1. INTRODUCTION AND EXPLANATORY NOTES¹

Shipboard Scientific Party²

GENERAL INFORMATION

The following notes are intended to aid interested investigators in understanding the terminology, labeling, and numbering conventions used by the Ocean Drilling Program during Leg 111. In general, Leg 111 accepted the precedents set by Leg 83 while drilling at Site 504B. In conformity with Leg 83, in the visual core descriptions, the basalts recovered at Site 504B are described by units, rather than by cores. Basalt units were defined by the shipboard scientists on the basis of changes in petrographic type and phenocryst abundances, changes in groundmass texture, and/or occurrence of chilled contacts.

AUTHORSHIP OF SITE CHAPTERS

The separate sections of the Site 504 Chapter were written by shipboard scientists as follows:

Background and Objectives (Becker, Sakai) Operations (Becker, Foss) Lithostratigraphy (Adamson) Petrography (Malpas, Ishizuka) Alteration (Alt, Bideau, Herzig) Geochemistry (Sparks, Uhlig) Borehole Water Chemistry (Mottl, Sakai, Masuda, Kawahata) Paleomagnetics (Pariso) Physical Properties (Lovell, Morin) Temperature Measurements (Gable, Morin, Becker) Neutron Activation Log (Anderson) Multichannel Sonic Log (Pezard) Vertical Seismic Profile (Phillips) Magnetometer Log (Kinoshita) Permeability Measurements (Becker) Resistivity Log (Pezard) Borehole Televiewer (Morin) Summary and Conclusions (Becker, Sakai) Appendix (Merrill)

The separate sections of the Sites 677/678 Chapter were written by shipboard scientists as follows:

Background and Objectives (Sakai, Becker) Operations (Sakai, Becker, Foss) Sedimentology (Alexandrovich, Houghton) Biostratigraphy (Houghton, Alexandrovich) Pore Water Chemistry (Mottl, Sakai, Masuda, Kawahata) Paleomagnetics (Pariso) Physical Properties (Lovell, Morin) Temperature Measurements (Becker) Summary and Conclusions (Sakai, Becker) Appendix (Merrill)

NUMBERING OF SITES, HOLES, CORES, SAMPLES

ODP drill sites are numbered consecutively from the first site drilled by *Glomar Challenger* in 1968. A site number refers to one or more holes drilled while the ship was positioned over one acoustic beacon. Multiple holes may be drilled at a single site by pulling the drill pipe above the seafloor (out of one hole), moving the ship some distance from the previous hole, and then drilling another hole.

The first hole drilled at an ODP site is assigned the site number modified by the letter A. Subsequent holes at the same site are designated with the site number modified by letters of the alphabet assigned in chronological sequence of drilling. Note that this differs slightly from the DSDP practice of designating the first hole at a given site by the site number, unmodified, and subsequent holes by the site number modified by letters of the alphabet (hence, Hole 504B, originally drilled by DSDP, was the third hole that DSDP drilled at Site 504). It is important, for sampling purposes, to distinguish among the holes drilled at a site, because recovered sediments or rocks from different holes usually do not come from equivalent positions in the stratigraphic column.

Three varieties of coring systems were employed during Leg 111: (1) the Rotary-coring (RCB) system was used for coring basalts, while (2) the Advanced Piston Coring (APC) system and (3) the Extended Core Barrel (XCB) system were used for coring sediments. Cores obtained with the different systems are designated as types "R," "H," and "X," respectively. Miscellaneous samples (designated "M") consist of basalt debris that fell to the bottom of the borehole and were collected with a (junk) basket while trying to recover broken drill bit parts from the hole.

¹ Becker, K., Sakai, H., et al., 1988. Proc. ODP, Init. Repts. (Pt. A), 111: College Station, TX (Ocean Drilling Program).

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The RCB, which is the standard coring device used since DSDP Leg 1, was used with both roller-cone bits and diamond-faced bits. Normally, a core approximately 9.5 m in length is cut and retrieved in each core barrel.

The APC is a modification of the Hydraulic Piston Coring (HPC) system originally deployed on DSDP Leg 64. This coring system utilizes an hydraulic piston principle. Fluid is pumped through the drill pipe, activating a piston-driven core barrel which is ejected through the core bit into the sediment at the rate of approximately 6.5 m/s. This extremely high penetration rate is used to decouple the core barrel from the motion of the drill string, and to avoid drilling disturbance due to rotation, normally encountered in drilling sediments with the RCB. On completion of each coring operation, the core barrel assembly is retrieved by wire line, and the core bit is then "washed" down to the next coring point, where the piston coring procedure is repeated.

The XCB, first deployed on DSDP Leg 90, was developed in order to recover undisturbed cores in the intermediate zone where the sediment is too hard to be piston cored, but too soft to be recovered effectively with the RCB. It is designed to continue in the same hole, following APC coring, without a bit change. Rotating with the drill string, the XCB employs a diamond-studded cutting shoe that extends 6 in. below the drill bit and that is lubricated by relatively low energy water jets. This configuration allows the XCB to core soft sediments before they can be washed away by the more energetic drill bit jets. Harder sediments cause the barrel to retract into the drill bit against the pressure of an internal spring, allowing indurated sediments to be cut predominantly by the roller cones and strong water jets of the drill bit.

The cored interval is measured in meters below the seafloor (mbsf). The depth interval assigned to an individual core begins with the depth below the seafloor that the coring operation began, and extends to the depth that the coring operation ended. For example, each coring interval is usually 9.5 m long, which is the nominal capacity of a core barrel; however, the coring interval may be shorter or longer. "Cored intervals" need not necessarily abut one another, but may be separated by "drilled intervals." In soft sediment, the drill string may be "washed ahead" with the core barrel in place, but not recovering sediment, by pumping water down the drill pipe at high pressure to wash the sediment out of the way of the bit and up the space between the drill pipe and wall of the hole; however, if thin, hard, rock layers are present, then it is possible to get "spotty" sampling of these resistant layers within the washed interval, and thus have a cored interval greater than 9.5 m. In drilling hard rock, a center bit may replace the core barrel if it is necessary to drill without core recovery.

Cores taken from a hole are numbered serially from the top of the hole downward (at Hole 504B, the first core recovered on Leg 111 was numbered 142, next in sequence after the last core recovered on Leg 83). Core numbers and their associated cored intervals in meters below the seafloor usually are unique in a given hole; however, this may not be true if an interval must be cored twice, due to caving of cuttings or other hole problems. Nominally, a fully-recovered core consists of 9.3 m of rock or sediment contained in a plastic liner (6.6 cm internal diameter) plus about 0.2 m (without a plastic liner) in the core catcher. The core catcher is a device at the bottom of the core barrel which prevents the core from sliding out when the barrel is being retrieved from the hole.

A recovered sediment core is cut into 1.5-m sections which are numbered serially from the top (Fig. 1). When full recovery is obtained, the sections are numbered from 1 through 7 with the last section possibly being shorter than 1.5 m. When less than full recovery is obtained, there will be as many sections as



Figure 1. Cutting and labeling core sections.

needed to accommodate the length of the core recovered; for example, 4 m of core would be divided into two 1.5-m sections and one 1-m section. If cores are fragmented (recovery less than 100%), sections are numbered serially and intervening sections are noted as void, whether shipboard scientists believe that the fragments were contiguous *in situ* or not. Material recovered from the core catcher is placed below the last section when the core is described, and labeled core catcher (CC); in sedimentary cores, it is treated as a separate section. Scientists completing visual core descriptions describe each section as a unit.

A recovered basalt core also is cut into 1.5-m sections which are numbered serially; however, each piece of rock is then assigned a number (fragments of a single piece are assigned a single number, with individual fragments being identified alphabetically). The core catcher sample is placed at the bottom of the last section and is treated as part of the last section, rather than separately. Scientists completing visual core descriptions describe each lithologic unit, noting core and section boundaries only as physical reference points.

When, as is usually the case, the recovered core is shorter than the cored interval, the top of the core is equated with the top of the cored interval by convention, in order to achieve consistency in handling analytical data derived from the cores. Samples removed from the cores are designated by distance measured in centimeters from the top of the section to the top and bottom of each sample removed from that section. In curated hard rock sections, sturdy plastic spacers are placed between pieces which do not fit together in order to protect them from damage in transit and in storage; therefore, the centimeter interval noted for a basaltic sample has no direct relationship to that sample's depth within the cored interval, but is only a physical reference to the sample's location within the curated core.

A full identification number for a sample consists of the following information: Leg, Site, Hole, Core Number, Core Type, Section Number, Piece Number (for basalts), and Interval in centimeters measured from the top of the section. For example, a sample identification of "111-504B-142R-3 (Piece 5B, 15-17 cm)" would be interpreted as representing a sample removed from the interval between 15 and 17 cm below the top of Section 3, Core 142 (R designates that this core was taken with the RCB) of Hole 504B during Leg 111, and that this interval fell within Piece 5, Fragment B, of that section.

BASEMENT DESCRIPTION CONVENTIONS

Visual Core Descriptions

Igneous rock representation on barrel sheets is too compressed to provide adequate information for potential sampling. Consequently, visual core description forms, modified from those used aboard ship, are used for more complete graphic representation. Copies of the visual core description forms, as well as of other prime data collected during Leg 111, are available on microfilm at all three ODP repositories.

Igneous rocks are split into archive and working halves using a rock saw with a diamond blade. The archive half is described. and samples for shipboard and shore-based analyses are removed from the working half. On a typical igneous core description form (Fig. 2), the left column is a visual representation of the archive half. A horizontal line across the entire width of this column denotes a plastic spacer glued between basalt pieces inside the liner. Each piece is numbered sequentially from the top of each section, beginning with the number 1. Pieces are labeled on the rounded, not the sawn surface. Pieces that can be fitted together (reassembled like a jigsaw puzzle) are assigned the same number, but are lettered consecutively (e.g., 1A, 1B, 1C, etc.). Spacers are placed between pieces with different numbers, but not between those with different letters and the same number. Presence of a spacer may represent a zone of no recovery. Whenever the original unsplit piece was sufficiently large that top could be distinguished from bottom before removal from the core liner (i.e., that it could not have revolved in the liner during drilling), an arrow was added to the label pointing to the top of the section. Care was taken to ensure that orientation was not lost during the splitting and labeling processes. Oriented pieces are indicated on the description forms by upward-pointing arrows to the right of the piece. Because pieces were free to rotate during drilling, azimuthal orientation is not possible.

Samples are taken for various measurements aboard ship. Type of measurement and approximate sample interval are indicated in the column headed "shipboard studies," using the following notation:

- XD = X-ray diffraction analysis
- XF = X-ray fluorescence analysis
- M = magnetics measurements
- T =thin-section billet
- P = physical properties measurements

Shipboard measurements of physical properties and magnetic properties were routinely made upon minicores which then were subdivided for X-ray fluorescence (XRF) analysis and manufacture of a thin section, in order to ensure that as many measurements as possible can be correlated directly.

Lithologic descriptions were prepared in a systematic way, with describers being guided by a series of specific questions (e.g., nature of contacts, distribution and percentage of phenocrysts, groundmass and texture, color, vesicle content, alteration, etc.) which had to be addressed for each unit described (see "Introduction and Explanatory Notes," Legs 106/109, first part of this book). Describers operated in two teams (shifts), each consisting of three petrologists. Interteam meetings were held frequently in order to ensure that descriptions were prepared consistently on both shifts, and that all petrologists agreed upon the division of recovered core into lithologic units.

Once the lithologic description had been agreed upon by the shipboard party, the final core description was assembled on an igneous barrel sheet (Fig. 2). These barrel sheets are published in this volume.

Igneous Rock Classification

Igneous rocks are classified mainly on the basis of mineralogy and texture. For the purpose of simplifying lithostratigraphy, basalts are first named purely on the presence of phenocryst phases and not on their relative abundance. This is in accordance with the practice adopted by petrologists during DSDP Leg 83 (Anderson, Honnorez, Becker, et al., 1985). Further, in barrel sheet and thin section descriptions basalts are termed aphyric, sparsely phyric, moderately phyric, or highly phyric, depending upon the proportion of phenocrysts visible with the hand lens or binocular microscope (approximately \times 10). Basalts are called aphyric if phenocrysts clearly amount to less than 1% of the rock, sparsely phyric if phenocryst content ranges from 1% to 2%, moderately phyric at 2%-10%, and highly phyric if phenocrysts amount to more than 10% of the rock. Basalts are further classified by phenocryst type, e.g., a plagioclase-olivine moderately phyric basalt contains 2%-10% phenocrysts, most of them plagioclase, but with some olivine. Basalts are termed "dikes" if one or two clear intrusive contacts were recovered; otherwise, they are termed "massive."

Thin-Section Billets

Thin-section billets of basaltic rocks recovered from Hole 504B during Leg 111 were examined to help define unit boundaries indicated by hand-specimen core descriptions, to confirm the identity of the petrographic groups represented in the cores, and to define their secondary alteration mineralogy. At least one thin section was made of each unit identified in hand specimen where sufficient rock was available.

Percentages of individual phenocryst phases are reported on the detailed thin-section description sheets (available in microform at the repositories). These are visual estimates checked by point counting on selected samples.

The term basalt here refers to a characteristic mineral assemblage and does not imply a particularly fine-grained texture. The term phyric is used to describe a texture in which larger crystals (phenocrysts) are set in a finer groundmass that may be crystalline or glassy or both. Aphyric rocks are essentially those without phenocrysts; for practical purposes this means that if one or two phenocrysts amounting to < 1% of the total rock are present and elsewhere the unit appears to lack phenocrysts, then the rock is described as aphyric. The minor occurrence of phenocrysts in such a case is, however, described in the detailed thin-section description forms. The terms sparsely, moderately, and highly phyric are used in the same manner as for hand-specimen descriptions. Thin-section descriptions are used in preference to the less definitive hand-specimen descriptions in the lithostratigraphic summary, particularly in cases where discrepancies arise over the composition and abundance of phenocryst phases between hand-specimen and thin-section analyses.

Basement Alteration

Alteration effects due to seawater interaction with igneous rocks were described in hand specimens and thin sections. The width and color of any alteration halos around fractures or vugs was noted, and the total percentage of veins and fracture fillings and their thicknesses were estimated in the core descriptions. The identities of secondary minerals which fill fractures and vesicles and which replace igneous phases were estimated in vis-



Figure 2. Igneous core description (barrel sheet) form.

ual core descriptions and these estimates refined in thin section. The total percentages of the various secondary minerals was also estimated from thin-section examinations.

XRD Analyses

A Philips ADP 3520 X-ray diffractometer was used for the X-ray diffraction (XRD) analysis of unknown secondary mineral phases. Instrument conditions were as follows:

CuK_{α} radiation with Ni filter 40 kV 35 mA Continuous scan from 2° to 60° 2_{Θ}

Samples were prepared by grinding under water with an agate pestle and mortar until reduced to a very fine slurry. A suspension was then pipetted onto the surface of a glass slide and allowed to air dry before X-ray analysis.

Resulting diffractograms were identified with the help of a computerized search and match routine using Joint Committee on Powder Diffraction Standards (JCPDS) powder files.

XRF Analyses

Samples considered by the shipboard party to be representative of individual lithologic units, or possibly of unusual composition, were analyzed for major and trace elements by XRF. The on-board XRF system (Applied Research Laboratory 8420) is a fully-automated, wavelength-dispersive, X-ray fluorescence spectrometer using a 3 kW rhodium X-ray tube as the excitation source for both major and trace elements. The current list of analyzed elements and operating conditions is given in Table 1.

Since the XRF lab aboard the JOIDES Resolution is a relatively new addition, much work has been aimed at developing sample preparation techniques and data reduction routines that are flexible, streamlined, and provide high-quality chemical data to the shipboard scientists. The scientists and technicians who sailed on Leg 109 had great success toward achieving this goal, and on Leg 111, we used their techniques with few changes. Two of these changes, however, are important: Trace element pellet preparation has been streamlined to eliminate the necessity for precise weighing of sample and wax binder, and a data reduction routine for the trace elements has been written to incorporate empirical approaches to calculating nonlinear backgrounds and removal of spectral interferences. Several other minor changes were made and are noted below, where appropriate.

Crushing and Grinding

Sample preparation is begun by taking approximately 10 cm³ of rock and removing any saw marks or unwanted material by wet-grinding on a silicon carbide disk mill. The sample is then ultrasonically washed in distilled water and methanol for 10 min each, followed by drying at 110°C for at least 2 hr. Larger pieces are reduced to less than 1 cm diameter by crushing between 2 plastic disks in a hydraulic press. Powders are produced by grinding pieces less than 1 cm in diameter in a Spex Shatterbox, employing a tungsten carbide grinding vessel, for 50–60 seconds. Despite documented (Thompson and Bankston, 1970) contamination effects, most notably from W, Co, and Ta, the grinding vessel was chosen because it proved to be far superior to an available motorized agate mortar and pestle in its ability to quickly produce a fine, uniform grain-size powder without sieving. The use of this grinding vessel has varied from leg to leg.

Loss on Ignition

Loss on ignition was determined by igniting fresh rock powders at 1000°C for 2 hr. The powders were not dried before ignition, therefore the loss values include adsorbed water (H_2O^-).

Major Elements

Major elements are determined on fused glass disks in order to reduce matrix effects and variations in background (Claisse 1956; Rose et al., 1962; Norrish and Hutton, 1969). The disks

Table	1.	Leg	111	XRF	measurement	parameters.
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					Peak angle	Background offset	Tota	l count time (s)
Element	Line	Crystal	Detector ^a	Collimator	(deg)	(deg)	Peak	Background
SiO ₂	Kα	PET(002)	FPC	Coarse	109.25	0	40	0
TiO ₂	Ka	LIF(200)	FPC	Fine	86.14	0	40	0
Al ₂ Õ	Ka	PET(002)	FPC	Coarse	145.27	0	100	0
Fe ₂ O ₃ ^b	Ka	LiF(200)	FPC	Fine	57.52	0	40	0
MnO	Ka	LiF(200)	KrSC	Fine	62.98	0	40	0
MgO	Ka	TLAP	FPC	Coarse	44.87	± 0.80	200	200
CaO	Ka	LiF(200)	FPC	Coarse	113.16	0	40	0
Na ₂ O	Ka	TLAP	FPC	Coarse	54.71	-1.20	200	200
K ₂ Ō	Ka	LiF(200)	FPC	Fine	136.65	0	40	0
P205	Ka	Ge(111)	FPC	Coarse	140.94	0	100	0
Rh	K-C	LiF(200)	Scint	Fine	18.59	0	100	0
Nb	Ka	LiF(200)	Scint	Fine	21.37	±0.35	200	200
Zr	Ka	LiF(200)	Scint	Fine	22.53	±0.35	100	100
Y	Ka	LiF(200)	Scint	Fine	23.78	±0.40	100	100
Sr	Ka	LiF(200)	Scint	Fine	25.13	±0.40	100	100
Rb	Ka	LiF(200)	Scint	Fine	26.60	±0.60	100	100
Zn	Ka	LiF(200)	Scint	Fine	41.79	±0.40	60	60
Cu	Ka	LiF(200)	Scint	Fine	45.02	±0.40	60	60
Ni	Ka	LiF(200)	Scint	Coarse	48.67	±0.60	60	60
Cr	Ka	LiF(200)	FPC	Fine	69.35	±0.50	60	60
Fe	Ka	LiF(220)	FPC	Fine	85.37	-0.40 + 0.70	40	40
V	Ka	LiF(220)	FPC	Fine	122.84	-0.50	60	60
TiO ₂	Ka	LiF(200)	FPC	Fine	86.14	±0.50	40	40
Cec	La	LiF(220)	FPC	Coarse	127.92	±1.50	100	100
Ba ^c	LB	LiF(220)	FPC	Coarse	128.53	±1.50	100	100

Note: All elements were analyzed under vacuum on goniometer 1, at generator settings of 60 kV and 50 mA. ^a FPC: Flow proportional counter using P_{10} gas; KrSC: sealed krypton gas counter; Scint: NaI scintillation counter.

^b Total Fe as Fe₂O₃.

^c Calibrated, but not analyzed on basalts.

are made by mixing 6.00 g of dry, lanthanum-doped (20% La2O3), lithium tetraborate flux (Spex #FF28-10) with 0.500 g of ignited rock powder. This sample/flux mixture is then melted at 1,030°C in platinum-gold (Pt-Au) crucibles for 6-10 min, followed by pouring into Pt-Au molds using a modified Claisse Fluxer apparatus. The 12:1 flux-to-sample ratio employed here has been found to sufficiently reduce matrix effects to the point where matrix corrections are unnecessary for normal basaltic to granitic composition ranges. Therefore, simple linear relationships exist between X-ray intensities and oxide concentrations, and major element concentrations are easily calculated using the equation:

$$C_i = (I_i \times m_i) - b_i$$

Where $C_i = \text{concentration (wt\%) of oxide i}$

- I_i = net peak intensity (cps) of oxide i
- m_i = slope of calibration curve (wt%/cps) of oxide i b_i = measured blank (wt%) of oxide i

Slope (m_i) is determined by measuring both natural and synthetic standards, and calculating a slope for each standard. Anomalous results are removed and the rest are averaged to give the mean slope m_i. A simple linear regression could also be used, but graphs should be prepared to help identify any anomalous numbers. A measured blank (b_i) is used in place of a blank derived from a regression. For most major elements, this makes little difference. For minor elements such as K₂O and P₂O₅, where concentrations often approach background levels, better results are achieved by measuring blanks on synthetic and natural standards.

When extreme compositions such as MgO in ultramafic rocks are to be determined, standards closer in composition to the unknowns should be used.

Trace Elements

Trace elements are determined on pressed-powder pellets made by mixing 7 g of fresh rock powder with 30 drops of polyvinyl alcohol binder, and then pressing this mixture into an aluminum cap with 7 tons of pressure. A minimum of 5 g of sample ensures the pellet will be "infinitely thick" for rhodium K-series radiation.

To compute trace element concentrations from measured Xray intensities, an off-line calculation program based on calculation routines modified from Norrish and Chappell (1967) and Reynolds (1967) was written by J. W. Sparks. A basic outline of the program is as follows:

1. Input X-ray intensities. Dead-time corrected X-ray intensities are read into the program from an Applied Research Laboratory result file.

2. Drift corrections. All peak and background intensities are corrected for machine drift by using a one-point correction of the form:

$$D_i = S_i / M_i$$
$$I_{di} = I_i \times D_i$$

- Where $D_i = Drift$ factor for element i, generally 1.00 \pm 0.01 S_i = Peak intensity for element i, measured on syn
 - thetic standard "POOP" at time of calibration. M_i = Measured peak intensity for element i, measured
 - on "POOP" at any time after the calibration.
 - $I_i = Uncorrected peak or background intensity, ele$ ment i.
 - I_{di} = Drift corrected peak or background intensity, element i.

3. Subtract backgrounds. Correct the peak intensities for nonlinear backgrounds by measuring a peak-to-average-background ratio (BF_i). This is determined for each element, on synthetic and natural blank standards, at time of calibration.

$$BF_i = PK_i / AVBg_i$$

Thus, when measuring unknowns, the true or modified background (MBg.) is calculated by multiplying the average measured background for element i (AVBg_i) by the BF_i. This new modified background value is then subtracted from the peak intensity (PK_i) to arrive at the net peak intensity (NETPK_i) for element i.

$$MBg_i = AVBg_i \times BF_i$$

NETPK_i = PK_i - MBg_i

4. Remove spectral interferences. During calibration, interferences are measured on synthetic pellets containing pure quartz and the interfering element. A ratio of the interference intensity to the net peak of the interfering element is calculated and assumed constant with respect to concentration. When measuring an unknown, the net interference (INTFER_{i,i}) is calculated and removed by:

$$INTFER_{i,i} = NETPK_i \times IR_{i,i}$$

$$CNETPK_i = NETPK_i - INTFER_{i,i}$$

Where $INTFER_{i,j}$ = The net interference intensity of element i on element j.

> $CNETPK_i$ = The net intensity of element j with the interference element i removed.

In the case of mutually interfering elements, an iterative approach to this same calculation is used until all the elements involved converge on their respective corrected values.

5. Measure mass absorption coefficients. To correct for matrix differences between samples, three separate mass absorption coefficients are determined following a modification of the Compton scattering technique of Reynolds (1967). Measured intensities from the rhodium K-series Compton, $Fe_{K\alpha}$, and $Ti_{K\alpha}$ lines are compared to the calculated absorption coefficients of Rb (A_{Rb}), Cr (A_{Rb}), and V (A_v) respectively. From this comparison, three equations can be written to describe the relationship between each coefficient and its respective line. The three equations derived from the Leg 111 calibration are as follows:

$$\begin{array}{l} A_{\rm Rb} \,=\, 10^4 \,/ \, [({\rm Rh}_{\rm cps} \,\times\, 0.0698) \,+\, 57.79] A_{\rm Cr} \,=\, A_{\rm Rb} \,/ \, [({\rm Fe}_{\rm cps} \,\times\, 1.044 \,\times\, 10^{-6}) \,+\, 0.081] \\ A_{\rm V} \,=\, A_{\rm Cr} \,/ \, [({\rm Ti}_{\rm cps} \,\times\, 6.140 \,\times\, 10^{-6}) \,+\, 0.778] \end{array}$$

Using this method, unknowns can be measured and corrected for matrix differences without calculating the absorption coefficients for each sample.

6. Calculate concentrations. Once all spectral and matrix corrections have been calculated, the equation to calculate elemental concentrations reduces to:

$$C_i = (CNETPK_i \times A_i) / K_i$$

Where $C_i = Concentration of element i in parts per million$ CNETPK_i = Corrected net peak intensity, element i

- $A_i = Mass$ absorption coefficient for element i
 - K_i = Calibration factor (ppm/cps) for element i. K_i is analogous to the calibration curve slope (mi) for major elements, and is determined in the same manner on natural rock and mineral standards.

DESCRIPTION OF SEDIMENTS AND SEDIMENTARY ROCKS

Introduction

The sediment classification system used on Leg 111 is a modified version of that devised by the former JOIDES Panel on Sedimentary Petrology and Physical Properties and adopted for use by the JOIDES Planning Committee in March 1974. This classification scheme was designed to adhere closely to ODP standards and to describe the nature of the sediments recovered on Leg 111. The classification is descriptive (based on sediment properties) rather than generic, and often tends to make the divisions between sedimentary categories artificial. The assignment of names is based on estimates of texture and composition by petrographic microscope examination of smear slides on board ship.

Sediment Classification Parameters

Induration

The criteria used to determine the induration of calcareous deposits found on Leg 111 are those of Gealy et al. (1971). For all other deposits, subjective estimates of induration are based on the behavior of the deposits during the core cutting procedure. There are three classes of calcareous sediments: (1) softoozes with little strength that are readily deformed under the finger or the broad blade of a spatula; (2) firm-chalks that are partly indurated oozes or friable limestones, readily deformed under the fingernail or the edge of a spatula blade; and (3) hard-restricted to limestones as a term for cemented rocks. Noncalcareous sediments are divided into two classes of induration: (1) if the material is at such a low state of induration as to allow the core to be split with a wire cutter, the sediment name only is used (e.g., silty clay, mud); and (2) if the core must be cut on the bandsaw or diamond saw, the suffix "stone" is used (e.g., silty claystone, mudstone, or shale, if fissile).

Drilling Disturbance

Recovered rocks and sediments may be slightly to extremely disturbed due to coring and drilling processes. There are six types of disturbance categories used on Leg 111 (Fig. 3) that were entered on the core description barrel sheets under the column entitled "Drilling Disturbance." The disturbance categories are defined as follows: (1) Slightly deformed: Bedding contacts are slightly bent; (2) Moderately deformed: Bedding contacts have undergone extreme bowing; (3) Highly deformed: Bedding is completely disturbed, sometimes showing symmetrical diapirlike structure; (4) Soupy: Water-saturated intervals that have lost all aspects of original bedding; (5) Breccia: Firm sediments or rocks fractured by drilling; and (6) Biscuits: Found only in rotary coring situations.

Sedimentary Structures

Sedimentary structures when identifiable were entered into the column entitled "Sedimentary Structures" on the barrel sheets. The symbols for sedimentary structures used on Leg 111 are shown in Figure 3. The most common sedimentary structures found were bioturbation features. These were recorded on the visual core description forms as shown in Figure 4.

Color

The color of recovered material of Leg 111 was determined according to standard Munsell and Geological Society of America Rock Color charts while the cores were still wet and was recorded on the core description forms.

Lithology

Lithologies are shown in the core description forms by one or more of the symbols shown in Figure 5. These lithologies were determined by the relative abundances of calcium carbonate, biogenic opal, and authigenic and terrigenous detrital components and by the degree of induration. The percent abundances of these components were routinely determined from smear slides; however, supplementary information was obtained from other sampling methods such as coulometric carbonate content analysis. The relative proportions of lithologies are simplified on the barrel sheets, so one should refer to the sediment descriptions and smear-slide data for more detailed lithologic information. The locations of all samples taken for analysis were indicated in the column marked "Sample" on the core description forms, and the results of the analyses are listed below the core descriptions.

Sedimentary Description Conventions

A summary of the lithologic classification scheme adopted by ODP is shown in Figure 6. Only two categories were encountered on Leg 111: pelagic biogenic siliceous and pelagic biogenic calcareous sediments. The major component of a sediment type is always listed last in the sediment name whereas qualifiers are used as long as they are present with greater than 10% abundance in smear slides. The least abundant qualifier is always listed first. As many qualifiers as necessary to adequately describe the sediments were used. Common qualifiers used include clay, radiolarian, diatom, sponge, foraminifer, and nannofossil, which refers to the calcareous tests of coccolithophorids and discoasters.

Pelagic Clay

Pelagic clay is principally composed of authigenic pelagic material that accumulated at very slow rates. The boundary of pelagic clay with terrigenous sediments is where authigenic components (Fe/Mn micronodules, zeolites), fish debris, etc., become common (more than 10% in smear slides). The boundary of pelagic clay with siliceous biogenic sediments is the point at which there is less than 30% identifiable siliceous remains. The boundary of pelagic clay with calcareous biogenic sediment is uncommon, but will usually occur at the base of many oceanic sections that are rich in iron, manganese, and other metallic trace elements. These types of sediments are therefore placed in the "Special Rock" category.

Siliceous Biogenic Sediments

Siliceous biogenic sediments are distinguished from pelagic clay because they contain common (more than 30% in smear slides) siliceous microfossils. Siliceous biogenic sediments are distinguished from the calcareous category by a calcium carbonate content less than total biogenic siliceous content. This differs from the ODP sediment classification in that siliceous biogenic sediments may contain greater than 30% calcium carbonate.

There are two categories of siliceous biogenic sediments: (1) pelagic siliceous biogenic sediments that contain greater than 30% siliceous microfossils and less than 30% silt and clay, and (2) transitional siliceous biogenic sediments that contain between 10% and 70% siliceous microfossils and greater than 30% silt and clay. Transitional siliceous biogenic components were not encountered on Leg 111.

When pelagic biogenic siliceous sediments are soft, they are called oozes such as radiolarian or diatom ooze. When sedi-



Figure 3. Sedimentary deformation and structure symbol codes.

ments of this type are hard they are called radiolarite or diatomite, depending on the dominant component. If the major component is unspecified, the sediments are called siliceous ooze, porcellanite, or chert depending on their hardness.

When only one siliceous component exceeds 10%, this component is used to describe the major category of the sediment and is listed last in the sediment name. If more than one siliceous component is in excess of 10%, these qualifiers are listed in order of increasing abundance. If no single siliceous component exceeds 10%, but all together total more than 30% (and are present in greater quantities than calcium carbonate), the qualifier siliceous is used. Qualifiers such as nannofossil, foraminiferal, or calcareous can be used when these components are present in excess of 10%. If no single calcareous component is in excess of 10%, but all together total over 10%, the qualifier calcareous is used. When more than one calcareous component is present with more than 10%, these qualifiers are used with the least abundant component listed first.

In the transitional biogenic siliceous category, silt and clay make up more than 30% of the sediment whereas siliceous skeletons make up between 10% and 70% of the sediment. These sediments are called siliceous muds, siliceous mudstones, or muddy siliceous oozes. Where the siliceous component exceeds 50%, the term muddy is used as a qualifier.

INTRODUCTION AND EXPLANATORY NOTES

SITE					1	HOL	E				CORE				CORED INTERVAL
TIME-ROCK UNIT	FORAMINIFERS	NANNOFOSSILS SSILS	RADIOLARIANS	SWOLVIG	/ reR	PALEOMAGNETICS	PHYSICAL PROPERTIES	CHEMISTRY	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURB.	SED. STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
						surement >	surement	I analysis ■	1	0.5					Lithologic description
						Paleomagnetic meas	ical properties meas	Chemica	2						
							Phys		3		(Fig. 5)			OG	Organic geochemistry sample
									4		hic lithology symbols	o symbols in Figure 3	o sylinus in signie o		Smear-slide summary (%): Section, depth (cm) M = minor lithology, D = dominant lithology
									5		See key to grap	San kav t	nee ved t	ıw	Interstitial water sample
									6					*	Smear slide or thin section
									7						
									сс						

Figure 4. Visual core description form for sediments/sedimentary rocks.



PELAGIC SEDIMENTS

VOLCANOGENIC SEDIMENTS



ADDITIONAL SYMBOLS



Figure 5. Graphic symbols corresponding to the lithologic visual core descriptions for sediment and sedimentary rocks.

Calcareous Biogenic Sediment

Calcareous biogenic sediment is distinguished by a biogenic calcium carbonate content in excess of 30%. There are two classes: (1) pelagic calcareous biogenic sediments and (2) transitional calcareous biogenic sediments, which were not encountered on Leg 111. Soft pelagic biogenic calcareous sediments are called oozes whereas sediments of this category that are firm are called chalk, and hard sediments are called indurated chalk. The term limestone is restricted to cemented rocks. Transitional bio-

t > 50%

INTRODUCTION AND EXPLANATORY NOTES



Figure 6. Summary chart of lithologic classification for oceanic sediments.

genic calcareous sediments are those that contain more than 30% silt and clay. These types of sediments are identified by the adjective "marly" in front of the dominant qualifier. For example, marly foraminifer ooze.

Qualifiers are used when components are present in excess of 10%. If no calcareous component is present with more than 10% but the sum of all calcareous components exceeds 30% (and is greater than the biogenic silica component), the qualifier calcareous is used to define the major component of the sediment. If more than one calcareous component is in excess of 10%, then more than one qualifier is used and the most abundant component is listed last. Qualifiers of minor components are also used if they are present greater than 10%. If no siliceous component exceeds 10% but the total of all siliceous components exceeds 10%, then the qualifier siliceous is used. When more than one siliceous component is present greater than 10% then qualifiers are listed in order of increasing abundance.

Terrigenous Sediments

Terrigenous sediments are divided into textural groups on the basis of the relative proportions of three grain-size constituents, i.e., clay, silt, and sand. Rocks coarser than sand sizes are treated as "Special Rock Types." The size limits for these constituents are those defined by Wentworth (1922) (Fig. 7).

Five major textural groups are recognized (Fig. 8). These groups are defined according to the abundance of clay (>90%, 90%-10%), <10%) and the ratio of sand to silt (>1 or <1). The terms clay, mud, sandy mud, silt, and sand are used for unconsolidated sediments whereas the suffix "stone" is added when the sediments are hard or consolidated. Sands and sand-stones may be subdivided further into very fine-, fine-, medium-,

coarse-, or very coarse-grained according to their median grain size. Qualifiers were used to note the dominant mineral constituents.

Volcanogenic Sediments

Pyroclastic rocks are described according to the textural and compositional scheme of Wentworth and Williams (1932). The textural groups are (1) volcanic breccia (greater than 32 mm in size), (2) volcanic lapilli (4-32 mm in size), and (3) volcanic ash, tuff if indurated (less than 4 mm in size). Compositionally, these pyroclastic rocks are described as vitric (glass), crystal, or lithic. Qualifiers for volcanic sediments apply the same way as in terrigenous sediments, where possible noting the dominant composition of the grains.

Special Rock Types

The definition and nomenclature of sediment and rock types not included in the classification system defined above are included in special rock types. On Leg 111 this category includes deposits such as metalliferous clays, iron-manganese, and pyrite, etc.

BIOSTRATIGRAPHY

Calcareous Nannofossils

The standard calcareous nannofossil zonation (Martini, 1971) was used during Leg 111 to identify nannofossil zones (Fig. 9). All latest Miocene through Pleistocene marker species used in the zonal scheme are listed in Table 2, together with their assigned age estimates.

MILLIMETERS	μm	РНІ (Ø)	WENTWORTH SIZE CLA	SS
4096 1024		-20 -12 -10	Boulder (-8 to -12 Ø)	
256		†*	Cobble (-6 to -8 Ø)	- <u> </u>
64			Debble (Data C.O.)	- N
16		-4	Peoble (-2 to -6 Ø)	GR
3 36		.1 75		0
2.83		.15	Granula	
2.38		-1.25	Grandie	
2.00		-1.0		
1.68		-0.75		
1.41		-0.5	Very coarse sand	
1.19		-0.25		
1.00		0.0		
0.84		0.25		
0.71		0.5	Coarse sand	
0.59		0.75		
1/2 0.50		1.0 -		
0.42	420	1.25		
0.35	350	1.5	Medium sand	2
0.30	300	1.75		SAI
1/4	250	2.0 -		
0.210	210	2.25		
0.177	177	2,5	Fine sand	
0.149	149	2.75		
1/80.125	—125——	3.0		
0.105	105	3.25		
0.088	88	3.5	Very fine sand	
0.074	74	3.75		
1/16 - 0.0625 -	- 63	4.0 -		
0.053	53	4.25		
0.044	44	4.5	Coarse silt	
0.037	37	4.75		
1/32 0.031	31	5.0		8
1/64 0.0156	15.6	6.0	Medium silt	
1/128 0.0078	7.8	7.0	Very fine silt	٥
1/256 - 0.0039 -	3.9	8.0	vory mic and	MU
0.0020	2.0	9.0		1275-1
0.00098	0,98	10.0	Clay	
0.00049	0.49	11.0		
0.00024	0.24	12.0		
0.00012	0.12	13.0		
0.00006	0.06	14.0		

Figure 7. Wentworth size scale.

Methods

Abundance

The abundances of individual nannofossil species are defined as follows:

Rare: <0.1% (of the total assemblage) Few: 0.1%-1.0% (of the total assemblage) Common: 1.0%-10.0% (of the total assemblage) Abundant: >10.0% (of the total assemblage).

Preparation

Smear-slide preparation followed standard procedures: a small piece of sediment was smeared onto a glass slide with a drop of water using a flat toothpick. A cover-slip was then mounted.



Figure 8. Class boundaries for terrigenous sediments.

Samples studied using scanning electron microscopy (SEM) were dispersed in water in a glass vial using ultrasonic vibration for about 30 s. A few drops of the suspension were pipetted onto an aluminum SEM stub, dried, and coated.

Planktonic Foraminifers

The planktonic foraminiferal zonal scheme of Jenkins and Orr (1972) developed for the tropical eastern Pacific was used during Leg 111 (Fig. 9). The late Miocene through Pleistocene marker species used in the zonal scheme are listed in Table 3, together with their assigned age estimates.

Methods

Abundance

The abundances of individual planktonic foraminiferal species are defined as follows:

Rare: <1.0% (of the total assemblage) Common: 1.0%-10.0% (of the total assemblage) Abundant: >10.0% (of the total assemblage).

Preparation

The core-catcher samples were disaggregated in distilled water, washed over a 63- μ m screen, and dried in a oven. The fraction >63 μ m was examined.

Radiolarians

The radiolarian zones used for the sediments at Site 677 are those of Riedel and Sanfilippo (1978). Several other schemes have been proposed for the Quaternary (Nigrini, 1971, and Goll, 1980). These zonal schemes could not be used for the sediments recovered during Leg 111 because indicator species are rare in the assemblages and do not exhibit consistent ranges, making selection of events used to define these zones difficult.

Methods

Preparation

Radiolarian slides were prepared by first removing organic materials with hydrogen peroxide and carbonates with hydrochloric acid from oven-dried samples. Calgon was added to the samples, which were then washed through a 63- μ m sieve at least three times in order to remove as much clay as possible. The radiolarian residue was then randomly settled in a 600-mL beaker onto a slide. The slides were dried and cover-slips were mounted with Canada balsam.



Figure 9. Biostratigraphic framework used as a guide to initially place the Leg 111 sediments in a time-stratigraphic sequence.

Procedure

Sixty-five radiolarian species (Table 4) known to occur in the equatorial Pacific and/or that have species events which occurred during the interval of late Miocene to Recent were sought in each sample. Due to the high preservation and great diversity of radiolarians in these assemblages, qualitative determinations of abundance were not easily made. The presence or absence of each species was noted. Ranges were determined by graphing the occurrences of each species. Two or more specimens per sample were considered to indicate that the occurrence of that species was consistent in each sample. If only one specimen of a species was noted in a sample, this was not considered to be a consistent occurrence.

PHYSICAL PROPERTIES

In considering the physical-properties measurements made during Leg 111 it is convenient to separate the Hole 504B basalt-core measurements from the measurements of cores taken at the sediment sites. Whilst many of the measurements made are common to both programs, differences do exist both in the range of measurements accomplished and in the techniques apTable 2. Species events defining calcareous nannofossil zonal boundaries and their assigned age estimates.

	Genus and		Age		
Event	species	Zone	(Ma)	Ref.	
Increase	Emiliania huxleyi	-	0.085	1	
f.o.	E. huxleyi	NN21	0.275	1	
1.0.	Pseudoemiliania lacunosa	NN20	0.475	1	
1.0.	Helicosphaera sellii	_	1.37	2	
1.0.	Calcidiscus macintyrei	—	1.45	2	
Pliocene/	Pleistocene boundary		1.66	3	
1.0.	Discoaster brouweri	NN19	1.89	3	
1.0.	D. pentaradiatus	NN18	2.35	2	
1.0.	D. surculus	NN17	2.41	2	
1.0.	D. tamilis		2.65	2	
l.o.	Sphenolithus spp.		3.45	2	
1.0.	Reticulofenestra pseudoumbilica	NN16	3.56	3	
1.0.	Amaurolithus tricorniculatus	NN15	3.7	4	
f.o.	D. asymmetricus	NN14	4.1	4	
1.0.	A. primus		4.4	4	
f.o.	Ceratolithus rugosus	NN13	4.6	2	
1.0.	C. acutus		4.6	2	
f.o.	C. acutus		5.0	4	
Miocene/	Pliocene boundary		5.3	4	
l.o.	D. quinqueramus	NN12	5.2-5.6	4, 5	
1.0.	A. amplificus	—	5.6	4	
f.o.	A. amplificus	-	7.4	6	

Note: f.o. = first occurrence, l.o. = last occurrence. Ref. pertains to the age column and represents (1) Thierstein et al. (1977), (2) Backman and Shackleton (1983), (3) Rio et al. (in press), (4) see data presented by Berggren et al. (1985), (5) Lohman (1986), and (6) Backman (pers. comm., 1987). All zonal assignments refer to the lower boundary.

Table 3. Species events defining planktonic foraminiferal zonal boundaries and their assigned age estimates.

Event	Genus and species	Zone	Age (Ma)	Ref
l.o.	Globigerinoides fistulosus	Pulleniatina obliquiloculata	1.6	1-3
Pliocen	e/Pleistocene boundary		1.66	4
f.o.	G. fistulosus	G. fistulosus	2.9	2
f.o.	Sphaeroidinella dehiscens	S. dehiscens	5.1?	2, 3
f.o.	Globorotalia tumida	G. tumida	5.2	3, 5
Miocen	e/Pliocene boundary		5.3	6

Note: f.o. = first occurrence, l.o. = last occurrence. Ref. pertains to the age column and represents (1) Berggren et al. (1980), (2) Hays et al. (1969), (3) Saito et al. (1975), (4) Rio et al. (in press), (5) Keigwin et al. (1982), and (6) see data presented by Berggren et al. (1985). All zonal assignments refer to the lower boundary.

plied in each case. The following physical-properties measurements were made routinely on the ship, although not all of the properties were measured for each core:

Hole 504B basalt cores: Bulk density (GRAPE 2-min count) Thermal conductivity (half-space needle probe) Compressional wave velocity (Hamilton Frame) Index properties (bulk density, porosity, water content, and grain density)

Sediment cores:

Bulk density (GRAPE continuous log) Compressional wave velocity (*P*-wave logger) Thermal conductivity (needle probe) Compressional wave velocity (Hamilton Frame)

Table 4. Radiolarian species list.

Stylatractus universus	Pterocanium prismatium
Collosphaera huxlevi	Lychnodictyum audax
Collosphaera invaginata	Stichocorys delmontensis
Collosphaera orthoconus	Stichocorys peregrina
Collosphaera tuberosa	Botryostrobus aquilonaris
Polysolenia lappacea	Botryostrobus bramlettei
Siphonosphaera tenera	Botryostrobus miralestensis
Solenosphaera omnitubus	Botryostrobus sp.
Acrosphaera trepanata	Phormostichoartus corbula
Acrosphaera cyrtodon	Phormostichoartus doliolum
Amphispyris roggentheni	Phormostichoartus fistula
Nephrospyris renilla renilla	Phormostichoartus marylandicus
Androspyris anthropiscus	Siphostichoartus corona
Androspyris fenestrata	Spirocyrtis gyroscalaris
Androspyris huxleyi	Spirocyrtis scalaris
Tholospyris devexa devexa	Didymocyrtis antepenultima
Tholospyris devexa finalis	Didymocyrtis avita
Pseudocubus warreni	Didymocyrtis penultima
Neosemantis hofferti	Didymocyrtis tetrathalamus
Sphaerozoum punctatum	Diartus hughesi
Sphaerozoum crassus	Spongaster berminghami
Amphirhopalum ypsilon	Spongaster pentas
Anthocyrtidium angulare	Spongaster tetras
Theocorythium trachelium	Spongodiscus ambus
Theocorythium vetulum	Dendrospyris bursa
Theoconus hertwigii	Calocycletta caepa
Pterocorys minithorax	Calocycletta robusta group
Pterocorys zancleus	Acrobotrys tritubus
Lamprocyrtis hannai	Centrobotrys thermophila
Lamprocyrtis heteroporus	Eucyrtidium sp. cf E. diaphanes
Lamprocyrtis neoheteroporus	Lithopera bacca
Lamprocyrtis nigriniae	Dictocoryne ontongenesis
Theocalyptera davisiana	

Shear strength (vane shear)

Index properties (bulk density, porosity, water content, and grain density)

Carbonate content (coulometric technique)

Standard procedures were invoked for the measurements as described below and in the appended references.

GRAPE Bulk Density

The Gamma Ray Attenuation Porosity Evaluator (GRAPE) was used to determine the density of both discrete samples of basalt and sections of whole-round sediment cores. In all cases the sample was positioned between a shielded gamma-ray source and a shielded scintillation detector. The beam attenuation is primarily due to Compton scattering and, as such, is directly related to the material's density. The principles of the technique are thoroughly described by Evans (1965), while its application to the (DSDP) ODP program, together with the necessary calibration procedures, are documented by Boyce (1976).

2-Minute Counts

In this static mode a discrete sample of material is placed between the source and detector, and the number of counts is monitored over a 2-min period. Consideration of this value in relation to the sample thickness and associated calibration results enables a value for the bulk density to be determined. The whole system is calibrated empirically using a quartz standard, and the computed bulk density of the sample is corrected for deviations from this standard value by considering the true grain density determined by conventional gravimetric and volumetric techniques.

Continuous Mode

Routine use of the GRAPE to log sections of whole cores prior to their being split was accomplished at the sediment sites. A whole-core section travels on a moving rack between the source and detector; a single measurement relates to a period of 2.19 s or approximately every 3.5 mm of core travel (Boyce, 1976). An aluminum standard was used for empirical calibration of the system. The raw data were logged on the PRO-350 and subsequently transferred to the VAX for processing.

Compressional Wave Logger

The compressional wave whole-core logging tool (PWL) is designed to log the compressional wave velocity of whole-core sections using a pair of 500-kHz PZT4 ceramic piezoelectric transducers. The transducer frame is bolted to the GRAPE, adjacent to the GRAPE source and detector such that the GRAPE and PWL can be run simultaneously. The data are currently logged on a dedicated BBC microcomputer. While a sampling interval of 2 mm is possible, experimental tests have shown that there is little to be gained by sampling more frequently than every 2 cm (Schultheiss, 1985). Calibration of the system was accomplished using a core liner filled with distilled water. The logger is designed for use on whole cores in good condition and exhibiting good recovery. Split liners, incompletely filled liners, or the presence of gas even in very small proportions will severely inhibit the propagation of the acoustic pulse and the attendant resolution of the measurement. Complete details of the system are given by Schultheiss (1985) and further information will be published in the ODP Proceedings volume for Leg 108 (Schultheiss and McPhail, in press).

Compressional Wave Velocity (Hamilton Frame)

Compressional wave velocity measurements were also made using the Hamilton Frame. These measurements were made on the minicores of basalt and samples of sediment taken for paleomagnetic analyses and index properties determinations. The design and operating procedure is described by Boyce (1976). Calibration of the device was undertaken using aluminum and plexiglas standards.

Index Properties

This suite of data comprises gravimetric and volumetric determinations used to evaluate the parameters of wet and dry densities, porosity, water content, void ratio, and grain density. At Hole 504B minicores of rock were used where possible, with rock-chips being substituted where poor recovery precluded such sampling. The sediment sites enabled samples of approximately 10 cm³ to be taken in 10-cm³ pre-calibrated aluminum containers from freshly split cores on a routine basis of one per section down the first hole at each site. Additional sediment samples were obtained from either the relevant section or, in the case of Site 677, the adjacent hole to supplement the data set at intervals where the GRAPE and/or PWL indicated significant local fluctuations in density or velocity, respectively.

Wet and dry weights were determined on board using the motion-compensated Scitech electronic balance to an accuracy of ± 0.01 g. Sample volumes were determined for both the wet and dry specimens using the Penta-pycnometer. This apparatus is designed for the precise evaluation of volumes of dry powders and as such it works well for dry samples. Problems can arise with wet samples where the helium gas used as a displacement fluid apparently dissolves in the pore water present. Measurements on wet samples thus result in pseudo-low volume determinations. With increased purge times the fluid apparently becomes helium-saturated, and the determined volume approaches a steady state. If due caution is not observed in the procedure adopted, it is possible to achieve a pseudo-low wet volume smaller than the pycnometer-measured dry volume! Purge times of 5 min were adopted and measurements repeated; the accuracy of the system under a calibration test was shown to be 0.7%. The basalt samples were oven-dried at 110°C to constant weight. The sediment samples were treated to a combination of oven- and freeze-drying, again to constant weight.

Vane Shear Measurements

Motorized vane tests were performed using the Wykeham Farrance apparatus. Sediments at each site were tested whilst still in their core-liners at a frequency of one per section. The technique is adequately described by Boyce (1977) and is valid only for fine-grained sediments.

Thermal Conductivity

Thermal-conductivity measurements were made on the basalt samples from Hole 504B and on the sediment samples from the remaining sites. The basalt samples were taken from either the same piece as the minicore used for the other physical-properties measurements or from a contiguous piece determined to be from the same lithological unit. Measurements in the sediments were made on whole cores at a frequency of one per section prior to their being split.

The measurement principle is that of the transient line source (Carslaw and Jaeger, 1959). In the sediments this involved the use of the needle probe technique (Von Herzen and Maxwell, 1959), whereas in the basalts the half-space modification was employed (Vacquier, 1985). Both techniques were calibrated using standards supplied by the ODP.

Carbonate Content

The inorganic carbon (carbonate) was determined using the Coulometrics Carbon Dioxide Coulometer as described by Ruddiman, Sarnthein, Baldauf, et al., (1987).

PALEOMAGNETISM

Hard-rock Paleomagnetism

Paleomagnetic measurements were performed on minicore samples taken from selected areas within the recovered cores. These areas were chosen on the basis of lithologic homogeneity and the ability to orient the samples with respect to the vertical direction. When possible, at least one shipboard sample was taken from each core section (1.5 m). However, some sections were not sampled at all, as much of the recovered core consisted of unoriented fragments and drilling rubble.

Magnetic susceptibility (X_0) was measured using a Bartington Magnetic Susceptibility Meter (Model MS1). This value of initial susceptibility was used in conjunction with natural remanent magnetism (NRM) values to calculate the Q ratio (Koenisberger) of the samples. In this calculation a field value of 0.5 Oe was assumed so that

$$Q = \frac{NRM}{(X_0 \times 0.5)}$$

Remanent magnetization was measured with a MOLSPIN Portable Rock Magnetometer. This spinner-type magnetometer was interfaced to a DEC PRO-350 microcomputer using software written by Dr. Y. Hamano on Leg 109. Step-wise alternating field (AF) demagnetization was performed with a single-axis Schonstedt Geophysical Specimen Demagnetizer (Model GSD-1) in 25-Oe steps until the speciman fell below the median destructive field (MDF), and a stable inclination was identified on a Zijderveld plot.

Sedimentary Paleomagnetism

Paleomagnetic measurements were made on recovered sediments in order to determine the magnetic reversal chronology. Because these are equatorial sediments with a theoretical inclination of zero, this task required cores that were oriented azimuthally. This type of orientation was measured with the Multishot camera system which, for cores taken with the APC technique only, is sent down with the overshot tool. The camera photographs the compass and inclinometer readings made with respect to the core barrel after the overshot tool is in place and the piston has been fired. This information allows us to correct observed magnetic declination and inclination values to magnetic north and true vertical. The first 15 cores of Hole 677A were taken with the APC, and of these only 7 had successful multishot data. The multishot system was not used at Hole 677B due to time constraints, and thus our measurements are restricted to Hole 677A.

Remanent magnetization was measured with a MOLSPIN Portable Rock Magnetometer. For these measurements, we used minicube samples (7 cm³) that were taken from the recovered core. Sampling density was one per section (1.5 m), and pervasive bioturbation prevented the selection of only laminated areas. Minicubes from unoriented cores were measured for NRM intensity and direction only. Oriented samples were measured for NRM intensity and direction and then demagnetized in steps of 50, 100, 200, and 300 Oe in order to determine stable inclination.

Magnetic susceptibilities were measured on whole cores using a Bartington Susceptibility Meter (Model MS1). This model uses a loop-type sensor which allows pass-through of whole cores. Prior to measurements, cores were cleaned thoroughly to reduce metal contamination. A sampling interval of 10 cm was chosen, and proved appropriate for these sediments.

WATER CHEMISTRY

Interstitial Waters from Sediments

Interstitial waters were obtained from sediments both by squeezing cored sediment and by *in-situ* extraction using the Barnes pore water sampler.

For the squeezed samples, three types of core subsample were used to satisfy the requirements of the stratigraphers for a complete section: (1) 5-cm whole rounds, (2) 20-cm quarter rounds, and (3) 50-cm³ plugs. The whole rounds were cut from the core immediately on recovery by slicing the plastic core tube and capping and taping the ends. These samples were then stored for several hours prior to squeezing while the biostratigrapher determined that they did not represent critical intervals. Where samples were needed from potentially critical intervals, 20-cm quarter rounds or 50-cm3 plugs were taken instead. These were removed from the working half of the core immediately after it had been split. Surfaces from the exterior of the core were scraped with a plastic spatula to remove any sediment contaminated with seawater during the coring procedure. (This precaution was taken with the whole-round samples as well.) The samples were then sealed in plastic zip-closure bags and squeezed as soon as possible. Samples from the upper part of the sediment column were refrigerated prior to squeezing to approximate insitu temperatures. Squeezing was done in a Manheim-type stainless steel squeezer, specially cleaned with alcohol and acetone for determination of various organic species. Other tools that contacted the sediment, including spatulas and cutting wires, were cleaned with HCl or alcohol and acetone. Both the squeezer and the samples were handled only with plastic gloves to avoid contamination. The squeezer was placed in a Carver press in the shipboard laboratory and squeezed at pressures up to 40,000 psi. Interstitial water was collected directly into a 50-mL plastic syringe, then filtered on-line through a 0.22-µm Millipore cellulose acetate filter into a second syringe, from which the various aliquots for analysis were ejected. Squeezed interstitial waters are here designated "IW" samples.

The *in-situ* pore water sampler is the new version designed by Dr. R. Barnes in 1986 and first used on Leg 110. This tool collects as much as 66 mL of interstitial water while making simultaneous measurements of sediment temperature and pore pressure. It is lowered on the sand line to the end of the drill string, where it locks into an assembly just above the bit. During its descent the hole is flushed with drilling fluid with the bit just off bottom, to keep the hole free of fill. After the sampler is latched into place the bit is lowered into the bottom with the sampling probe projecting about 20 cm through the bit. A timer-operated valve opens and interstitial water is drawn under negative pressure through two 40-µm stainless-steel filters and one 1-µm nylon filter into the sampler. There it passes through a stainlesssteel entry tube of 6 mL volume into two sample coils arranged in series and separated by an open ball valve, and then into a steel overflow cylinder of 1200 mL volume that also contains the sample coils and valving. The tubing and sample coils are initially filled with distilled water, which is displaced along with about 1 mL of seawater from the dead volume outside the entry valve, into the overflow cylinder. The first of the two sample coils in series is made of stainless steel and has a volume of 20 mL. The second is copper and has a volume of 46 mL; it typically is used for determination of helium isotopes and dissolved gases. We have also analyzed the water from the overflow cylinder, as it often is useful for determination of major and minor dissolved species. The amount of dilution of this overflow aliquot can usually be determined from its chlorinity relative to that of the undiluted sample. The length of time required to fill the Barnes sampler varies with permeability of the sediment, but typically is about 20 min. Interstitial water samples collected with the Barnes tool are here designated "BW." On removal from the stainless steel coil, they were filtered (0.22 μ m) as for the squeezed samples.

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