TERRIGENOUS CONGLOMERATES AND SANDS CORED ON MIDWAY ISLANDS

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ABSTRACT

The Midway Islands are an atoll formed atop a volcano which once protruded above the sea, was subaerially eroded, and then submerged. Drilling with continuous core recovery of two holes on Midway has recovered sections of terrigenous sediments between the basaltic basement and limestone cap of the islands. These sediments consist of basalt pebble conglomerates, some layers rich in organic material, a buried soil, and sandy muds of variable color and composition. Study of the basalt pebbles in thin section shows olivine basalt to be the predominant rock type. The rock types found indicate that the Midway volcano is part of the Hawaiian petrographic province. Rocks of both the tholeiitic and alkalic basalt suites are present and the volcano is tentatively designated as "Haleakala" type. A basalt containing quartz, new to the Hawaiian petrographic province, is described. Its origin is attributed to the mixing of magmas.

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INTRODUCTION

Several attempts have been made over the last 75 years to drill through the limestone cap of Pacific atolls. The first drilling was done by the British at Funafuti in 1896-98. They drilled through 1114 feet of carbonate deposits without penetrating sediments as old as the latest Miocene. The Japanese made the next attempt in 1934-36 at Kita-Daito-Jima. They reached a depth of 1416 feet recovering sediments of Miocene age, all of carbonate composition. American drilling on Bikini in 1947 also recovered Miocene sediments, all carbonate, in drilling to a depth of 2556 feet (Ladd, 1948).

The limestone cap of an atoll was finally pierced by two holes drilled on Eniwetok in 1953 by the Atomic Energy Commission and the U. S. Geological Survey. Hole F-1 presumably reached basement at 4610 feet, and hole E-1 cored basalt below 4208 feet. Both holes were drilled alternately with rock and coring bits, and recovery of the samples was not complete. Hole F-1 lacks any samples from the final 60 foot interval, and E-1 had no recovery for the 108 feet immediately above the basalt cores, except for a few basalt cuttings from the middle of the missing interval (Ladd, 1953). Because no cores were taken or cuttings recovered from the sediments immediately above the basement of either hole, the nature of those sediments was not learned. The Eniwetok drilling provided the first proof that a basaltic basement underlay the thick sections of reef deposits making up Pacific atolls.

The next drilling in the mid-Pacific was done in 1964 on the Ewa Plain of Oahu, Hawaii, supported by a National Science Foundation grant to Stearns and Chamberlain. The program was designed to test new continuous coring and recovery techniques, to gain a better understanding of sedimentation around a volcanic Pacific island, and to obtain additional samples of Pacific basement rocks (Stearns and Chamberlain, 1967). The Number 1 hole penetrated 1072 feet of carbonate, terrigenous, and mixed sediments before reaching basalt. The Number 2 hole, drilled farther inland, reached basalt at 517 feet. The overlying section of Number 2 was predominantly terrigenous, but also contained mixed and carbonate sediments.

The drilling apparatus used at Ewa was then taken to Midway in 1965 and used to drill two holes (Fig. 3). This project was also funded by the National Science Foundation, grant No. GP4728 to H. S. Ladd, G. P. Woollard, and G. A. Macdonald. The cores contained limestone, terrigenous sediments, and basalt. The Reef hole, with recovery of 92 percent, reached basalt at 1261 feet, and the Sand Island hole, with recovery of 72 percent, penetrated the basement at only 516 feet (Ladd, _et al_., 1967).

A location map of Pacific drillings is presented in Figure 1. Figure 2 summarizes the lithology and recovery of the Pacific drillings. Figure 3 shows the location of the drilling sites at Midway.

This thesis is a report of analyses of the coarser fractions of the terrigenous sediments obtained in the drilling at Midway. The clay size material from these sediments is being studied by Dr. Dorothy Carroll. The sediments consist of basalt pebble conglomerates, some highly carbonaceous layers, and sandy muds varying in color and composition.

The following terms are defined as they will be used in this thesis. Saprolite is used as it was by Walker (1964): Saprolite is "masses of rotten rock whose mineralogical and chemical nature have been changed through weathering from that of the parent rock, but whose structure still reflects that of the original rock." Mud is used to designate the fine-grained sediments containing roughly equal amounts of silt and clay size material. Figure 13 shows that the ratio of silt to clay is maintained within fairly restricted limits centered around a value of 1:1 for almost all samples, whereas the amount of sand varies widely. Material described as mud in the core descriptions varies from sandy muds to muddy sands and these two types make up more than 90 percent of the fine-grained sediments of the core. The term iddingsite is used here in its mineralogical sense of having a

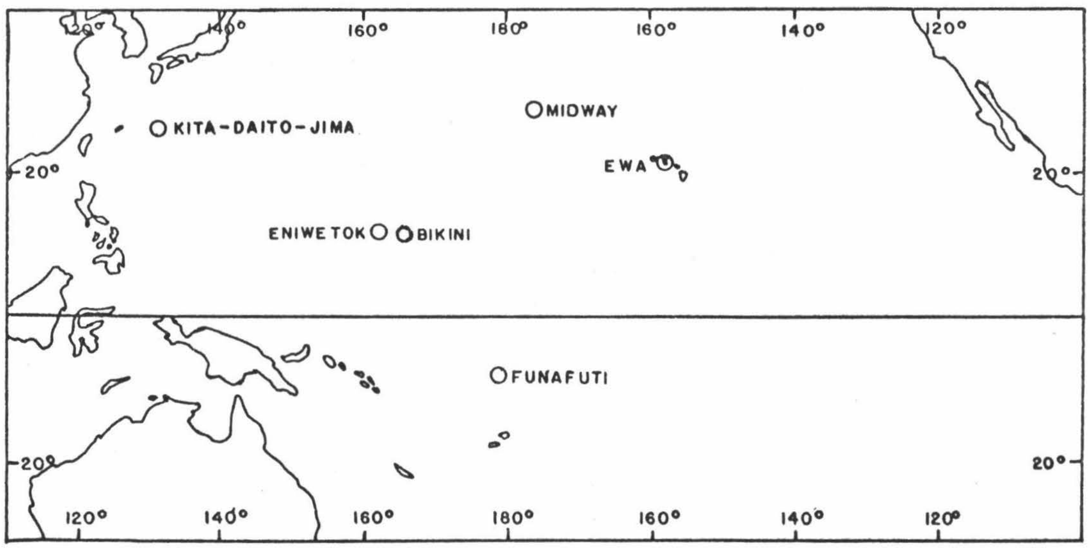

FIGURE 1: PACIFIC DRILLING LOCATION MAP
(after Schlanger, et al., 1963)

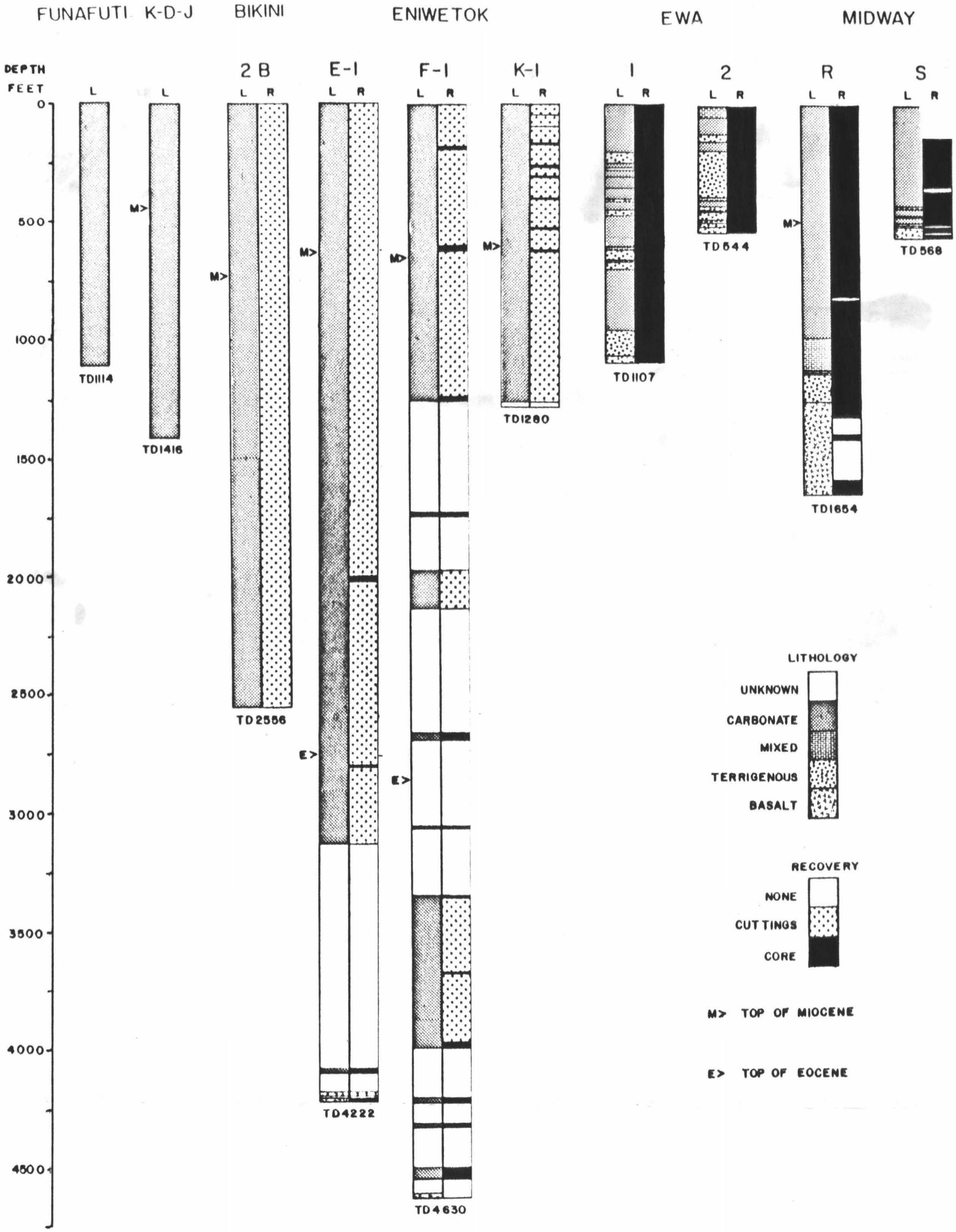

FIGURE 2: LITHOLOGY AND RECOVERY OF PACIFIC DRILLING
The lithology is implied where there has been no recovery.

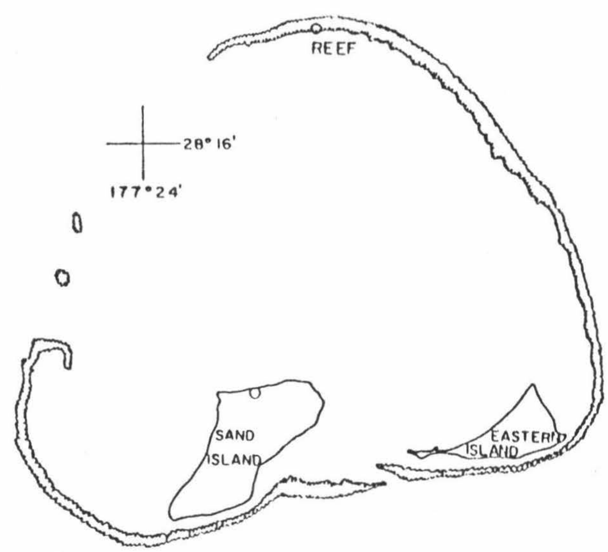

FIGURE 3: MIDWAY ISLANDS: DRILLING LOCATIONS

O DRILL HOLE

definite, though variable, set of optical properties. It is recognized that iddingsite is not a mineral but rather a mixture of at least two minerals.

GENERAL DESCRIPTION OF SEDIMENTS

A general description of the terrigenous sections of the cores is presented in Figures 4 and 5. It has been made by combining the field description of Ladd, et al. (unpublished) with the more detailed description made by the author during the course of sampling the cores for analysis.

Samples of the basalt pebbles and the sandy muds were taken for study. They were labeled and are referred to in the text according to the core from which they came and the depth in that core. For example, R1145.5 came from the Reef core at a depth of 1145.5 feet. If two or more basalt pebbles were taken from the same depth, they are designated by a letter following the depth number, as R1187B.

The sedimentary sequences of both cores reflect the history of the Midway volcano after it was built up out of the sea, as it was subaerially eroded and then submerged. The sediments (Figs. 4 and 5) show an overall trend from terrigenous to marine sedimentation with minor fluctuations demonstrating temporary reversals of that trend.

The muds of the cores are good indicators of sedimentary conditions. Deeper in the cores, or where not associated with much carbonate, the muds are dark browns, red browns, or mottled purples. The muds associated with marine carbonates, on the other hand, are usually green, but may also be reddish or light brown. At two levels in the Sand Island

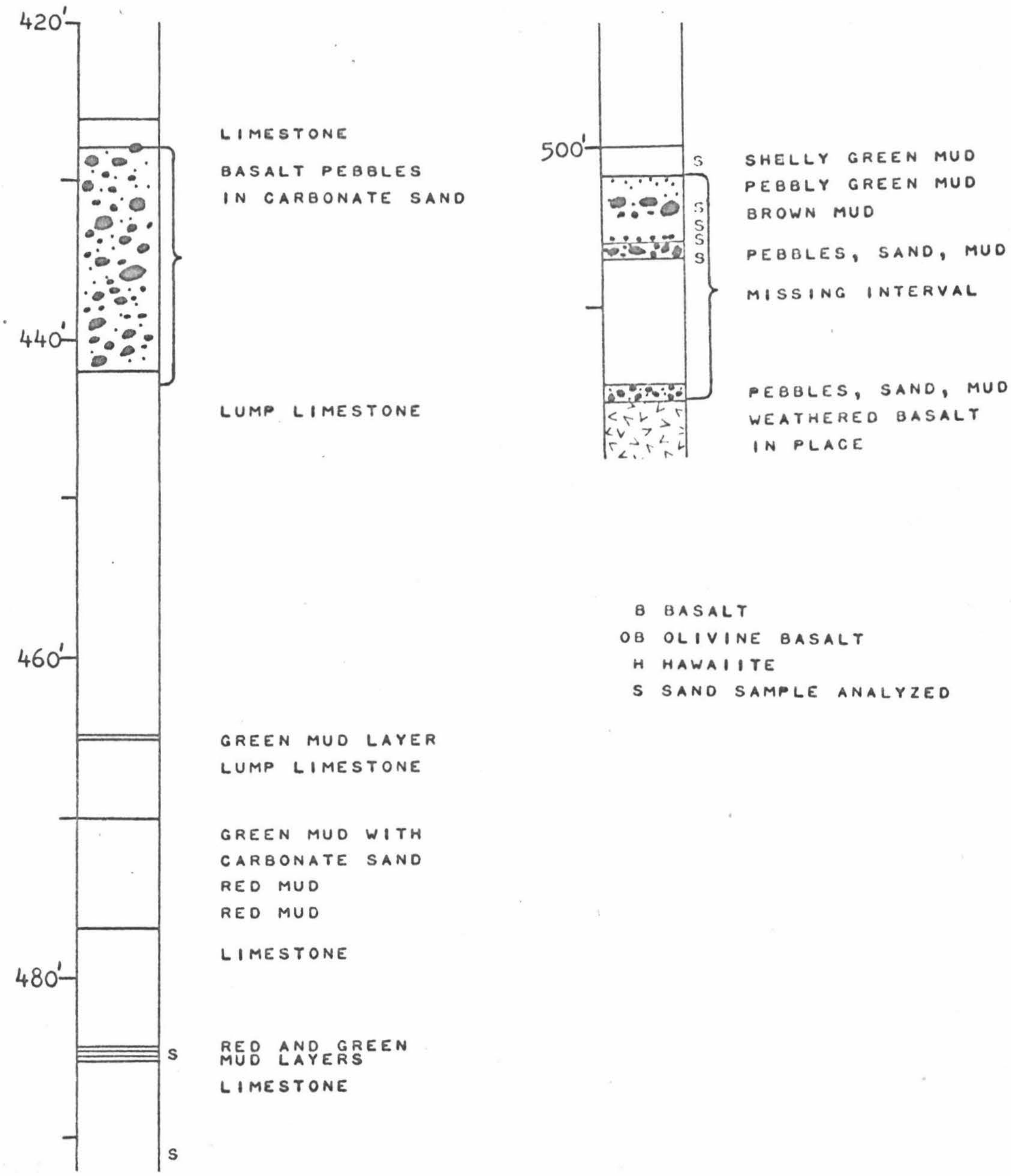

FIGURE 4: GENERAL DESCRIPTION OF THE TERRIGENOUS SECTION OF THE MIDWAY SAND ISLAND CORE

Brackets mark portions of core described in detail in fig. 7.

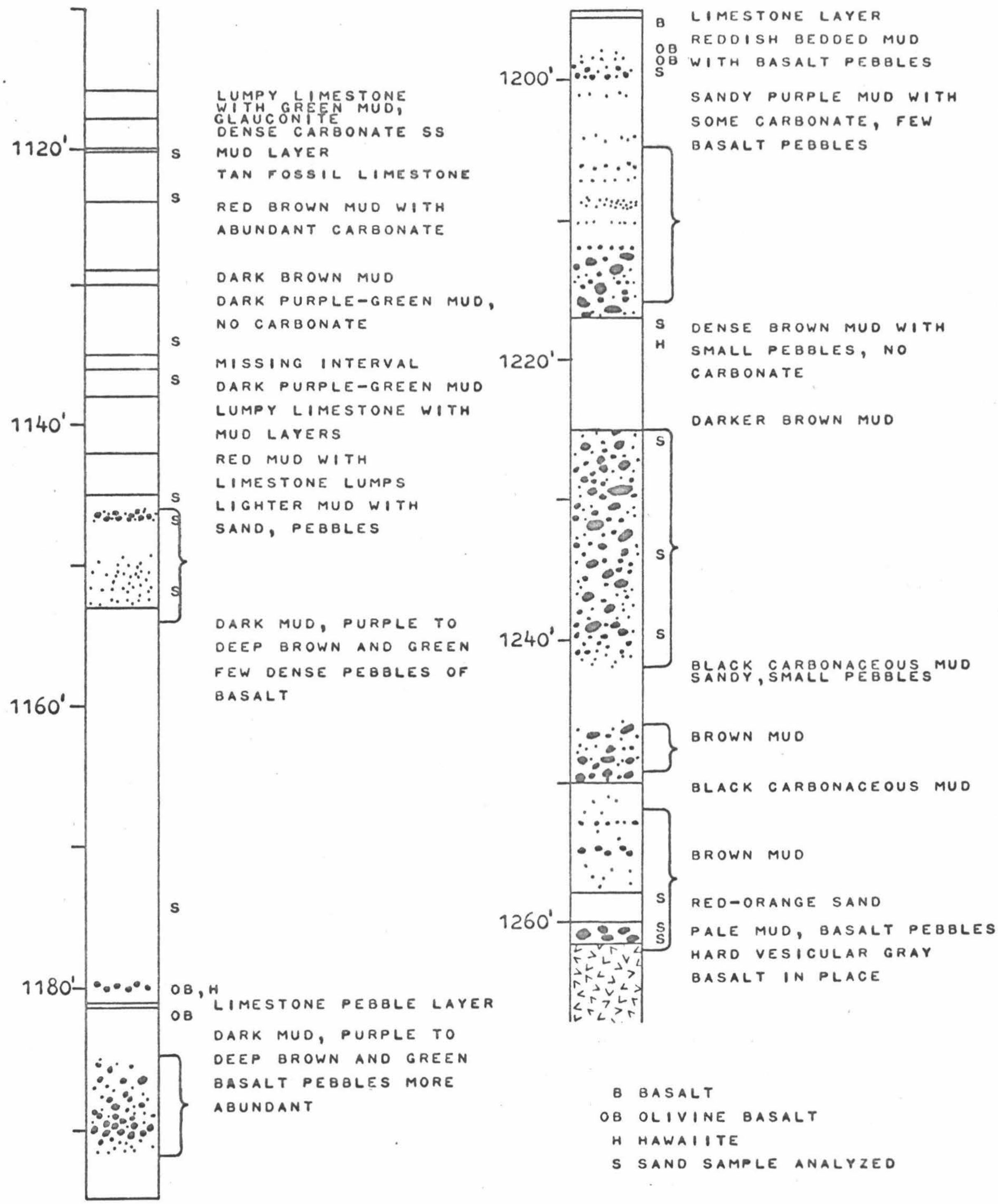

FIGURE 5: GENERAL DESCRIPTION OF THE TERRIGENOUS SECTION

OF THE MIDWAY REEF CORE

Brackets mark portions of core described in detail in fig. 8.

core, mud layers show a variation in color from brown at the bottom to green (with carbonate) at the top, indicating inundation and a change from oxidizing to reducing conditions. The only sediments rich in organic matter, those near the bottom of the Reef core, are probably tidal swamp deposits formed at the inner margins of a lagoon. Their association with coarse conglomerates suggest their proximity to the shore of that time.

STUDY OF BASALT PEBBLES

The basalt pebbles are concentrated in zones in the cores. Pebbles are without exception rounded and usually are found in a matrix of terrigenous sandy muds. The poor sorting suggest stream, rather than marine, transportation and deposition. They are also all altered chemically. Their state of preservation varies widely, from one pebble in which unaltered olivine is found, to pebbles so badly weathered that they can be crushed in the hand.

The layers where basalt pebbles are concentrated were studied statistically in an attempt to disclose their variation in size, abundance, and preservation. For this study, a sampling grid was used which provided 60 regularly spaced sampling points for every foot of core. The points were arranged in rows of five spaced at half inch intervals across the core, the rows being spaced one inch apart along the core. Each point was then identified as mud, carbonate, void, or basalt pebble. In addition, the long axis dimension and hardness of each pebble was measured. Hardness was used as a measure of preservation and was determined by means of a home-made penetrometer calibrated in pounds but not to any standard. Standardization is not necessary, as the measurement is used only to provide relative values for rating preservation.

The data of the point counts are summarized in Figures 7 and 8 along with some other data gathered during the investigation. Figure 6 explains the form in which the data are presented. Average pebble long axes were calculated by weighting each pebble equally. Preservation and abundances of different lithologies were calculated from the point counts.

The data show that different layers of pebbles do differ from one another, though not a great deal. The internal variation of the layers is large.

Pebbles were selected for thin section study with two criteria in mind: that they should be distributed over the entire terrigenous section of both cores, and that they should be well enough preserved to allow thin sectioning without elaborate preparation. The statistical study of the core indicates that the second consideration will have a considerable effect on the chances of obtaining the desired spread of the samples. If, however, it is assumed that all the layers are homogenous with respect to the composition of the pebbles, then a representative sample of the entire core can be obtained while only the better preserved layers are sampled. A total of 77 pebbles was selected, and 126 thin sections made of them.

The pebbles, even though preserved well enough to be thin sectioned without difficulty, all show alteration under the microscope. Olivine is entirely replaced by secondary

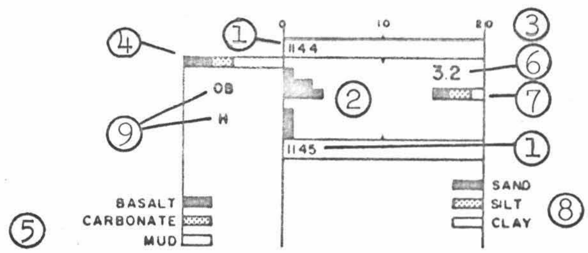

FIGURE 6: EXPLANATION OF THE PRESENTATION OF CORE DATA

The depths of the core in feet are indicated by the numbers at ①. The data displayed between two depths has been collected over the interval between those depths except for pebble identities and sand-silt-clay analyses. Hardness (preservation) of the pebbles in the core is displayed by the histogram at ② which is in eight parts from soft at the top to hard at the bottom. The number of points counted in making the histogram are shown by the scale at ③. A bar graph showing percentages of different lithologies is at ④, and the lithologies are identified at ⑤. The number at ⑥ is the average pebble long axis in centimeters. The bar graph at ⑦ displays the results of a sand-silt-clay analysis, and is at the approximate depth that the sample was taken from. The sediment sizes are indicated at ⑧. Rock identities are shown at the level from which the pebbles came, as at ⑨. The abbreviations are: OB, olivine basalt; M, mugearite; H, hawaiite; B, basalt; O, oceanite; T, tachylite; MM, mixed magma rock.

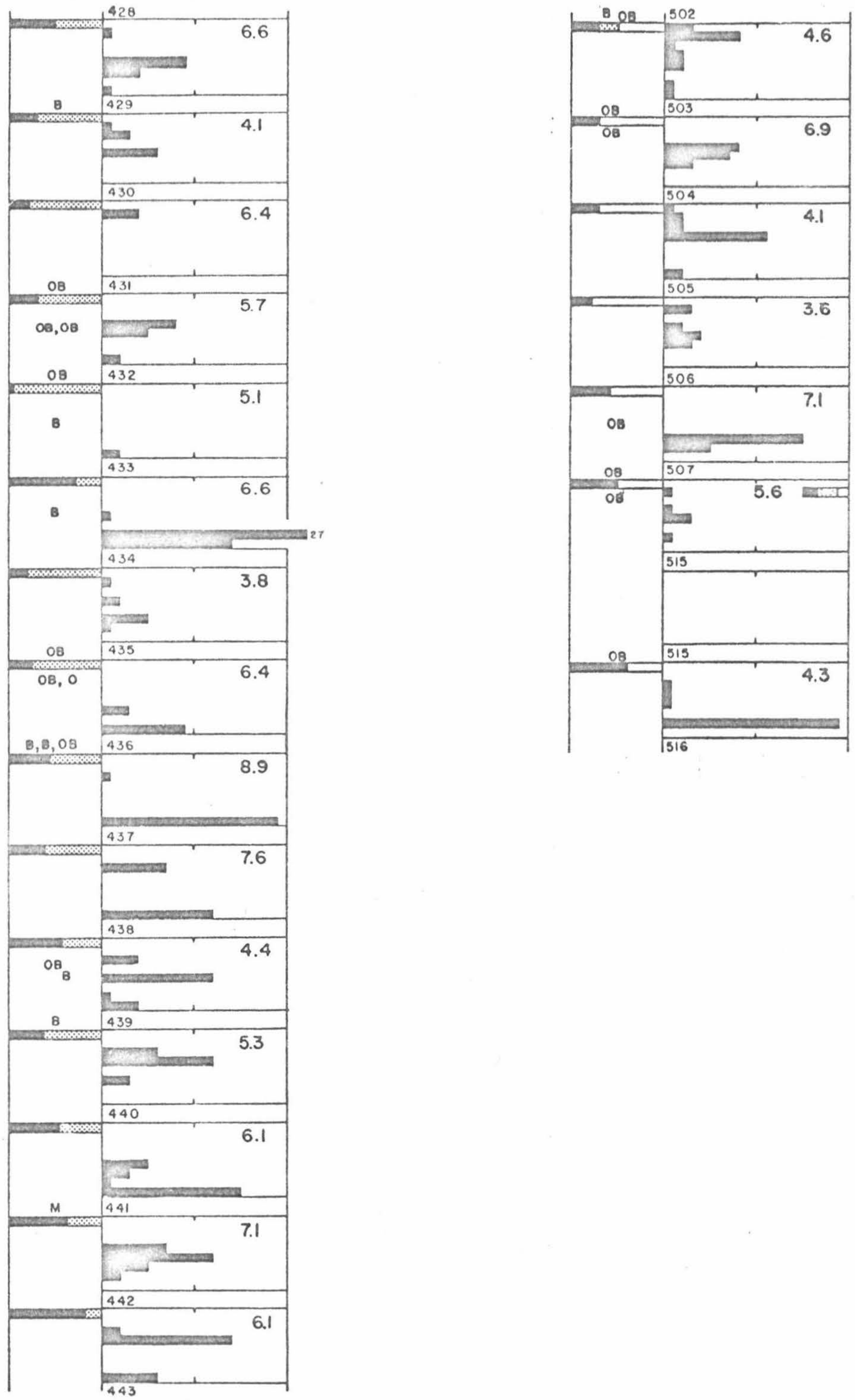

FIGURE 7: CORE DATA: SAND ISLAND CORE

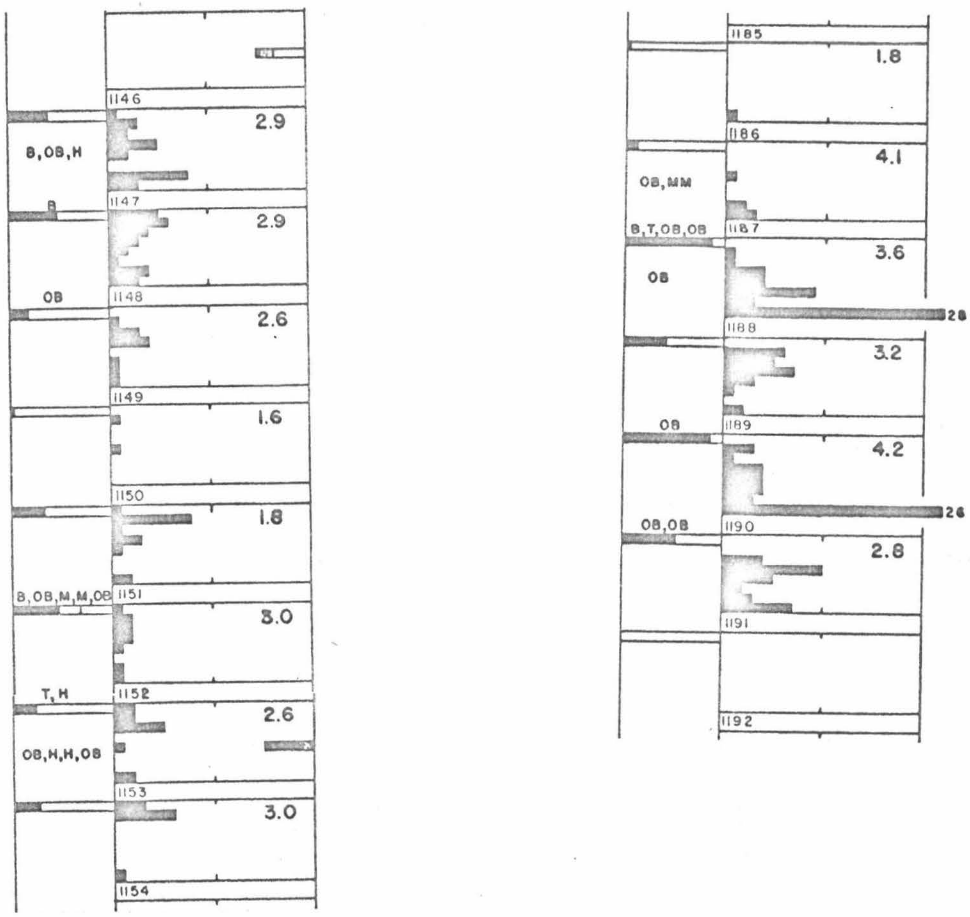

FIGURE 8: CORE DATA: REEF CORE

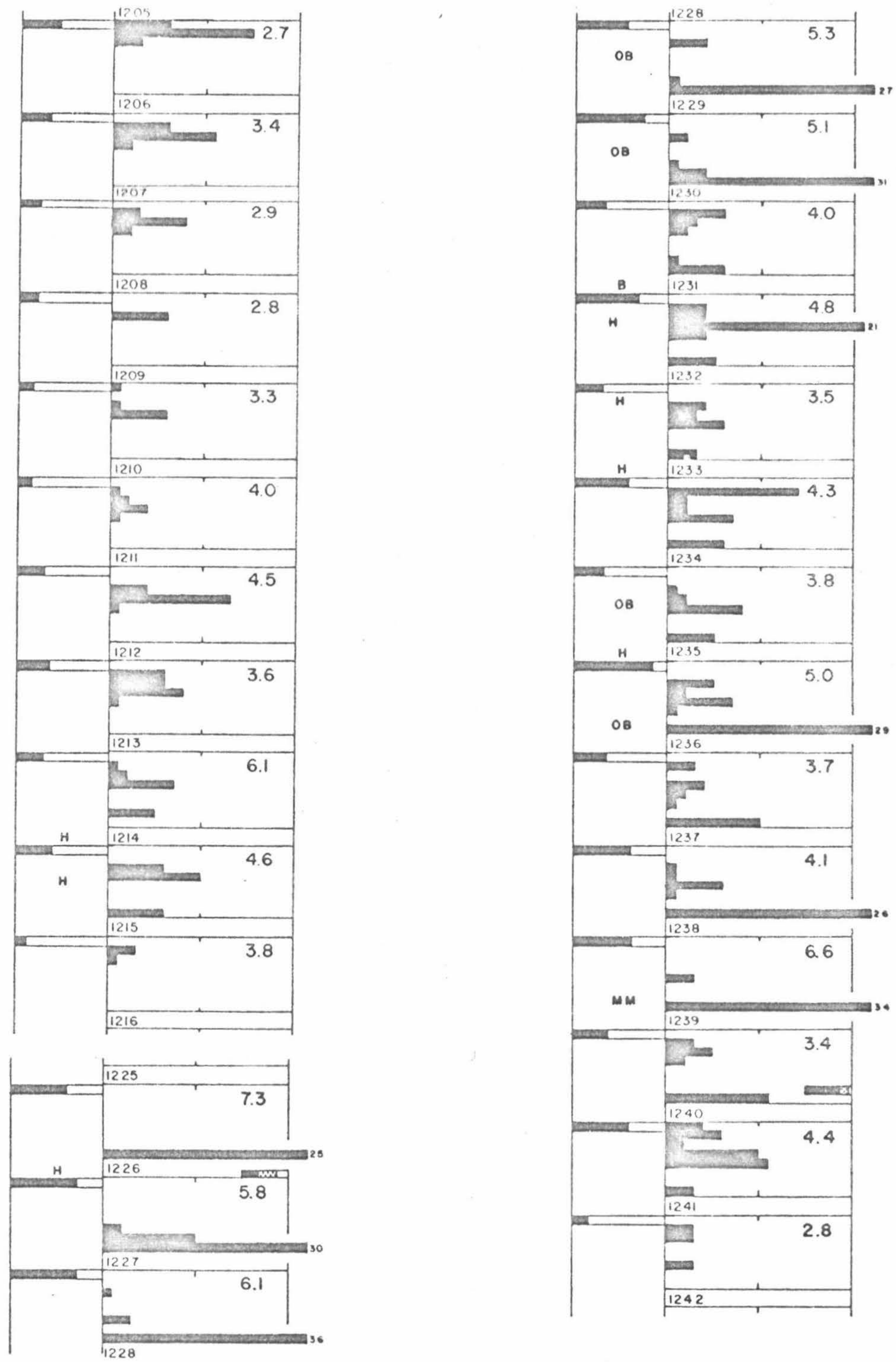

FIGURE 8 (CONTINUED): CORE DATA: REEF CORE

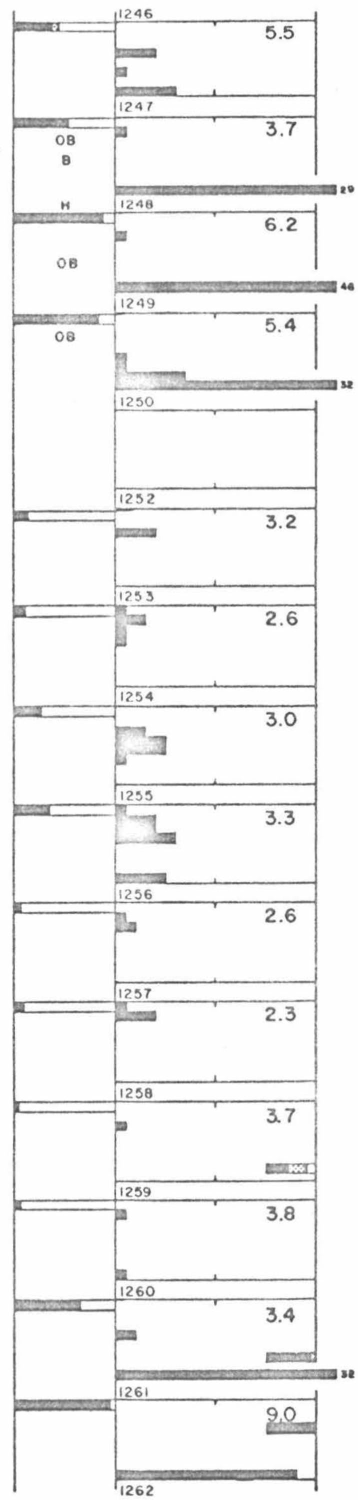

FIGURE 8 (CONTINUED): CORE DATA: REEF CORE

minerals in all the pebbles but one. Feldspars usually show some alteration to pale-colored opaque material, probably clay. Pyroxene, on the other hand, except for some doubtful cases, shows no alteration at all.

The feldspar compositions of the rocks were determined by three methods. Groundmass feldspars were identified by the microlite extinction method. Where feldspar phenocrysts were present in the rock, samples were crushed and the intermediate index of refraction determined in oils. In special cases, Rittmann's universal stage method for plagioclases was used (Emmons, 1943, chap. 7). In a thin section where all three methods were used, agreement on composition was good, the three values falling within a 10 percent variation in albite content. Most feldspars were in the sodic labradorite range, Ab50-40, but the total variation was from Ab89 to Ab27.

Pyroxenes, where they were large enough for their properties to be determined, all showed axial angles from 40 to 50 degrees, indicating that they are augite. Pigeonite was not recognized in any of the slides.

The identification of rock types was made according to the table by Macdonald (1949), modified by the author (Table 1) to be in accord with present terminology (Macdonald, 1960). The original abundances of minerals were reconstructed by designating obvious secondary replacements as the original primary minerals and ignoring all other secondary or obscure

TABLE I: ROCK IDENTIFICATION BY MODE
(Macdonald, 1949; modified according to Macdonald, 1960)

Minerals	Olivine Basalt (OB)	Basalt (B)	Oceanite (O)	Hawaiite (H)	Mugearite (M)
Phenocrysts:					
Plagioclase Comp.	Ab20-30	Ab20-50	Ab20-45	Ab20-70	Ab45-80
Plagioclase %	0-25	0-20	0-5	0-15	0-5
Augite %	0-15	0-3	0-5	0-1	----
Olivine %	0-20	0-3	20-50	0-8	0-5
Groundmass:					
Plagioclase Comp.	Ab35-50	Ab35-50	Ab30-45	Ab50-70	Ab70-85
Plagioclase %	25-45	30-50	20-30	40-55	50-60
Pyroxene %	25-45	30-50	20-35	20-40	15-30
Olivine %	1-15	0-3	1-5	1-10	1-8
Ore %	7-15	7-15	5-15	7-20	8-25

material. Consequently, iddingsite was counted as olivine where it appeared as grains, and ignored where it filled cracks. The estimations provided the relative abundances necessary to identify the rocks according to Macdonald's classification.

The most common type of rock in the cores is olivine basalt. The abundance of the various types of rocks is shown in Table 2. The unusual varieties of rocks found in the cores are discussed below.

The general distribution of rock types is reasonably uniform throughout the cores, except in two cases which run counter to the assumption of homogeneity made in collecting the samples. Hawaiites are found exclusively in the Reef core where they make up 27 percent of the rocks sampled. They are also concentrated at certain levels: four samples around 1150 feet, four from 1214 to 1225 feet, and four more from 1230 to 1235 feet.

Phenocrysts of pyroxene are never present as more than 5 percent of any rock, and of the 13 samples that contain them in greater than trace amounts, 11 are found among the top 18 sampled pebbles of the Sand Island core, all above 441 feet. All the pebbles in that interval are basalt or olivine basalt, except for one each of mugearite and oceanite. This concentration suggests that the final material eroded from the volcano was different from that eroded earlier, and may have come from late eruptions that were richer in

TABLE II: ROCK TYPES FOUND IN THE TWO MIDWAY CORES
(Rock names are abbreviated as shown in Table I, with the addition of: MM, mixed magma rock; and T, tachylite)

		OB	B	O	H	M	MM	T
Reef Core:	Number	24	7	0	14	2	2	2
	Percent	46	13	0	27	4	4	4
Sand Island Core:	Number	15	8	1	0	1	0	0
	Percent	60	32	4	0	4	0	0
Total:	Number	39	15	1	14	3	2	2
	Percent	51	20	1.3	18	4	2.6	2.6

pyroxene phenocrysts.

During the course of the thin section study a few specimens were found that differed from the majority of the samples. One was the single pebble which contained unaltered olivine. Two others had solidified as glass with phenocrysts, and two more contain quartz.

The olivine-bearing pebble, S435.3B, was designated an oceanite because of the abundance of its olivine phenocrysts. The phenocrysts are all heavily rimmed or replaced by magnetite dust. Augite phenocrysts are rounded, fresh, and unaltered. The feldspar is a sodic to intermediate labradorite. The alteration of the olivine is unusual in that most of the other thin sections show olivine altered to iddingsite or green secondary minerals, without any magnetite dust.

The samples that appear to have been largely glass are badly altered. R1152A contains many tiny phenocrysts of feldspar. R1187B also contains tiny phenocrysts, largely iddingsite after olivine, with small amounts of feldspar and pyroxene. The groundmass of both samples is so featureless and opaque that it is assumed that it was originally a tachylite glass which has been devitrified, its opacity due to large amounts of opaque minerals, which could be either of primary or secondary origin.

The most unusual rocks of all are the two samples which contain quartz. They are quite similar, as can be seen from the point counts (Table 3). The quartz is present as clear, irregularly shaped embayed grains surrounded by coronas of pyroxene (see Figs. 9, 10, 11). They make up, on the average, 0.6 per cent of the rock. In addition to the quartz, approximately ten per cent of the rock is made up of feldspars with reversed zoning. The largest phenocrysts were examined with the universal stage. These grains have a core of oligoclase or andesine (Ab58 to 76) which are sometimes normally zoned, as a core which had a composition of Ab58 at its center and Ab65 at its edge. Surrounding the core is a body which is "honeycombed" or "motheaten," which is in turn surrounded by a calcic rim which has the composition of the groundmass feldspar (see Figs. 11, 12). The composition of the groundmass feldspar was measured as Ab38-42 by the microlite method and Ab45-50 by the Rittmann zone method for the universal stage and by measurement in oils.

This rock apparently represents a basalt solidified in the process of assimilating a sizeable amount of oversaturated rock. The source for such a rock is difficult to find in the Hawaiian petrographic province, but presumably a sufficiently long and complete differentiation of a basaltic magma can give rise to such material. Macdonald (1944) describes quartz trachytes from Samoa which contain up to ten per cent quartz and oligoclase feldspar, and are similar to the rocks postulated here. The quartz-containing rocks were probably created when a primitive basaltic magma came

TABLE III: MODES OF MIXED MAGMA ROCKS IN MIDWAY CORES

Sample Number	Phenocrysts			Groundmass			
	feldspar	pyroxene	quartz	feldspar	pyroxene	olivine	ore
R1186.5B	6.3	----	0.4	63.1	11.8	5.4	12.8
R1238.8	5.4	----	0.8	55.1	17.2	----	22.5

FIGURE 9: Photomicrograph of quartz grains with a pyroxene corona, sample R1238.8. The lower grain is 0.25 millimeters long.

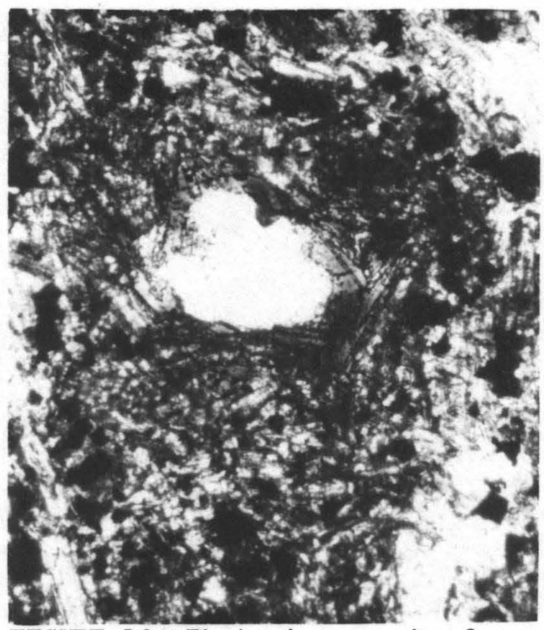

FIGURE 10: Photomicrograph of a quartz grain with a pyroxene corona, sample R1238.8. The grain is 0.10 millimeters long.

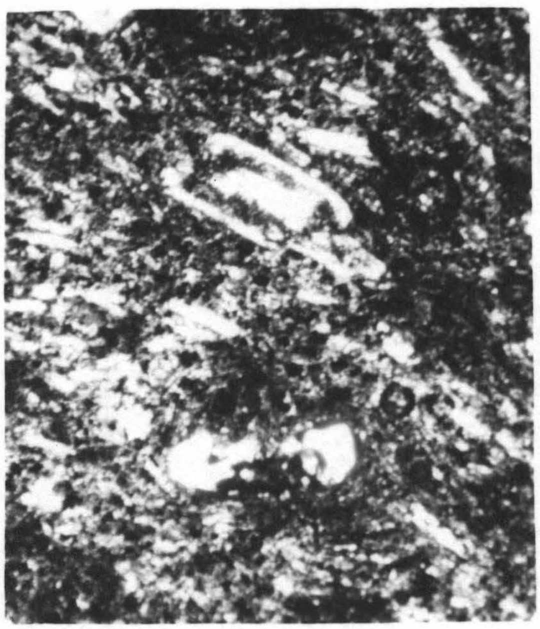

FIGURE 11: Photomicrograph of a rimmed feldspar and quartz grains, sample R1238.8. The feldspar is 0.75 millimeters long.

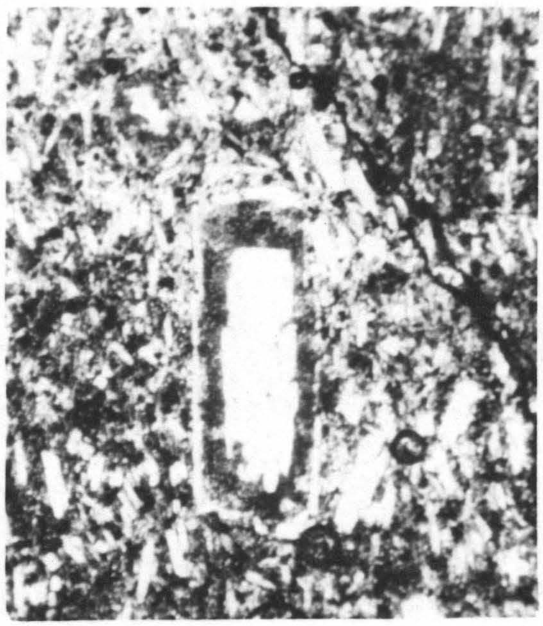

FIGURE 12: Photomicrograph of a large rimmed feldspar from sample R1186.5B showing core, body, and rim. It is 1.5 millimeters long.

in contact with a highly differentiated earlier basaltic magma as the primitive magma made its way to the surface or as it erupted. The new primitive magma incorporated some of the differentiated magma which was largely crystallized. Before the reaction between magma and xenocrysts had completely changed quartz to pyroxene and plagioclase from a sodic to a calcic variety, the magma was extruded and solidified. The rocks, then, had their origin in mixed magmas.

Rocks of both the Tholeiitic and Alkalic Basalt Suites exist in the Midway Volcano, as they do in the southeastern Hawaiian Islands (Macdonald and Katsura, 1962, 1964). The mugearites and hawaiites fall in the alkalic variation trend (Macdonald and Katsura, 1964). The olivine basalts and basalts are more difficult to distinguish in thin section. The best distinction, that of chemical analysis, would be invalid for all the Midway rocks because of their alteration. The presence of biotite (Macdonald, personal communication) and lack of pigeonite (Kuno, _et al_., 1957) in a basalt would suggest that it is alkalic. Some of the basalts contain as much as one or two percent biotite, which would require more potassium than is present in tholeiitic rocks. The general absence of pigeonite noted earlier may be due to its fine grain size preventing identification, or may be due to alkaline suite basalts. The basalt in place in the bottom of the holes was examined by Macdonald (in press) who, with the aid of a chemical analysis, concluded that it was tholeiitic.

This similarity between the Midway volcano and the other islands of the Hawaiian chain is not unexpected, as they have been considered as part of the same petrographic province. The abundance of alkalic rocks among the pebbles studied is probably due to the fact that alkalic rocks are the last to be erupted and the first to be removed by erosion. The cores appear to be sampling material which has largely come from the erosion of the alkalic cap of the volcano. Whether the Midway volcano was "Kohala" or "Haleakala" type (Macdonald and Katsura, 1962) is uncertain. Mugearites are characteristic of the "Kohala" type, hawaiites of the "Haleakala" type, and the types are supposed to be quite distinct (Macdonald, 1949, Macdonald and Katsura, 1962, 1964). If the small sample obtained is a good indication, the hawaiites are more than four times as abundant as the mugearites, and would seem to indicate that the volcano is of "Haleakala" type (see Table 2).

STUDY OF SAND SAMPLES

Sand size material is present in all of the samples taken for study. Material larger than 2 millimeters is often present, but was generally avoided in getting these samples, as it is more important to the pebble study.

At intervals along the cores samples were taken for size and mineral analysis in conjunction with the thin section study. The mineral analysis was undertaken with the idea that variations in mineral species or their abundance through the cores would give additional evidence of the erosional and eruptive history of the Midway volcano or the climate at that time. The mineral analysis showed no variations in mineral species or relative abundance and provided little of the information hoped for. Consequently, only 24 samples were processed completely and their sand fractions examined in oil mounts. Twenty-one of these samples were subjected to sand-silt-clay size analysis, the results of which are displayed in Figure 13.

Duplicate samples, weighing from 10 to 26 grams, averaging 16 grams, for sand-silt-clay analysis were soaked overnight in distilled water and then disaggregated by stirring for ten minutes in a Hamilton Beach blender without any dispersing agent. They were then washed through a 2 millimeter and a 61 micron sieve and the coarse and sand fractions saved and dried. The material passing the 61

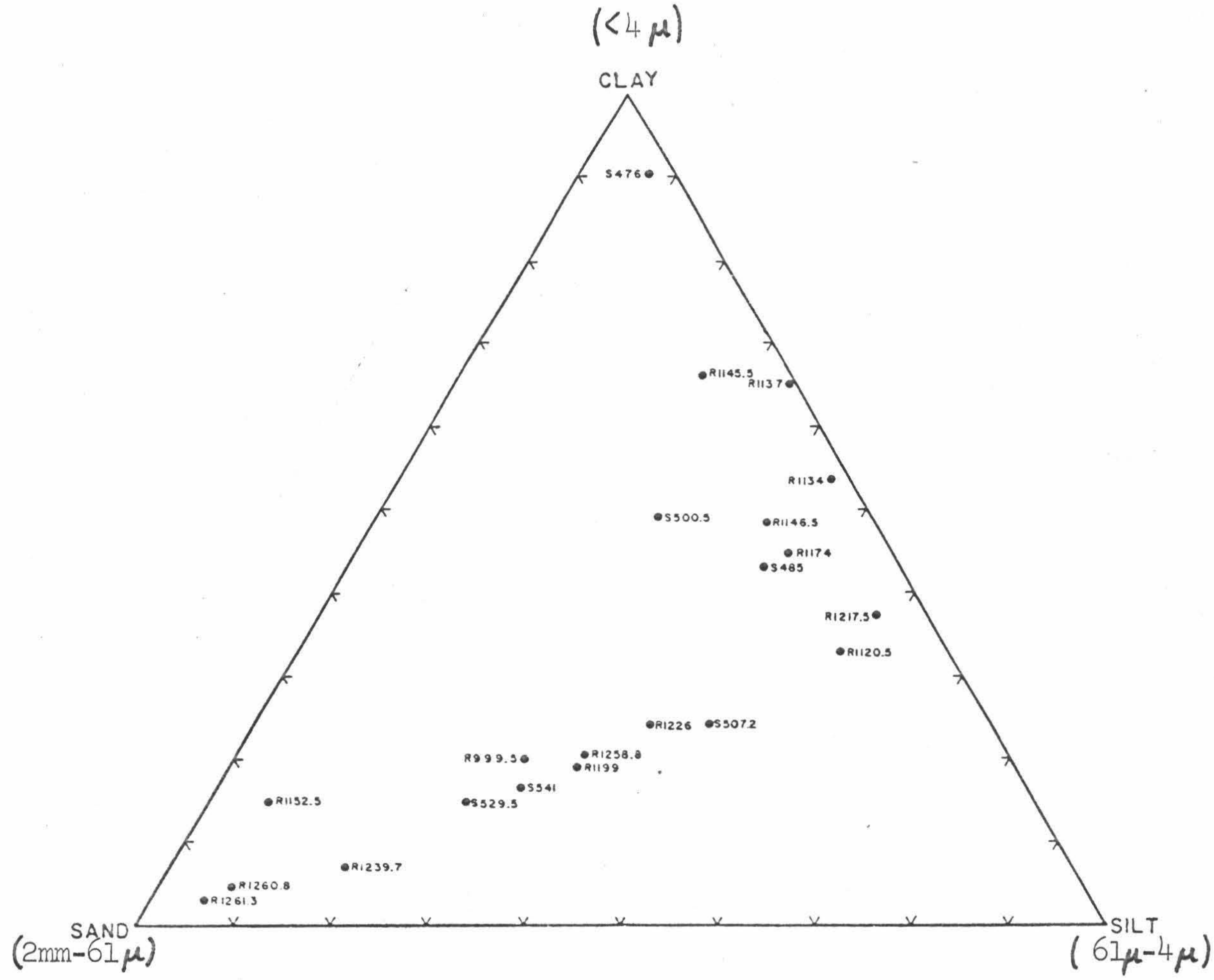

FIGURE 13: SAND-SILT-CLAY COMPOSITION OF MUDS FROM THE MIDWAY CORES

micron sieve was transferred to 1000 milliliter graduated cylinders, the volume being reduced as necessary by centrifugation. The samples were then washed by centrifugation and decantation with distilled water until they showed no flocculation after standing for 24 hours. The samples were then subjected to an abbreviated pipette analysis to determine the amount of silt and clay.

The samples for sand study were washed and disaggregated by soaking in distilled water overnight followed by stirring with one gram of Calgon for 5 minutes in a Hamilton Beach blender. The sample was then washed into an 800 milliliter beaker, filled with water and allowed to stand for one minute (a 64 micron particle sinks 20 centimeters in 58 seconds) and then decanted. It was refilled, and the decantation repeated. The sample was then washed into a small beaker and again allowed to stand in water overnight. On the following day the same process was repeated, and the sample dried and stored.

The cleaned samples were wet sieved in a "Pulvurit" shaker after the fraction larger than 2 millimeters had been removed. The sand fraction was divided into four parts for study: 2-.351 millimeters, .351-.246 millimeters, .246-.124 millimeters, and .124-.061 millimeters. In addition, the runoff carrying the fines was caught in a container and the surplus allowed to overflow, leaving some of the coarser silt size material which was also collected.

The sand fractions studied all consist of two distinct portions, one of marine organic or inorganic origin, the other detrital, derived from the weathering and erosion of the Midway volcanic terrain. The relative abundances of these two portions in any sample is dependant upon the level within the studied sections the sample came from. The marine component is more abundant at higher levels in the cores.

The marine material is almost entirely carbonate, though in a few samples glauconite is present. The carbonate material is in the form of small rhombic crystals and translucent crystal masses of inorganic origin, and a variety of foraminiferal tests and other fossils.

The material derived from the volcanic rocks is very angular and contains a large amount of lithic fragments, both indicating little transport of the material before deposition. The other part of the sample, usually very much smaller than the lithic fragments, consists of mineral grains. Secondary and replacement minerals observed in the thin sections are more common than primary minerals. There is almost always a very limited number of mineral species found, and they all have wide distribution in the cores. The species are: Opaques: black, shiny metallic ore minerals and pale colored clay minerals; Translucent: clay minerals and other secondary products, the yellow to green serpentine (?) and red to brown iddingsite; Transparent: serpentine (?), iddingsite, and feldspar. Less common, with a narrower distribution, are augite and quartz. In addition, a few other minerals have been noted which are rare and have not been identified.

Hand picking of some distinctive mineral types from the sands has provided reasonably pure samples which were prepared for study for x-ray diffraction and other methods. The clear glass-like grains picked from sample R1152.5 give an x-ray pattern which agree well with patterns obtained for several Hawaiian plagioclases by R. Grunwald (personal communication). The method described by Peterson and Goldberg (1962) indicated that the composition is in the range of volcanic (high temperature) oligoclase to labradorite. Examination of index of refraction in oils confirms the identity as plagioclase, a calcic oligoclase, Ab_{71}.

The .124-.061 millimeter fraction of sample R1239.7, after treatment with 1:3 hydrochloric acid, was picked for opaque white to pale pink subrounded grains. X-ray diffraction examination produced a single broad peak centered on a d-spacing value of 14.7 angstroms. This d-spacing, combined with the observation that a great proportion of the muds of the cores swell considerably when immersed in water, suggests that montmorillonite group clays are abundant in the terrigenous cores as products of basalt weathering, and that some are forming into sand size particles. As clay mineralogy is properly the study of another researcher, this fraction was not studied any further.

Examination of the black metallic to submetallic grains of samples S500.5 and R1145.5 led to the division of this fraction into three more or less distinct groups. The first consists of shiny metallic grains, often tabular, always irregular, nonmagnetic to a magnetized needle, identified as ilmenite. The second, small black octahedral crystals which are nonmagnetic to a magnetized needle, tentatively identified as a chromium-bearing spinel. The third is made up of irregular, often pitted and dull grains which are magnetic and probably magnetite. From a visual examination of the samples during picking, it is estimated that the three minerals are present in these approximate amounts: ilmenite: 70 per cent; chromian spinel, 20 per cent; magnetite, less than 10 per cent.

The chemical test described by Dinnin (1961) to distinguish between ilmenite, magnetite, and chromite failed to give any results. X-ray diffraction of a crushed whole sample from S500.5 indicates that all three may be present. The difficulty in this case lies in the virtually identical crystal lattice parameters for magnetite and chromite, both of which are spinels. To overcome this difficulty, an x-ray fluorescence examination for chromium was made of the same sample, and gave positive results.

Chromium is found in the rocks throughout the Pacific area, in abundance generally greater than the world average (Hough, _et_ _al_., 1941; Nakamura and Sherman, 1958; Goldschmidt, 1958; Walker, 1964) and in Hawaii has been shown to be concentrated in the soil by weathering (Nakamura and Sherman, 1958). The presence of chromium in the sample, then, is not unusual. It apparently represents a lag concentration of heavy, resistant minerals. Goldschmidt (1958) states that chromium is concentrated in the early crystallized phase of cooling melts, and that in basalts, it is much more likely to form chromian spinel than chromite. This assertion, based on theoretical considerations, has been confirmed by Evans and Moore (1968) who have identified chrome spinels in Hawaiian olivine crystals by microprobe analysis. It is likely, then, that the octahedral nonmagnetic crystals are chrome spinel which has been concentrated either in a soil horizon or as a lag deposit.

The samples taken at R1145.5, R1146.5, and R1152.5 are different from the rest of the samples in that they contain numerous smooth, shiny, hard concretions or nodules in the coarser fractions. Their color varies from light to very dark brown. They are especially large, up to a centimeter across, and abundant in R1145.5. The nodules are found in dark brown mud with small amounts of carbonate material and small pieces of saprolite. Where the nodules are broken, they commonly show concentric layering around a core of material that resembles saprolite.

The generally accepted explanation for the origin of such nodules is by soil forming processes in humid tropical environments (Sherman, et al., 1967). Weathering of basalt terrains under these conditions results in the removal of silica in solution and the mobilization of aluminum hydroxides, and also iron hydroxides to a lesser extent. These hydroxides are redeposited in an amorphous form around lumps of saprolite in soil. The amorphous hydroxides crystallize upon dehydration, primarily to gibbsite and goethite. The nodules from R1145.5 were sampled and x-rayed. The diffraction data showed no peaks whatsoever, suggesting that the material has a very low crystallinity.

The general section of the core that the samples are from shows, on close examination, variable layers of brown and red brown mud, with a few large basalt pebbles and some coarse and fine carbonate material. Pipette analyses of samples R1145.5 and R1146.5 showed 66.2 and 48.3 percent of clay respectively. These two samples contained a great amount of very fine clay-size material which was moderate reddish brown in color. This was not seen in the other samples which contained large amounts of clay-size material, where the clay was apparently coarser.

The data suggest that this level in the core is a buried soil. But the lack of gross soil structures or horizons and the consistent admixture of some carbonate material indicate that the soil is not undisturbed.

It is probable that the soil has been slightly reworked in a marine environment, and that there has been little transport because the delicate pieces of saprolite have survived the process.

SUMMARY AND CONCLUSIONS

The Midway Islands are an atoll built upon a volcano which was once elevated above sea level and has since submerged. The findings of the research reported in this thesis can be summarized in a few sentences: The volcano was above sea level for a period long enough for soils to form and plant life to establish itself. The subaerial erosion of the volcano took place under essentially uniform humid tropical climatic conditions. The volcano is of the Hawaiian petrographic province and has rocks of both the tholeiitic and alkalic basalt suites. The volcano is probably of the "Haleakala" type, and possesses a rock type resulting from the mixing of primitive and highly differentiated basaltic magmas, which has not been met with before in the Hawaiian petrographic province.

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