1. INTRODUCTION

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BACKGROUND

The second planned attempt at deep penetration of the igneous section of the oceanic crust took place during Leg 37 of the Deep Sea Drilling Project. A previous unsuccessful attempt occurred on Leg 34. On Leg 37 we penetrated successfully the upper part of the oceanic crust on the western flank of the FAMOUS (Franco-American Mid-Ocean Undersea Study) area of the Mid-Atlantic Ridge at 36°N. Detailed investigations of the Median Valley some 30 km to the east were carried out concurrently by surface ships and three manned submersibles (*Alvin, Archimede,* and *Cyana*).

The main purpose of Leg 37 was to investigate the petrological and geophysical nature of oceanic layer 2. This 1.5-km thick layer, which underlies the floor of most of the world's oceans, is thought to be generated at crustal spreading centers, and to hold evidence for the origin of oceanic magnetic anomalies, for crustal and mantle evolution, and perhaps, for the origin of some types of ore deposits.

Leg 37 grew out of interest expressed by the Igneous and Metamorphic Petrology Panel of JOIDES for deeper penetration into the oceanic crust, and out of a specific proposal to the JOIDES Atlantic Advisory Panel by the Dalhousie University/Bedford Institute group to drill a deep hole in the area of the HUDSON Geotraverse, on the Mid-Atlantic Ridge at 45°N. This proposal was accepted in principle, and Leg 37 was assigned to the deep penetration experiment. On subsequent evaluation of the climatic expectations at 45°N, the Atlantic Advisory Panel proposed to change the drilling site to the more favorable weather zone of the Mid-Atlantic Ridge at 36°N, where FAMOUS submersible and surface ship investigations were well underway, anticipating that a considerable body of knowledge, comparable to that at 45°N, would be available by the summer of 1974. The latter is crucial to any deep penetration experiment, since it is of the utmost importance to be able to correlate deep drilling data with that obtained by detailed, but more conventional techniques.

Thanks to the concentrated efforts of the research vessels *Hudson, Discovery* II, and *Jean Charcot,* which together extended the FAMOUS survey area westward to cover the prime drilling site with detailed bathymetric and magnetic surveys, seismic reflection and refraction profiles and dredging, coring, and heat-flow measurements, *Glomar Challenger* sailed from Rio de Janeiro with sufficiently detailed information on the drilling site and its setting to permit a direct approach to a specific site within a 3-km-wide valley, called DEEP DRILL VALLEY, at 36°52'N, 33°39'W, about 30 km west of the Median Valley, that is, in a geologically very young part of the American plate.

CRUISE OBJECTIVES

The prime objective for Leg 37 was the deep penetration of at least the upper part of the igneous section of the oceanic crust. With such penetration and its associated core recovery, we hoped to answer many of the problems associated with mid-oceanic ridges which are still outstanding, including the following:

1) The problem of the separation of the material now constituting layer 2, from layer 3 and, indirectly, the nature of the upper mantle beneath oceanic rises and other spreading centers (Green, 1971). This problem can be approached when a detailed knowledge of the petrology and major, minor, and trace element geochemistry of the layer is available. Before the cruise we knew some of the rock types contributing to the layers but not their relative proportions, representative average compositions, or within-layer variation ranges. A single section through the layers has provided sufficient information to start on this problem.

2) The construction of layer 2. This problem can be tackled from the results of careful macroscopic studies of the cores. It was hoped to determine the relative contributions of sediments and igneous materials, and more difficultly, of intrusives and extrusives. Paleontological, paleomagnetic, and geochronological data provide constraints on the time required to build up layer 2, and hence whether it forms entirely within the Median Valley, or whether off-ridge volcanism plays a substantial role.

3) Changes during the evolutionary history of layer 2. A complete attack on this problem needs information from several drill holes and from the submersible work on the axis of the ridge. Dredging and heat-flow measurements have already provided hints that temperature gradients in excess of 100°C/km commonly exist in layer 2 close to the ridge axes, with concommitant extensive early metamorphism of the constituents of that layer (Melson et al., 1968; Aumento et al., 1971; Aumento et al., 1974).

4) The existence, nature, and thickness of the postulated highly magnetized layer 2A. This information can be obtained from a combined magnetic and

petrological study of a number of sections through layer 2.

5) Constitution of submarine basalt lava flows. The proportion of pillows to massive basalt can be obtained from a macroscopic study of flows. The internal, chemical, mineralogical, and magnetic variations within flows can be obtained by the means already described.

6) Heat flow and heat production in layer 2. This can be determined by in-hole temperature measurements and laboratory thermal conductivity measurements of the core. It was thought possible to determine whether or not the observed low heat-flow values arise from hydrothermal circulation. Heat production in layer 2 can be estimated from laboratory measurements on the core.

7) The possibility that processes occur in layer 2 that result in the concentration of economic minerals such as sulfides. This can be tested by macroscopic examination of the core, ore mineral determinations, and geochemical investigations.

8) The nature, provenance, and state of alteration of any sediment intercalated in the igneous rocks of layer 2.

The prime goal of Leg 37 was achieved at Site 332 with a penetration of 583 meters into acoustic basement. Site 333 was a second, but unsuccessful, attempt at deep penetration in the same sediment pond in which Site 332 is located. Sites 334 and 335 were single bit holes drilled along a sea-floor spreading flow line passing through Sites 332 and 333 (Figure 1).

GEOLOGY OF THE FAMOUS AREA

Regional Studies

A number of research vessels, including the *Knorr, Atlantis* II, *Discovery* II, *Hayes*, *Jean Charcot*, and *Hudson*, have contributed to our knowledge of the area termed FAMOUS between 36° and 37°N straddling the axis of the Mid-Atlantic Ridge. Information has come from conventional survey and sampling techniques, as well as from more sophisticated techniques involving acoustic navigation, submersibles, deep towed bodies, long-range side scanning sonar (GLORIA), bottom seismographs, multiple narrow beam echo sounders, and LIBEC photomosaics. Most of the investigations were concentrated within the Median Valley itself, but the surrounding ocean floor has also undergone considerable study.

The whole area is one of intense fracturing, both by block faults parallel to the spreading axis, and transverse to it along both major and minor fracture zones (see Figure 1). The Median Valley is offset just south of 37°N by a major fracture (Fracture Zone A) and by Fracture Zone B at 36°30′N. Both fractures have westward offsets to the south on the order of tens of kilometers, and detailed investigations show them not to be simple lines of movement, but rather complex zones of fractures, scarps, and depressions. The Median Valley blends into these fracture zones by increasing its overall width between confining walls, and in one case, south of 36°30′N, there appear to be two Median Valleys parallel to one another, possibly one of them being an older, extinct spreading center (Figure 2).

The Median Valley

Needham and Francheteau (1974) describe the Median Valley in detail. Their description is of interest because we drilled sections of the oceanic crust generated within the confines of the Median Valley during the interval from 3.5 to 13 m.y.B.P.

They summarize that: "The Rift Valley between 36°42′N and 36°55′N is 31 km wide, with halfwidths of 12 and 19 km for the western and eastern side, respectively. Both outer edges of the Rift Valley stand about 1500 meters above an Inner Floor where very fresh pillow lavas occur. The Inner Floor probably includes the locus of new crust; and its bordering slopes, which are particularly well-defined on the western side, limit to less than about 2.5 km the width of the zone over which new crust may have evolved with little or no vertical displacement. Near 36°50′N, the Inner Floor accommodates an approximately 1-km wide, 4-km long Central High, with a height of up to 250 meters. In this area, the locus of new crust may also occupy a very narrow zone; it may lie either along the Central High or along a trough flanking the Central High. The magnetic anomaly pattern indicates that, since the beginning of the Brunhes epoch (6.9×10^5 yrB.P.), the eastern limb has grown approximately twice as fast as the western limb. Using extrapolated spreading rates, the ages of the outer edges of the Rift Valley are 1.3 and 1.7 m.y. for the eastern and western side, respectively."

More recent investigations of the Median Valley have detected other features of interest: (a) The central high itself contains a deep longitudinal axial fracture in places, and in others symmetrical cones with definite dimples at their apices lie over the axial fracture. (b) Recent volcanism has been found not only on the central high, but also along the foot of the eastern fault scarps, obviously overlying somewhat older sediment-covered and ferromanganese-coated material. Some of the lava flows showing pillowed surfaces and tubular pillowed fronts may be as much as 50 meters thick. (c) Between the central high and the eastern and western fault scarps there are parallel zones of uplifted blocks and deep, narrow fractures. Indeed, at 45°N one such feature was discovered accidentally by dredging, and found to be 400 meters deep, and sufficiently narrow for it not to register with a standard PDR. (d) Specific rock types have been found to occur within restricted environments; olivine basalts grading to picrites appear to be restricted to the central high, whereas plagioclase-phyric basalts are found primarily on the fault scarps. Complete major and minor element chemical analyses by H. Bougault of these basalts dredged from the Median Valley by *Jean Charcot* are given in Table 1A, and electron probe analyses by W.G. Melson on glasses recovered from the Median Valley by Woods Hole Oceanographic Institution are given in Table 1B.

Geology of Deep Drill Valley

The following criteria were used in the original selection of the prime drilling sites:

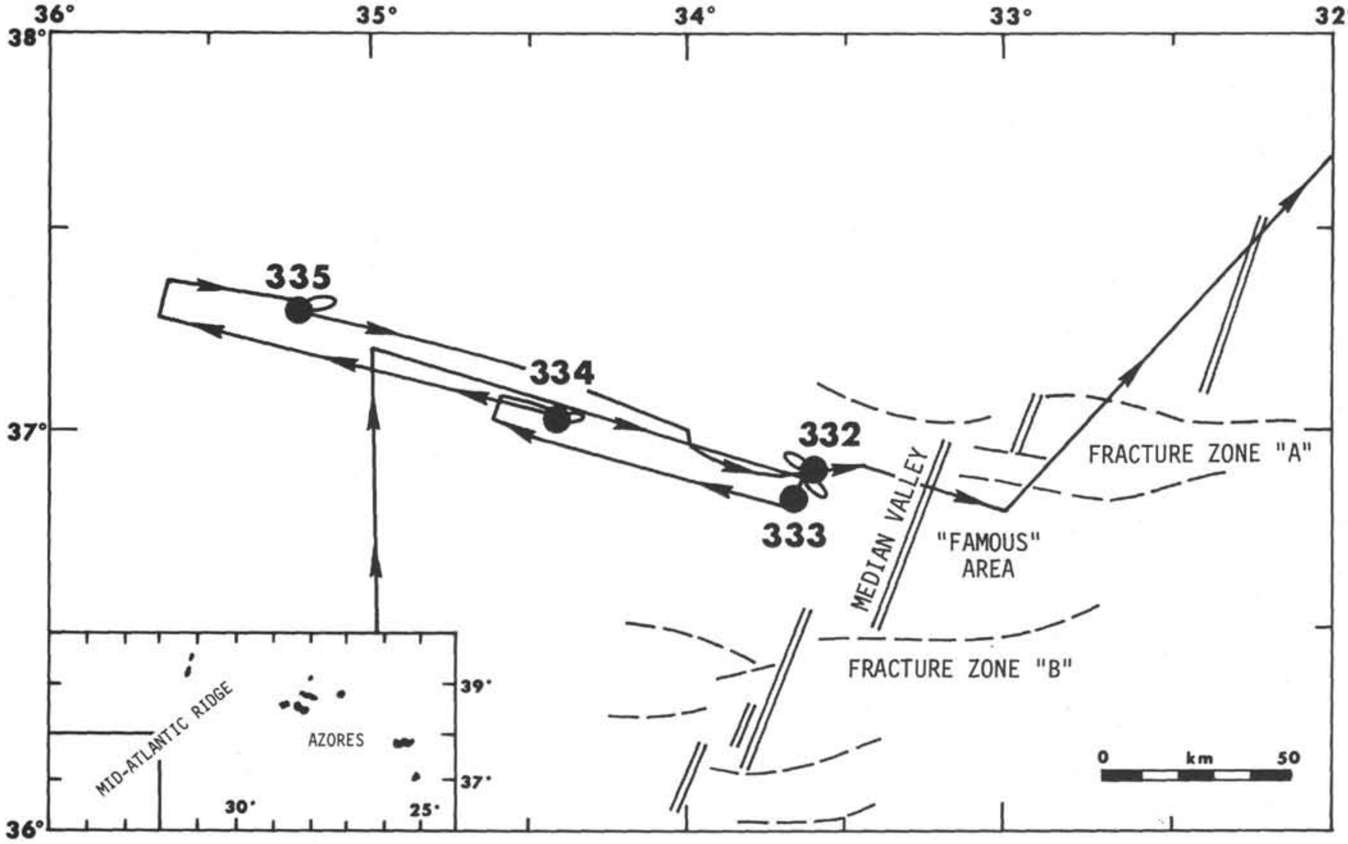


Figure 1. *Location of Leg 37 drill sites and* Glomar Challenger *track in relation to the FAMOUS area.*

a) Sediment thickness should exceed 100 msec (two-way time equivalent to 80 m at 1.6 km^{-1} velocity) and the area of the sediment pond should exceed one mile.

b) Fracture zones should be avoided.

c) The magnetic anomaly pattern over the area should be linear and undisturbed.

d) The sites should lie over a magnetized block of a single polarity, preferably negative.

e) The site should be well within a block of sea floor between fracture zones where the topographic trends are continuous and parallel to the Median Valley.

f) The site should be as near to the Median Valley as possible, and not further than 25-30 miles, in order to provide the best possible correlation with FAMOUS area work, and the freshest possible basalt for geochemical studies.

DEEP DRILL VALLEY, with its longitudinal axis at approximately 33°38′W, and lying between 36°50′N and 36°57′N was found to fit all the above requirements. The detailed geology of the valley is discussed in the site report for Site 332.

SHIPBOARD LABORATORY EXPERIMENTS

Glomar Challenger on Leg 37 of the Deep Sea Drilling Project carried extensive laboratory facilities for shipboard investigations of igneous rocks. These included: (a) equipment for the preparation of polished thin sections of high quality along with excellent transmission and reflection microscopes with camera attachments, (b) ceramic and tungsten carbide mills for the pulverization of specimens and a precision electromagnetic balance for accurate weighing of powders, (c) a gas chromatograph for rapid determination of H_2O and CO_2, (d) a high temperature resistance furnace for fusion of rock powders with preweighed mixtures of lithium tetraborate and lanthanum oxide fluxes, (e) a tube-excited dispersive X-ray fluorescence unit for the routine determination of major and minor element compositions, (f) a spinner magnetometer and ac demagnetization unit for determination of NRM characteristics (polarity and remanent intensity) of both igneous and sedimentary rocks, (g) equipment for measuring sonic velocities of specimens, both at atmospheric pressure and at elevated pressures, and (h) equipment for measurement of porosity, density, and electrical and thermal conductivities.

The routine use of the support facilities mentioned above permitted shipboard scientists to evaluate the drill core soon after its recovery and to modify both the drilling and sampling program accordingly.

SHORE-BASED LABORATORY EXPERIMENTS

The unique nature of a deep core to be recovered from the oceanic crust spurred an unprecedented number of laboratories and individuals to submit research proposals for the study of core material well before it was obtained. Over 50 laboratories were involved in the most exhaustive study ever undertaken of any suite of terrestrial rocks. Laboratories from the USA, Canada, USSR, France, Germany, Great

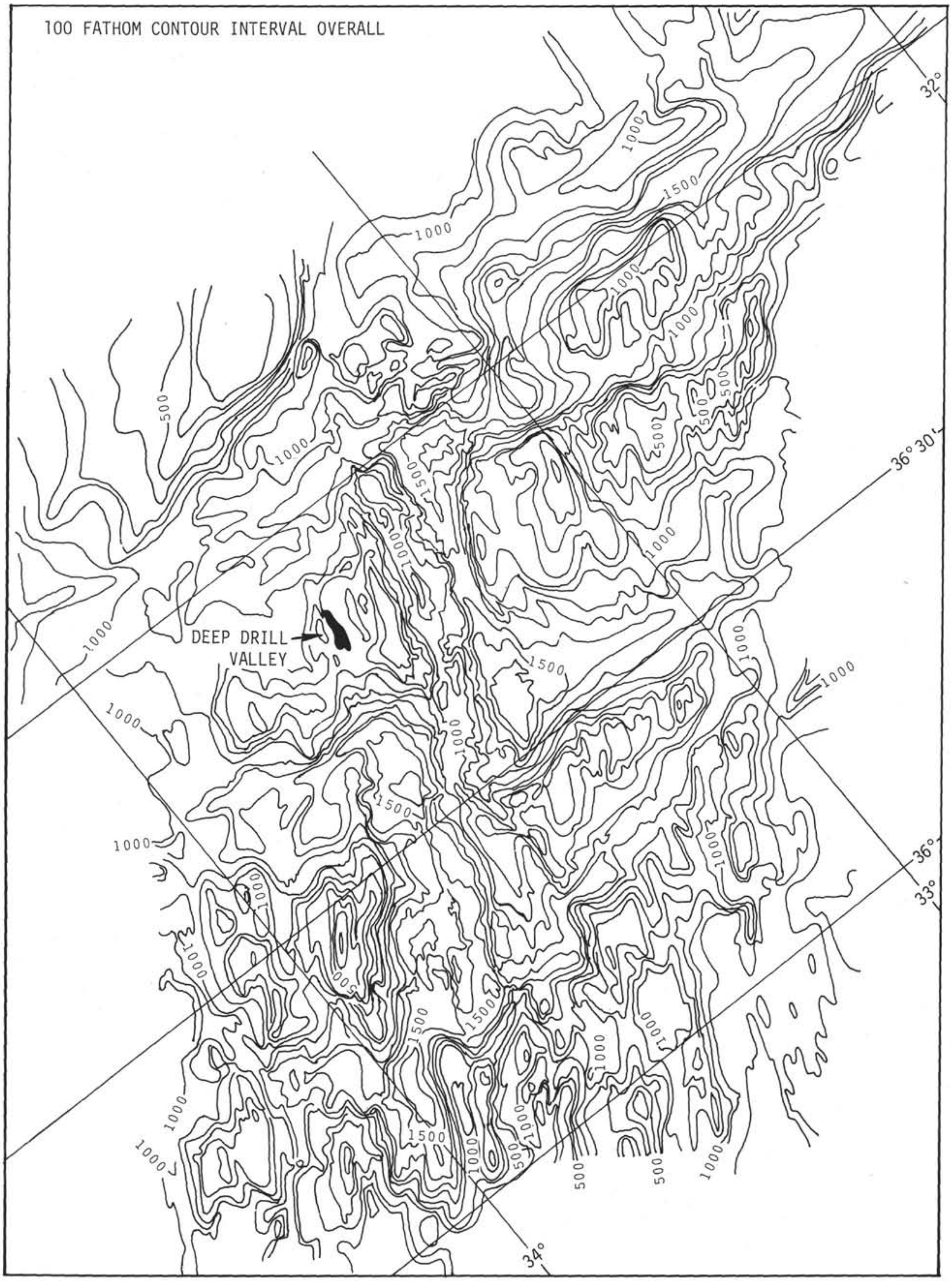


Figure 2. *Bathymetric map of the Mid-Atlantic Ridge in the vicinity of the FAMOUS area. Contour interval is 100 fathoms.*

TABLE 1A
Chemical Analyses of Basalts Dredged from the Median Valley of the Mid-Atlantic Ridge in the FAMOUS Area by Jean Charcot (Analyst H. Bougault)

	Picrite		Olivine Basalts												
Oxides	DR12 316	DR12 320	DR1 122	DR1 124	DR4 303	DR9 309	DR5 304	DR9 322	DR9 322	DR9 308	DR8 314	DR5 100	DR12 319	DR11 315X	DR11 315Y
SiO_2	47.45	46.77	50.45	50.05	49.34	49.28	50.33	49.92	49.96	49.96	49.79	49.93	49.83	50.20	50.24
Al_2O_3	13.49	14.20	15.40	16.19	14.75	15.30	14.92	15.29	15,04	14.83	14.86	14,53	14,82	14,86	14,72
Fe_2O_3	1.04	1.20	1.37	1.47	0.91	1.68	1.43	1.66	1.34	1.46	1.39	1.45	1.35	1.65	0.98
FeO	7.72	7.69	7.41	7.48	7.42	7.44	7.71	8.03	8.24	8.06	8.32	9.37	9.37	9.28	9.50
MnO	0.16	0.16	0.15	0.16	0.14	0.16	0.15	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18
MgO	16.65	16.06	9.33	10.53	11.00	9.20	10.12	9.12	9.02	9.02	9.54	9.22	8.44	8.23	8.24
CaO	11.42	11.89	12.26	12.18	11,48	12,70	11.89	12.55	12.59	12.43	12.51	12.08	11.82	11.90	11.82
Na_2O	1.37	1.98	2.23	2.51	1.55	2.55	1.79	2.23	2.08	2.01	2.18	2.34	2.28	2.28	2.14
K_2O	0.08	0.09	0.16	0.15	0.16	0.17	0.17	0.13	0.13	0.12	0.22	0.23	0.23	0.22	0.23
TiO_2	0.59	0.62	0.90	0.91	0.86	1.02	1.07	1.04	1.04	1.02	1.09	1.27	1.44	1.45	1.44
P_2O_5	0.09	0.07	0.11	0.12	0.10	0.13	0.10	0.10	0.10	0.12	0.12	0.18	0.18	0.18	0.18
H_2O	0.07	0.11	0.09	0.05	0.09	0.17	0.11	0.12	0.09	0.11	0.11	0.13	0.07	0.07	0.05
H_2O+	0.46	0.37	0.42	0.46	0.75	0.62	0.58	0.51	0.53	0.54	0.41	0.59	0.50	0.55	0.50
Ignition Loss	–0.39	–0.47	–0.39	–0.36	–0.06	–0.20	–0.27	–0.37	–0.37	–0.34	–0.50	–0.36	–0.53	–0.47	–0.54
Total	100.60	101.22	100.31	101.22	98.59	100.44	100.40	100.40	100.32	100.66	100.72	100.76	100.51	100.87	100.22

TABLE 1A – *Continued*

Oxides	DR3 123	DR2 301	DR6 306	DR10 310	DR10 105	DR6 305	DR10 311	DR10 100	DR10 314	DR3 131	DR2 132	DR7 318	DR3 321
SiO_2	50.46	50.32	49.27	50.19	50.58	50.32	49.51	49.31	49.50	49.24	49.65	46.76	48.52
Al_2O_3	14.81	15.03	14.57	14.27	14.54	14.69	15.77	17.04	15.89	18.30	19.25	19.46	20.99
Fe_2O_3	1.92	2.35	1.76	2.22	1.78	2.58	2.32	2.04	2.73	2.00	1.24	2.99	1.21
FeO	6.71	6.45	7.90	7.61	7.85	6.86	6.54	6.15	6.60	5.24	5.51	5.58	4.67
MnO	0.15	0.15	0.17	0.17	0.17	0.16	0.15	0.15	0.16	0.12	0.12	0.14	0.10
MgO	8.07	8.26	8.44	8.18	8.35	8.00	8.78	8.17	8.67	7.96	6.90	6.75	6.59
CaO	13.26	13.68	12.50	12.43	12.67	12.89	12.81	13.42	13.10	14.32	14.60	14.10	15.03
Na_2O	2.34	1.84	2.65	1.74	1.91	2.42	2.28	1.61	1.98	1.60	1.80	2.23	1.88
K_2O	0.23	0.32	0.25	0.31	0.30	0.40	0.23	0.27	0.28	0.15	0.12	0.12	0.12
TiO_2	0.90	1.02	0.98	1.00	1.03	1.09	0.99	0.97	1.15	0.73	0.75	0.98	0.59
P_2O_5	0.11	0.16	0.12	0.12	0.11	0.13	0.14	0.15	0.13	0.08	0.11	0.19	0.07
H_2O	0.37	0.26	0.18	0.31	0.16	0.29	0.25	0.22	0.23	0.19	0.09	0.35	0.15
H_2O+	0.64	0.89	0.55	0.74	0.74	0.99	0.65	0.83	0.89	0.90	0.52	0.97	0.52
Ignition Loss	–0.10	0.18	–0.32	–0.10	–0.12	0.24	–0.07	0.16	0.17	0.33	–0.09	0.36	0.01
Total	100.00	100.76	99.35	99.30	100.20	100.84	100.45	100.33	101.30	100.83	100.64	100.66	100.46

Britain, and Australia undertook the following investigations.

1) Petrography, including fabric analysis.

2) Major, minor, and trace element geochemistry.

3) Mineralogy, using optical, X-ray diffraction, electron microprobe and neutron activation determinations.

4) Isotopic studies of argon, oxygen, sulfur, strontium, uranium, thorium, and lead.

5) Paleomagnetism, rock magnetism, and opaque mineralogy.

6) Thermal conductivity and heat production.

7) Seismic velocities and their anisotropy at elevated temperatures and pressures.

8) Studies of geothermal waters, mineral deposits, and fluid motion.

9) Electrical conductivities at elevated temperatures and pressures.

10) Age determinations by paleontological, isotopic, and fission track methods.

The results of these investigations are reported in the following chapters.

EXPLANATORY NOTES

Organization of This Volume

Part I of this volume consists of an introductory chapter outlining the cruise objectives and giving background information on the geology of the FAMOUS area and the prime deep drill site. Part II contains the Site Reports which basically are detailed summaries of the geological data obtained at each site.

TABLE 1B
Electron Microprobe Analyses of Basalt Glasses Dredged from the Median Valley of the Mid-Atlantic Ridge
(Analyst W. G. Melson)

	36°75'N 33°28'W	36°51'N 33°66'W	36°71'N 33°29'W		36°77'N 33°31'W
	6	8	9	10	11
SiO_2	50.70	51.02	50.30	50.42	50.59
Al_2O_3	15.28	15.14	15.18	14.95	14.91
TiO_2	1.11	1.11	1.30	1.30	1.21
FeO*[a]	9.20	9.30	9.73	9.82	9.53
MgO	8.05	7.74	7.78	7.76	7.95
CaO	12.45	11.87	11.73	11.99	12.04
Na_2O	2.21	2.22	2.23	2.31	2.19
K_2O	0.14	0.20	0.18	0.18	0.17
P_2O_5	0.14	0.13	0.15	0.17	0.17
Total	99.28	98.73	98.58	98.89	98.76

[a]FeO* total Fe as FeO

The text in the Site Reports has been kept brief with the major emphasis on presentation of data on the core summary forms and in data tables. The core summary forms contain data generated by the shipboard party during the cruise and updated where necessary. The tables contain prime data generated by both shipboard and shore-based investigators. The site reports are organized as follows:

Site data
Summary
Background and Objectives
Operations
Lithology and Geochemistry
Paleomagnetism
Physical Properties
Paleontology

Special studies of varied nature are reported in Part III. Part IV contains the results of physical properties measurements on both igneous rocks and sediments, and Part V deals with paleomagnetic and rock magnetic studies. Geochemical studies and petrologic studies are contained in Parts VI and VII, respectively. Paleontological investigations and a biostratigraphic summary are given in Part IX and a cruise synthesis is given in Part X.

Responsibility for Authorship

The site reports are co-authored by the entire scientific party. In general, summaries and background were written by F. Aumento and W.G. Melson; operations by D. Edmiston; lithology and geochemistry by H. Bougault, L. Dmitriev, J. Fischer, M. Flower, P. Robinson, and T. Wright; physical properties by R. Hyndman; paleomagnetism by J. Hall; and paleontology by R. Howe and G. Miles.

Numbering and Depth Convention

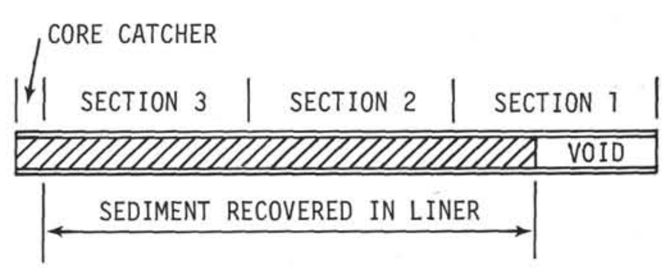
Drill site numbers run consecutively from the first site drilled by *Glomar Challenger* in 1968. The site number is unique; thus, use of a leg number is optional. A site refers to the hole or holes drilled from one acoustic positioning beacon. Several holes may be drilled at a single locality by pulling the drill string above the sea floor ("mud line") and offsetting the ship some distance (usually 100 m or more) from the previous hole.

Holes drilled at a site take the site number, and are distinguished by a letter suffix. The first hole has only the site number; the second has the site number with suffix A; the third has the site number with suffix B; and so forth. It is important, for sampling purposes, to distinguish the holes drilled at a site because recovered sediments or rocks usually do not come from equivalent positions in the stratigraphic column at different holes.

Cores are numbered sequentially from the top down. In the ideal case, they consist of 9 meters of sediment or rock in a plastic liner of 6.6 cm diameter. In addition, a short sample is obtained from the core catcher (a multifingered device at the bottom of the core barrel which prevents cored materials from sliding out during core-barrel recovery). This usually amounts to about 20 cm of sediment which is stored separately. Basalt fragments contained in the core catcher are usually less than 20 cm in length and are normally added to the regular plastic liner because full recovery is rare in igneous rocks. The core-catcher sample represents the lowest stratum recovered in the particular cored interval and is designated by CC (e.g., 333-4, CC = core-catcher sample of the fourth core taken in the first hole at Site 333.

The cored interval is the interval in meters below the sea floor, measured from the point at which coring for a particular core was begun to the point at which it was terminated. This interval is generally 9.5 meters (nominal length of a core barrel), but may be shorter or longer if conditions dictate. For example, at Site 333 many cores are 19 or even 38 meters long. Cores and cored intervals need not be contiguous. In soft sediments, the drill string can be "washed ahead" without recovering core by applying sufficiently high pump pressure to wash sediment out of the way of the bit. In a similar way, in hard rocks a center bit, which fills the opening of the bit face, can replace the core barrel if drilling ahead without coring is necessary.

When a core is brought aboard *Glomar Challenger* it is labeled and the plastic liner and core cut into 1.5-meter sections. A full 9-meter core thus consists of six sections, numbered from the top down, 1 to 6. Generally something less than 9 meters is recovered. In this case, the sections are still numbered starting with one at the top, but the number of sections is the number of 1.5-meter intervals needed to accommodate the length of core recovered, as illustrated below:



Thus, as shown, recovery of 3.6 meters of sediment results in a core with three sections, with a void of 0.9 meter at the top of the first section. By convention, and for convenience in routine data handling at the Deep Sea Drilling Project, if a core contains a length of material less than the length of the cored interval, the recovered material is placed at the top of the cored interval, with the top of Section 1, rather than the top of the sediment, equal to the top of the cored interval. Thus, the depth below the sea floor of the top of the recovered material of this hypothetical core lies at 150.9 meters (not 150.0 m) and the bottom at 154.5 meters (the core catcher is regarded as being dimensionless).

A discrepancy exists between the usual coring interval of 9.5 meters and the 9-meter length of core recovered. The core liners used are actually 9.28 meters in length, and the core catcher accounts for another 0.20 meter. In cases where the core liner is recovered full, the core is still cut into six 1.5-meter sections, measured from the bottom of the liner, and the extra 0.28-meter section at the top is designated Section 0, or the "zero section." The zero section is ignored in calculations of depth below the sea floor of cores or levels within cores.

Sedimentary Cores

In the core laboratory on *Glomar Challenger*, after some routine processing, the sediment cores are split in half lengthwise. One half is designated the "archive" half, which is described by the shipboard geologists, and photographed. The other half is the "working" half, which is sampled by the shipboard sedimentologists and paleontologists for further shipboard and shore-based studies.

Samples taken from core sections are designated by the interval in centimeters from the top of the core section from which the sample was taken; sample size, in cm^3, is also given. Thus, a full sample designation would consist of the following information:

Leg (optional)
Site (Hole, if other than first hole)
Core Number
Section Number
Interval (in centimeters from the top of the section)

Thus, 332B-4-3, 122-124 cm (10 cm^3) designates a 10 cm^3 sample taken from Section 3 of Core 4 from the third hole drilled at Site 332. The depth below the sea floor for this sample would then be the depth to the top of the cored interval plus 3 meters for Sections 1 and 2, plus 122 cm (depth below the top of Section 3).

Core Disturbance

The rotary drill coring technique quite often results in a high degree of disturbance of the cored sediments. This is especially true of the softer unconsolidated sediments. Core disturbance has been treated at length in other volumes of the Initial Reports of the Deep Sea Drilling Project and is not elaborated upon here. A qualitative estimate of the degree of deformation is given on the sediment core logs. Four degrees of drilling deformation were recognized as follows:

- - - - - Slightly deformed
— — — moderately deformed
~~~~~~ intensely deformed (soupy)
△△△△ brecciated

Carbon-Carbonate Data

Sediment samples are analyzed on a Leco 70-Second Analyzer following procedures outlined in Volumes 9 and 18 of the Initial Reports of the Deep Sea Drilling Project. Accuracy and precision of the results are as follows:

Total carbon:	±0.3% (absolute)
Organic carbon:	±0.06% (absolute)
$CaCO_3$:	±3% (absolute)

X-Ray Mineralogy

Semiquantitative determinations of the mineral composition of bulk sediment samples are tabulated on the core logs. In each listing the percentage of "amorphous scattering" (noncrystalline, unidentifiable material) is shown along with the crystalline, identified fraction. The percentages of the identified minerals sum up to 100%. The analytical methods used are described in Volumes 1 and 2 of the Initial Reports of the Deep Sea Drilling Project and in Appendix III of Volume 4.

Grain Size Analyses

The grain size analyses presented on the sediment core logs are performed by standard sieve and pipette techniques, described in detail in Appendix III of Volume 4 of the Initial Reports, with modified settling times as in Volume 9.

Sediment Classification

The sediment classification used here is similar to the one used in Volume 18 of the Initial Reports which was devised by O.E. Weser. A set of lithologic symbols used on Leg 37 are given in Figure 3.

Smear slides are the basic means of mineral identification for sediments on shipboard. Smear-slide estimates of mineral abundances were based on area of the smear slide covered by each component. Past experience has shown that accuracy may approach a percent or so for very distinctive minor constituents but for major constituents accuracy of ±10% to 20% is considered very good.

The results of several random sieve analyses of samples from Leg 37 for which smear-slide percentages were estimated indicate that the percentage of nannofossils was frequently overestimated. This is attributed to the extreme thinness of many smears. This thinness made it appear that the fine-grained nannofossils made up a very high percentage when in fact their percentage was 10%-30% lower; consequently, reported percentages of foraminifera, volcanic glass, and other constituents are correspondingly low. For example, volcanic glass percentages in Cores 5-10, Site 334, actually run as high as 20% of the sediment. Some samples may have even higher percentages.
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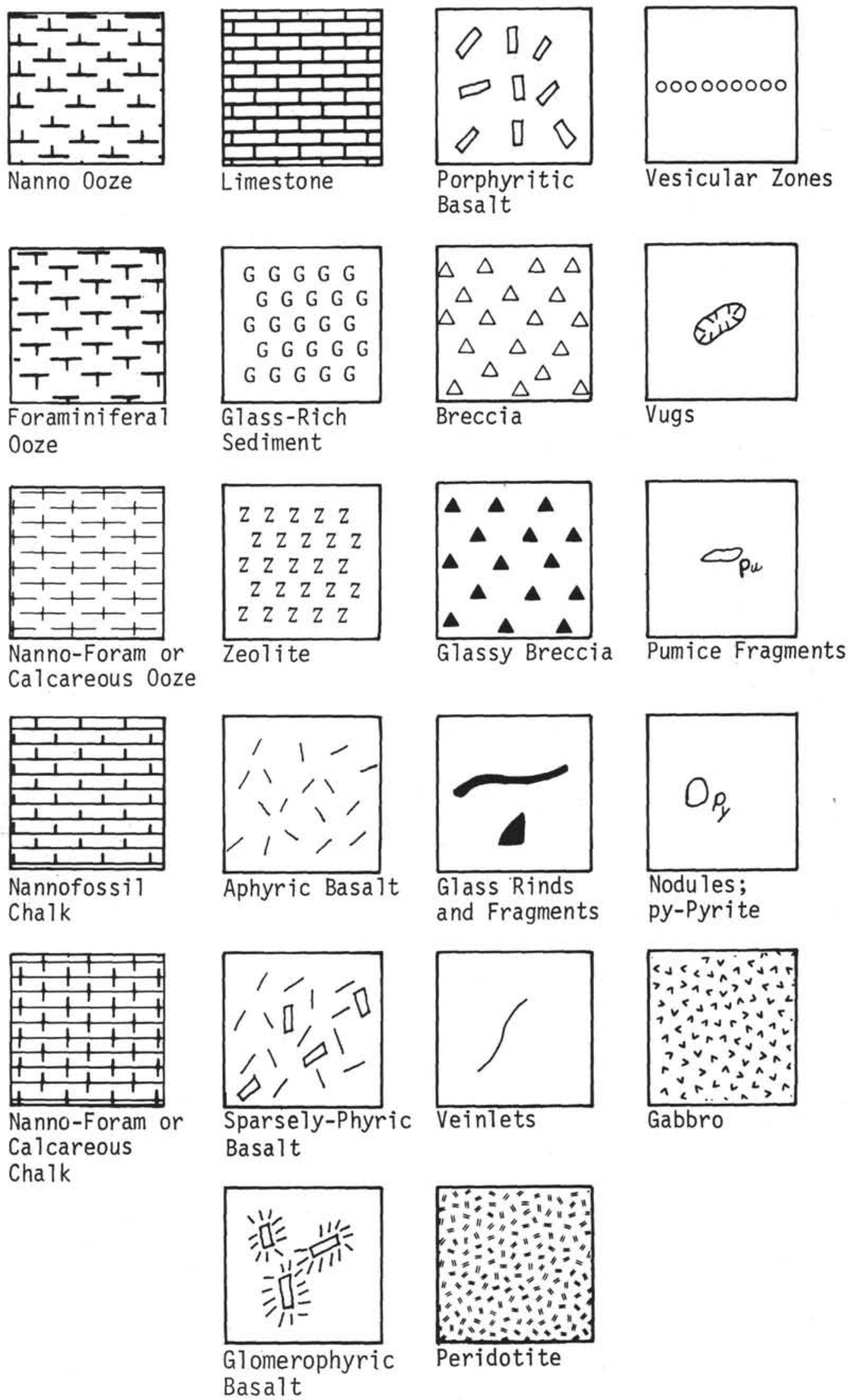

Figure 3. *Lithologic symbols used on Volume 37 core summary forms.*

Physical Properties of Sediments

The physical properties of sediments measured on Leg 37 were bulk density, water content, porosity, sonic velocity, and thermal conductivity. Densities and porosities were determined from the total weight and volume of each core section, by the syringe technique involving weighing and oven drying 0.5-1.0 cm^3 of sediment, and by the gamma ray attenuation (GRAPE) method. The section weight method gives values that are of poor reliability being generally too low, because of incomplete filling of the liner and mixing and disturbance of the sediment. Even well-preserved cores have a thick layer of slurry between the core and liner so the densities determined in this way are a lower limit. Densities by the syringe method have less bias, but the amount of material is so small that the results are of low accuracy (Bennett and Keller, 1973, have given a critical discussion of these methods).

The GRAPE technique utilizes the attenuation of gamma ray intensity in a beam passing through a sediment sample. For the 0.30-0.36 mev $Barium^{133}$ source, Compton electron scattering is the dominant attenuation process. The attenuation thus depends on the electron density in the material, which in turn is approximately proportional to the bulk density for common geological materials (e.g., calcite, quartz, dolomite, and some clays). Aluminum cylinders of different diameters are used for calibration.

A shore-based program is used to correct for variations in electron densities of different core material, particularly for the seawater component. The method is described by Evans (1965) and Harms and Choquette (1965), and as used on *Glomar Challenger*, by Boyce (1973, 1974). Cores are passed continuously through the gamma beam on a carriage so that a nearly continuous profile of counts per unit time is obtained. The data are averaged over 3-cm-long core length intervals. Cores with significant gaps or voids give an irregular trace.

GRAPE densities are computed for 150 points along each core section or every centimeter. These data include many low density points associated with voids, breaks, or disturbances in the core. In order to obtain estimates of the average in situ density in the sea floor, these points must be removed. An example of such a profile is shown on page 17, Volume 26 of the Initial Reports. Particularly at the ends of the core sections there are points of apparent low density that represent simply unfilled core liner. A simple truncation procedure is used to eliminate the spurious points. The procedure must be simple and universally applicable because the large amount of data precludes subjective evaluation.

The program starts by computing the average of the 150 densities in a core section. It then truncates or removes all points that are outside prescribed limits above and below this average. Out limits are +10% and -5%. The smaller lower limit is an attempt to compensate for the bias toward too low densities (gaps and voids) rather than too high densities. The remaining points are averaged again. If the new average differs from the first by more than a prescribed factor (0.5% here), a second truncation with the same window is applied and so on until a stable average is reached. Two iterations are usually sufficient. If more than 20% of the data points have been truncated for the final average, we consider the section average to be unreliable and the value is not plotted.

Estimates of average density for each core are presented in this volume. The complete data are available from the Deep Sea Drilling Project. The cores giving irregular GRAPE traces probably have many gaps or voids and the computed densities have not been presented. Unfortunately, some data on cores with real, large density variations also are discarded.

Sonic (acoustic, seismic) velocities on cores are needed for the interpretation of seismic reflection and refraction data, particularly for converting seismic reflection times to depths in the sedimentary column. Acoustic impedance, given by the product of the sonic velocity and bulk density, is closely related to reflection coefficients. Thus, rapid changes in acoustic impedance may be associated with seismic reflectors. The velocities were measured by determining the time delay of a high-frequency pulse transmitted through sediment or rock samples using a Hamilton frame (Hamilton, 1965; Cernock, 1970). The resolution is better than 0.1 km/sec and accuracy about ± 0.02. Velocity was measured on at least one sample from each core. In the unconsolidated uppermost cores measurements were made through the split core and liner, a correction being made for the thickness and travel time of the liner (0.295 cm and 1.36 μsec for the liner used on this leg). Variations in liner thickness were monitored, but significant changes were not detected. Semiconsolidated sediments were measured in and out of the liner. There was a negligible difference in the velocities obtained by the two methods (less than 0.02 km/sec).

The sonic velocities were all measured at room temperature (20°-25°C) and 1 atm pressure. The in situ temperatures range from 0° to 15°C with most below 10°C and pressures between 0.3 and 0.5 kbar. The data of Schreiber et al. (1972) suggest that the velocities will be 5% to 10% higher at 0.5 kbar. Wilson (1969) finds an increase in velocity for seawater of 5.4% from 1 bar to 0.5 kbar and a decrease of 5.1% from 20° to 0°C. Thus, the effects of temperature and pressure approximately cancel for seawater. The effects are likely similar for unconsolidated sediment.

Thermal conductivity is an important physical property of sediments. Its relationship to composition, other physical properties, and depth is needed to facilitate conductivity estimates required for the downward extrapolation of temperatures from near-surface heat-flow determinations. Conductivities are required to be combined with downhole temperatures for geothermal heat flux (see Chapter 8, this volume). The thermal conductivity was measured at least once on each core of the unconsolidated sediments using the needle-probe technique (Von Herzen and Maxwell, 1959).

Core Forms

The basic lithologic data are contained on the core summary forms. As far as possible the following data are presented for sediment cores:

Sediment or rock name

Deformation

Color name and Munsell or GSA number

The reader is advised that colors recorded in core barrel summaries were determined during shipboard examination immediately after splitting core sections. Experience with carbonate sediments shows that many of the colors will fade or disappear with time after opening and storage. Colors particularly susceptible to rapid fading are purple, light and medium tints of blue, light bluish-gray, dark greenish-black, light tints of green, pale tints of orange. These colors change to white or yellowish-white or pale tan.

Composition

Grain Size, Carbon-Carbonate, and X-Ray Data

Analyzed samples are identified by section and depth (cm). Carbon-carbonate data are reported as % total carbon, % organic carbon, and % $CaCO_3$. X-ray data are given for both bulk samples and for 2-20 μm separates. The following abbreviations are used on the core forms: Amor.—Amorphous percentage, Quar.—Quartz, K-Fe.—Potassium feldspar, Plag.—Plagioclase, Kaol.—Kaolinite, Mica—Mica, Chlo.—Chlorite, Mont.—Montmorillonite, Paly.—Palygorskite, Phil.—Phillipsite, Anal.—Analcime, Pyri.—Pyrite, Amph.—Amphibole, Augi.—Augite, Cris.—Cristobalite, Tr—Trace, Pres—Present.

Biostratigraphy

The following zonations were used in this report: Planktonic foraminifera, Blow (1969); calcareous nannofossils, Martini and Worsley (1970); and Radiolaria, Riedel and Sanfilippo (1970, 1971).

Igneous Rock Cores

Igneous rock cores are treated quite differently from sediment cores. After the core is numbered and divided into 1.5-meter sections in the normal way, the core liner is cut, and the individual pieces of rock are washed with distilled water, dried with a blower, and placed in a clean, presplit core liner. The pieces are then numbered with india ink starting with 1 at the top of the core and marked with an arrow pointing up. When two or more adjacent pieces can be clearly fitted together, they are given the same number and designated A, B, C, etc, starting at the top. When adjacent pieces cannot be fitted together, a styrofoam spacer is inserted between the pieces and taped into place.

Most igneous rock cores were not split on Leg 37. Instead small minicores were taken for shipboard and shore-based investigations using a drill press and a small diamond-studded coring device. The minicores were oriented, labeled, and divided for specific sampling needs. Samples taken from igneous rock cores are designated in the same way as samples from sediment cores except that the piece number is also included.

Measurement of Physical Properties of Basement Rocks

The physical properties measured on basement rocks of Leg 37 are: seismic compressional and shear wave velocity, bulk and grain density, porosity, water content, electrical resistivity, and thermal conductivity. (The magnetic properties are treated separately.) The measurement techniques and interpretations are given (Hyndman and Drury; Hyndman, both this volume). The samples all are cylinders 2.5 cm in diameter and 2.5 to 5.0 cm in length. It should be emphasized that the core recovery in the basement parts of Leg 37 holes was only about 20%, and, although we have attempted to include all rock types and states of alteration and weathering, only parts of the recovered core is sufficiently unfractured to be suitable for measurement. Much of the section not recovered probably is broken and fractured volcanic material with extensive voids and some sediment. Thus, the mean physical properties given may be a poor approximation of the average bulk values for the section drilled. This problem is discussed particularly in Hyndman (this volume). A summary of the measurement techniques and estimated accuracies is given below.

1) Bulk Density—Samples are seawater saturated. The sample volume is obtained from the difference in weight in air and suspended in distilled water. Estimated accuracy ± 0.005 g/cm^3 ($\pm 0.15\%$).

2) Grain Density — Density of solid minerals obtained by subtracting weight and volume of the pore fluid (from porosity estimate). Estimated accuracy -0.007 and +0.014 g/cm^3 (-0.2% and +0.5%).

3) Porosity (percent volume that is pore spaces)—Obtained from the loss in weight by heating at 60° to 70°C in vacuum for at least 72 hr. A small correction is made for residual salt. Estimated accuracy -0.2 and +0.4 (-5% and +10% of value).

4) Water Content (percent of weight of saturated sample that is water)—Obtained as for porosity, without correction for salt that remains after drying. Estimated accuracy -0.1 and +0.2 (-5% and +10% of value.

5) Electrical Resistivity—Obtained from the electrical resistance of cylindrical samples with ends painted with conducting epoxy resin, approximately 0.5 v, 50 Hz, 1 atm, 23°-25°C, seawater saturated. Estimated accuracy $\pm 10\%$.

6) Seismic Velocity (compressed wave)—At 0.5-kbar pressure, with hydraulic fluid excluded by a jacket so confining pressure is much greater than internal or pore water pressure. Seawater saturated. Estimated accuracy $\pm 1\%$.

Core Summary Forms

A new set of core summary forms was developed on Leg 37 in order to portray the igneous rock cores. In addition to basic lithologic data, the core forms include shipboard magnetic, chemical, and physical properties data updated where appropriate.

Lithologic Data

Lithologies are based on macroscopic descriptions of the core supplemented by thin section data. Symbols used to designate the different lithologies are given in Figure 3.

Samples

A and B represent minicores taken for shipboard studies. Magnetic, chemical, and petrographic analyses were conducted on "A" cores and physical properties determinations and petrographic analyses were carried out on "B" cores. "T" represents a thin section prepared onboard ship in addition to those prepared from the "A" and "B" cores. "C" represents a chemical analysis completed onboard ship in addition to those conducted on "A" cores.

Magnetic Data

NRM intensity is in units of 10^{-4} emu/cm^3. NRM intensity is the value for the undemagnetized moment, i.e., probably the value the sample had in situ. Polarity is shown before and after demagnetization and is given in four categories as follows:

n N Normal ($I \geqq +20°$)
shn SHN Shallow normal (I = 0° to +20°)
shr SHR Shallow reverse (I = 0° to -20°)
r R Reverse ($I \leqq -20°$)

Lower-case letters give the polarity of undemagnetized NRM, i.e., the probable magnetic polarity of the in situ rocks. Capital letters give the polarity of the cleaned NRM, i.e., the magnetic polarity of the earth's magnetic field during the initial cooling of the rock. The demagnetized values date from the time of initial cooling of the unit and should be used in temperature studies. Polarities marked "?" are likely but not certain to remain as designated after further demagnetization.

Chemical Data

Values given are the results of shipboard determinations by X-ray fluorescence for Al_2O_3, Fe_2O_3 (total iron expressed as Fe_2O_3), MgO, and K_2O. Values for H_2O and CO_2 are the result of shipboard determinations with a CHN analyzer.

Physical Properties

All values reported are from shipboard measurements. D = Bulk density (g/cm^3); V = Compressional velocity measured at laboratory temperature (20°-25°C) and 0.5 kb pressure.

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