse silt and sandy zones. The refractive index of the glass shards is 1.558, which indicates a basic-intermediate or andesitic composition (George, 1924, as modified by Churkin and Packham, 1973).

Just above the dramatic color change in Core 35 (interval 49-50 and 59-60, see Table 1), the recovered sediment is mainly light-olive-gray, feldspar-bearing, mottled siltstone; a piece of coarse-grained volcanic sandstone is also present. This coarse volcanic sand contains euhedral phenocrysts of clear andesine 1 mm or less in diameter that display slight discoloration along cleavage planes. Also present are pristine phenocrysts of augite 1 mm or less in diameter. The pyroxene phenocrysts constitute less than 2 percent of the whole rock. Abundant light-colored clasts of volcanic glass are altered to clay, but the shape of the clasts remain. Quartz, clinoptilolite, and cristobalite constitute the remaining minerals. Fifty percent of the silt-size grains are montmorillonitic masses containing microlites of andesine and finely disseminated black magnetic grains. The yellowish-gray montmorillonite, dark glassy clasts, augite, and disseminated iron-rich grains produce the olive-gray color of the bulk sample. Only scattered particles of red-orange iron oxide are presented in the montmorillonite in this interval; however, several vesicular clasts have a reddish-brown color due to partial oxidation.

The next sample (35-1, 69-70, see Table 1), taken 10 cm below this olive-gray interval, is near the top of the bright orange-pink zone of alteration.

Mineralogy of this altered zone (Table 1) consists of silt-size water clear andesine, traces of chlorite, quartz, clinoptilolite, cristobalite, and palygorskite, all embedded in a matrix of iron-stained montmorillonite. Manganese-iron oxides are distributed as lenses or nodules throughout the altered section. The pink color is due to iron-oxide coatings on the clay minerals. This coating can be removed with a Dithionite-Citrate wash (Mehra and Jackson, 1960).

Montmorillonite is used in this paper as a species name for the dioctahedral silica-rich end member of the smectite group. Because of extensive alteration and the presence of significant amounts of iron and manganese, it was decided to investigate this smectite to determine its location in the montmorillonite-beidellite or nontronite-beidellite series. The trioctahedral smectites were not considered since an X-ray diffraction analysis clearly showed the smectite to be dioctahedral. According to Green-Kelley (1953) montmorillonites subjected to a lithium treatment collapse irreversibly, whereas beidellites will re-expand. Schultz (1969) indicated that even partial re-expansion could be related to a proportion of beidellite-like layers. Nontronites behave in a manner similar to beidellites after lithium saturation. On the basis of these criteria this sample is a montmorillonite. X-ray diffraction analyses show that the 060 spacing is 1.50 Å, which corresponds to montmorillonite rather than nontronite, which should be near 1.52 Å (MacEwan, 1961). A 2-micron fraction of the sample was analyzed by the methods of Shapiro and Brannock (1962); however, the disseminated particles of iron-oxide and the trace of cristobalite noted in X-ray diffractograms prevented an accurate assessment of iron and magnesium substitution.

Palygorskite is the only other clay mineral present in the altered zone. Confirmation was not possible with X-ray diffraction, but the acicular fibers diagnostic of hormites were seen with the electron microscope (Figure 2).

Angular and subhedral silt-size phenocrysts and micron-size anhedral microlites of water clear andesine (An_{35}) represent the only feldspar in the altered zone. Zoned andesine crystallites are common with alteration visible along cleavage planes. Some of the more calcic

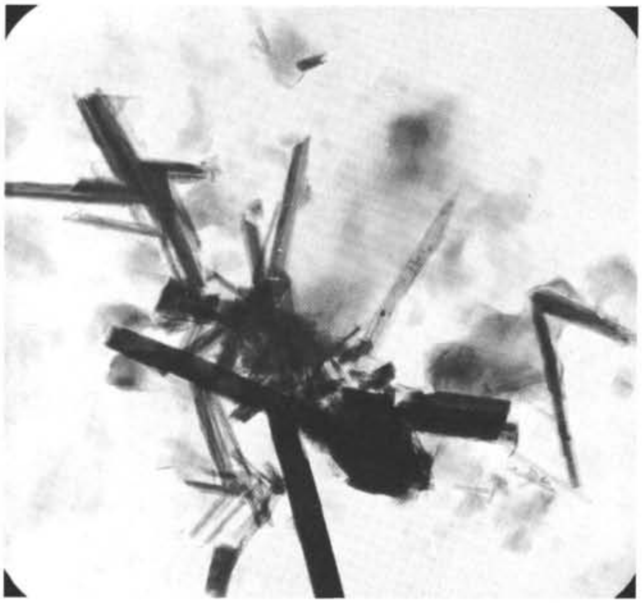

Figure 2. *Acicular fibers of palygorskite. Transmission electron microscope, X~100,000 from Sample 286-35-1, 99 cm.*

centers of the crystallites have been altered to montmorillonite.

Pyroxenes were not observed in this zone; however, grains of chlorite that may represent uralitized augite or hornblende are visible in thin section.

Both phillipsite and clinoptilolite-heulandite are found frequently in the greenish-gray siltstones above the altered zone (Figures 3, 4A, 4B). These zeolites are probably formed through alteration of volcanic ash and glassy clasts. The only zeolite found in the altered section was a member of the clinoptilolite-heulandite series, and is noted as clinoptilolite in Table 1.

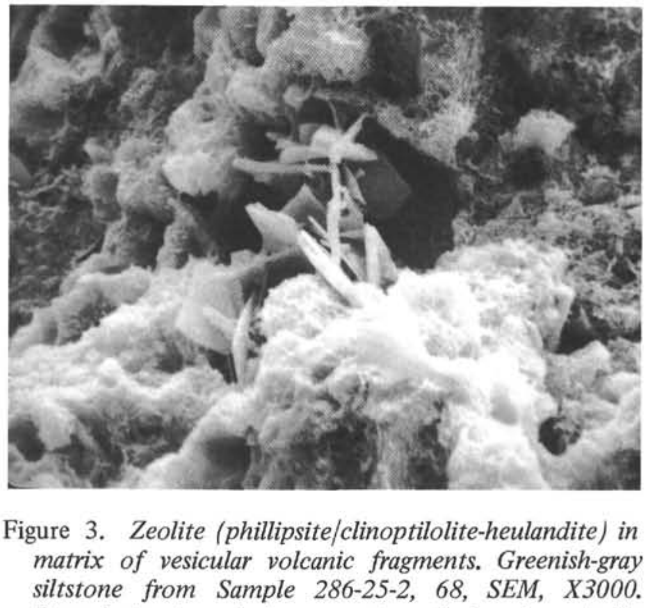

Figure 3. *Zeolite (phillipsite/clinoptilolite-heulandite) in matrix of vesicular volcanic fragments. Greenish-gray siltstone from Sample 286-25-2, 68, SEM, X3000. Round structure in lower center of view is probably cristobalite.*

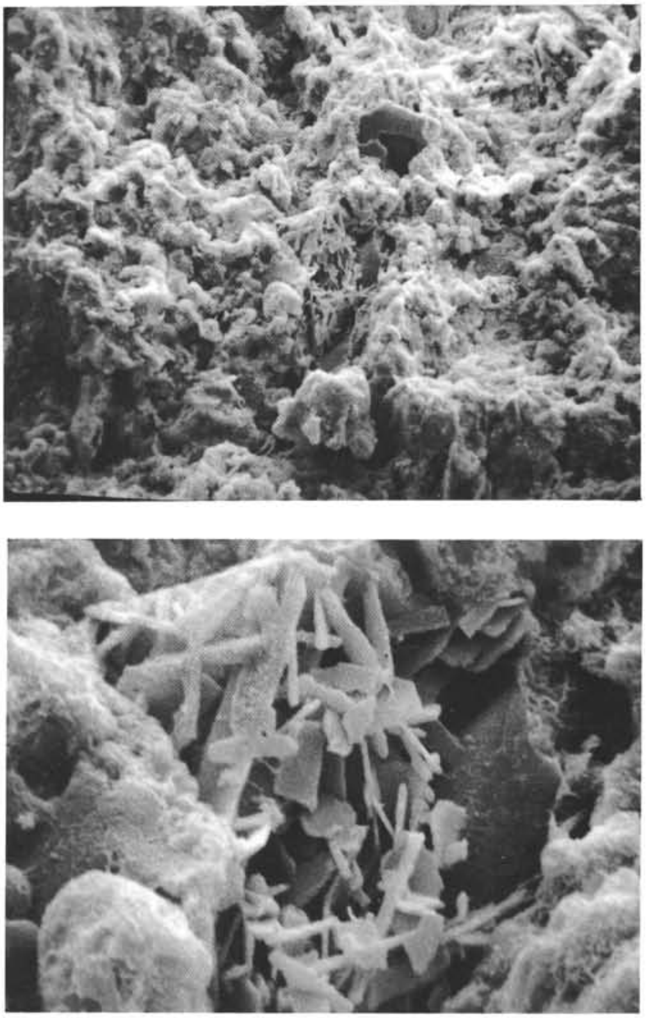

Figure 4. *(A) Zeolites (phillipsite/clinoptlolite-heulandite) in matrix of volcanic fragments. SEM, ×700. Sample 268-25-2, 68 cm; greenish-gray siltstone. (B) Enlargement of zeolites, SEM, ×3000.*

Calcite is completely absent from the altered zone, in striking contrast to higher in the section where fairly abundant calcareous nannofossils occur (Figures 5, 6). However, the absence of calcite does not correspond to the boundary of the altered zone, as it is not present in Core 34 either.

The most noticeable variation within the altered zone is the distribution of manganese which occurs in three distinct morphologies: nodular, lenticular, and disseminated. The nodules are nearly spherical, generally from 1-2 mm in diameter and seldom occur more frequently than two or three per cubic centimeter. Their surface is dull black with a smooth to vesicular texture. Internal banding is not recognizable, and a clearly distinguishable nucleus is absent (Figures 7A, 7B). The

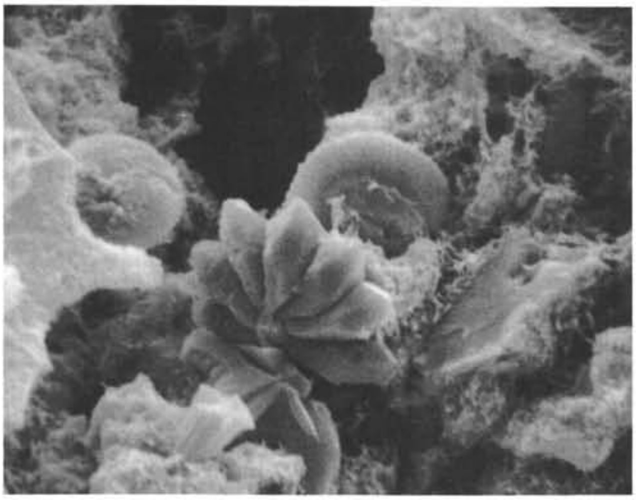

Figure 5. *Calcareous nannofossils in matrix of vesicular volcanic clasts. Greenish-gray siltstone, Sample 286-25-2, 68 cm, SEM, ×5000.*

nodules are soft and quite easily crushed. Manganese lenses from 0.5 to 1 mm in thickness occur in several intervals (Table 1) and were continuous through the sample. Internal layering was not observed, and the lenses are also soft. The disseminated grains are present only in the samples from the top 10 cm of the altered zone where they are almost uniformly distributed.

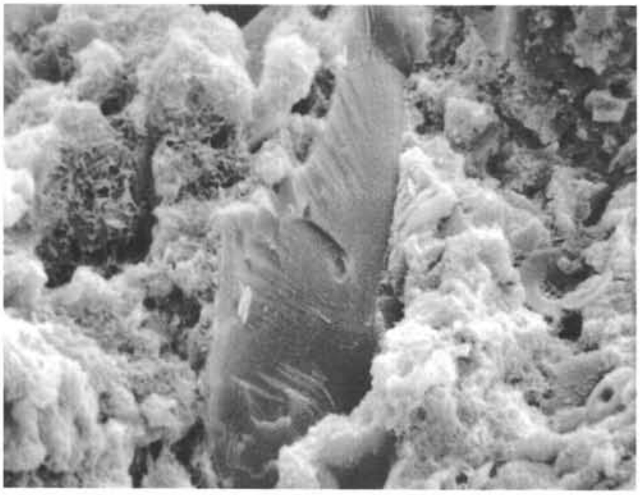

Figure 6. *Quartz(?) fragment and calcareous nannofossils (at right) in matrix of vesicular volcanic fragments. From Sample 286-25-2, 68 cm; SEM, ×3000.*

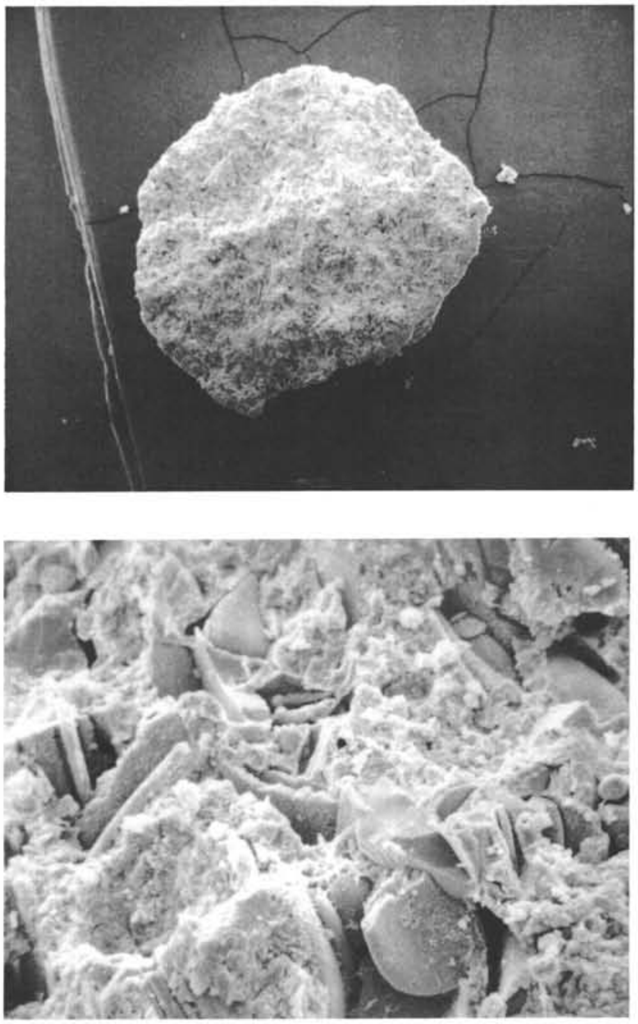

Figure 7. *(A) Manganese-iron nodule from Sample 286-35-1, 129 cm. SEM, ×50. (B) Texture of manganese-iron nodule shown in (A). SEM, ×1000. Note lack of nucleus and concentric banding.*

CONCLUSIONS

In the absence of chemical analyses of the altered and unaltered material, it is impossible to specify all of the chemical changes that have occurred during formation of the orange-pink altered zone. However, if we assume that the altered zone was originally similar in composition to overlying sediments, as suggested by the similarity of andesine crystals and sedimentary structures, then the following gross mineralogic changes have taken place:

1) Montmorillonite increased from an average of 20 percent in the unaltered sediment to an average to 54 percent in the altered zone (Figure 8). This increase was apparently at the expense of plagiolcase and glass, as the former declined from 69 percent (average unaltered) to 37 percent in the altered zone, whereas crystallinity increased from 45 percent (unaltered) to 59 percent (see site summary, core descriptions for analytical data).

2) Manganese and iron were either introduced or redistributed within the altered zone, and concentrated into bands and nodules, both of which are absent in the unaltered sediments.

3) Clacite is lacking within the orange-pink zone, and this absence extends up to Core 34, suggesting that less intense alteration extended much higher in the section above the altered zone.

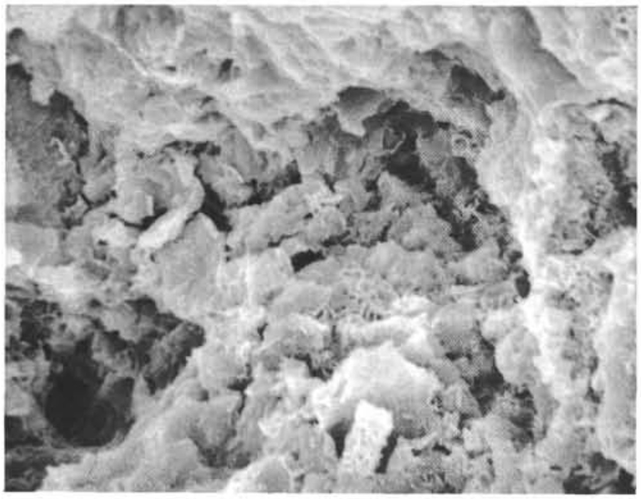

Figure 8. *Texture of altered sediments from Sample 286-1-118, showing montmorillonite and minor amounts of vesicular volcanic grains. SEM, ×3000.*

4) These changes are consistent with those produced by the passage of warm, perhaps slightly acidic, waters through the sediment column, producing rapid weathering and transformation of the unstable feldspars and glassy volcanic fragments to clay. We suggest that these warm waters may have emanated from the gabbro intrusion found at the bottom of Core 286.

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