3. EXPLANATORY NOTES¹

Shipboard Scientific Party²

INTRODUCTION

In this chapter, we have assembled information that will help the reader understand the basis for our preliminary conclusions and also help the interested investigator select samples for further analysis. This information concerns only shipboard operations and analyses described in the site reports in the *Initial Results* volume of the Leg 142 *Proceedings of the Ocean Drilling Program*. Methods used by various investigators for shore-based analysis of Leg 142 data will be detailed in the individual scientific contributions published in the *Scientific Results* volume.

Authorship of Site 864 Chapter

The separate sections of the "Site 864" chapter were written by the following shipboard scientists:

Site Summary: Batiza, Shipboard Scientific Party Igneous Petrology: Allan, Bach, Batiza, Boström, Brophy, Harpp, Haymon, Hekinian, Niu Magnetism: Sharma Inorganic Geochemistry: Von Damm Organic Geochemistry/Biology: Lilley Physical Properties: Anderson, Fryer, Johnson, Polyak Downhole Measurements: Fryer, Polyak Conclusions: Batiza

Shipboard Scientific Procedures

Numbering of Sites, Holes, Cores, and Samples

Ocean Drilling Program (ODP) drill sites are numbered consecutively and refer 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 the hole), moving the ship some distance from the previous hole, and then drilling another hole.

For all ODP drill sites, a letter suffix distinguishes each hole drilled at the same site. For example, the first hole drilled is assigned the site number modified by the suffix A, the second hole takes the site number and suffix B, and so forth. Note that this procedure differs slightly from that used by the Deep Sea Drilling Project (DSDP) (Sites 1 through 624), but prevents ambiguity between site- and hole-number designations. It is important to distinguish among holes drilled at a site, because recovered rocks from different holes usually do not come from equivalent positions in the stratigraphic column.

The cored interval is measured in meters below 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 (see Fig. 1). For example, each coring interval is generally up to 3.05 m long, which is the length of a diamond coring system (DCS) core barrel. Coring intervals may be shorter and may not necessarily be adjacent if separated by drilled intervals.

Cores taken from a hole are numbered serially from the top of the hole downward. Core numbers and their associated cored intervals in meters below seafloor usually are unique in a given hole; however, this may not be true if an interval must be cored twice, because of caving of cuttings or other hole problems. Maximum full recovery for a single core is 3.05 m of rock contained in a plastic liner (5.6-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.

All recovered core is divided into approximately 1.5-m-long sections which are numbered serially from the top. As all individual recovered cores during Leg 142 were accommodated within single sections, all sections are numbered 1. An exception was Core 142-864A-1M, which represented two bit samples and four junk-basket recoveries from the interval 0–6.6 mbsf during drilling and holecleaning operations. These samples were sieved into three size fractions (<1 mm, 1–5 mm, and 5 mm to 5 cm). For descriptive purposes, the largest size fraction was deemed representative of the material and loaded into D-tubes, where it was separated into different sample types and described within the HARVI and HRTHIN databases. Each individual recovery received a succeeding section number, thereby retaining the "stratigraphy" of recovery (Fig. 2).

Each piece of rock within contiguous core was assigned a number. Fragments of a single piece were assigned a single number, and individual fragments were identified alphabetically. Scientists completing visual core descriptions described each lithologic unit, noting core and section boundaries only as physical reference points. When, as is usually the case, the recovered core was shorter than the cored interval, the top of the core was 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 were designated by distance measured in centimeters from the top of the section to the top and bottom of each sample removed from that section. Sturdy plastic spacers were placed between pieces that did not fit together in order to protect them from damage in transit and in storage; therefore, the centimeter interval noted for a hard-rock sample has no direct relationship to that sample's depth within the cored interval, but is only a physical reference to the location of the sample within the curated core.

Å full identification number for a sample consists of the following information: leg, site, hole, core number, core type, section number, piece number (for hard rock), and interval in centimeters measured from the top of section. For example, a sample identification of "142-864A-3Z-1, 10–12 cm" would be interpreted as representing a sample removed from the interval between 10 and 12 cm below the top of Section 1, Core 3 (Z designates that this core was taken during DCS coring) of Hole 864A during Leg 142.

All ODP core and sample identifiers indicate core type. The following abbreviations are used: R = rotary core barrel (RCB); B = drill-bit recovery; C = center-bit recovery; I = in-situ water sample; S = sidewall sample; W = wash-core recovery; Z = diamond coring system core, and M = miscellaneous material. M, W, and Z cores were cut during Leg 142.

¹ Storms, M.A., Batiza, R., et al., 1993. Proc. ODP, Init. Repts., 142: College Station, TX (Ocean Drilling Program).

² Shipboard scientific party is as given in the list of participants preceding the contents.



Figure 1. Terms used in the discussion of coring operations and core recovery.

Core Handling

Once on deck, the core catcher was placed at the bottom of the core liner and total core recovery was calculated by shunting the rock pieces together and measuring to the nearest centimeter; this information was logged into the shipboard core-log database program. After carrying into the lab, the contents of each section were transferred into 1.5-m-long sections of split core liner, where the bottom of oriented pieces (i.e., pieces that clearly could not have rotated top to bottom about a horizontal axis in the liner) were marked with a red wax pencil. This was to ensure that orientation was not lost during the splitting and labeling process.

The core was then split into archive and working halves. A plastic spacer was used to separate individual pieces and/or reconstructed groups of pieces in the core liner. These spacers may represent a substantial interval of no recovery. Each piece was numbered sequentially from the top of each section, beginning with number 1; reconstructed groups of pieces were assigned the same number, but were lettered consecutively downcore. Pieces were labeled only on external surfaces. If the piece was oriented, an arrow denoting the up direction was added to the piece label.

The working half of the hard-rock core was sampled once a day by the entire scientific party for shipboard laboratory studies. Each extracted sample was logged into the sampling computer database program that notes its location. Records of all samples are kept by the curator at ODP. Minicore samples were routinely taken for physical properties and magnetic studies. Some of these samples were later subdivided for X-ray fluorescence (XRF) analysis and thin-sectioning, so that as many measurements as possible are made on the same pieces of rock. At least one minicore was taken per lithological unit when recovery permitted, generally from the freshest areas of core. Additional thin sections and XRF samples were selected from areas of particular interest. Samples for shore-based studies were selected in a single sampling party held after drilling on the leg had ended.

The archive half was described visually, then photographed with black-and-white film, one core at a time. Close-up photographs (black and white) were taken of particular features for illustrations in the summary of each site, as requested by individual scientists. Both halves of the core were then shrink-wrapped in plastic to prevent rock pieces from vibrating out of sequence during transit, put into labeled plastic tubes, sealed and transferred to cold-storage space aboard the drilling vessel. At the end of the leg, the cores were transferred from the ship in refrigerated airfreight containers to cold storage at the Gulf Coast Repository at the Ocean Drilling Program, Texas A&M University, College Station, Texas.

IGNEOUS PETROLOGY

Visual Core Descriptions

Visual core description (VCD) forms were used in the documentation of the igneous rock cores (see Section 3 of this volume). The left column is a graphic representation of the archive half. A horizontal line across the entire width of the column denotes a plastic spacer. Oriented pieces are indicated on the form by an upward-pointing arrow to the right of the piece. Shipboard samples and studies are indicated in the column headed "shipboard studies," using the following notation: F = X-ray fluorescence analysis; T = petrographic thin section; P = physical properties analysis; and X = magnetic analysis.

To ensure consistent and complete descriptions, the visual core descriptions were initially entered into the computerized database HARVI. The database is divided into separate data sets for finegrained rocks and coarse-grained rocks. Each record was checked by the database program for consistency and completeness, with the final record printed next to the visual core descriptions and core photos (see Section 3 of this volume).

When describing sequences of rocks, the core was subdivided into lithologic units on the basis of changes in one or more of the follow-





 Other comments, including notes on the continuity of the unit within the core and on the interrelationship of units.

Basalts are termed aphyric (<1%), sparsely phyric (1%-2%), moderately phyric (2%-10%), or highly phyric (>10%), depending upon the proportion of phenocrysts visible with the hand lens or binocular microscope. Basalts are further classified by phenocryst type (e.g., a moderately phyric olivine plagioclase basalt contains 2%-10% phenocrysts, mostly plagioclase, with subordinate olivine). Volcanic rock names were initially assigned from megascopic phenocryst assemblages. As chemical analyses or thin sections became available, rock names were occasionally modified.

The descriptive terms used for basalts differs somewhat from that suggested in the "Shipboard Scientist's Handbook." For phyric rocks, the order of mineral name modifiers to the rock name is given in order of increasing abundance in the sample. In addition, the proportion of phenocrysts (e.g., sparsely phyric) is given as the first modifier to the rock name.

Visual core descriptions of igneous rocks are given in the Section 3 of this volume, and descriptions of each rock unit are available from the computerized database at the ODP repositories.

Thin-section Descriptions

Thin sections of igneous rocks were examined to complement and refine the hand-specimen observations. The modal percentages and textural descriptions of individual phases were initially entered into the computerized database HRTHIN, with subsequent editing after transferral to a word-processing program. The same terminology was used for thin-section descriptions as was used for the megascopic descriptions. Thin-section descriptions are included in Section 4 of this volume and are also available from the ODP computerized database.

Lavas erupted on the seafloor typically show a chilled glassy margin grading inward to a spherulitic (synonymous with variolitic) zone of quench phases, which may then grade into a coarser microlitic zone toward the interior of the flow. The interiors of thicker flows commonly show intergranular to subophitic and ophitic textures. In many samples, especially those from sheet flows and lobated flows that are commonly flow-banded, these zones are not well defined and may be expressed as alternating layers or areas. Varioles commonly show a sheaflike or radial form, and microlites commonly show crystal clustering networks in areas of microlitic texture. We follow Bryan (1972) and Natland (1978) in believing that these textures are quench-growth features and do not represent post-solidification phenomena. We also believe that microlitic texture occurs independently of the presence of phenocrysts. Finally, we use the term intergranular to refer to groundmass textures in which individual crystals are granule-shaped with little intergrowth. Figures 3, 4, 5, and 6 show examples of quench-growth crystal textures.

Estimations of phenocryst content are complicated by the fact that the term phenocryst has both textural and size connotations. We have used the textural connotation for the phenocryst descriptions in the HRTHIN phenocryst subheading.

X-ray Fluorescence Analysis

Prior to analysis, samples were crushed in a Spex 8510 shatterbox using an alumina ceramic barrel in order to avoid W, Nb, Ta, and Co contamination. Where recovery permitted, at least 20 cm³ of material was ground to ensure representation of the sample, and to allow for use in shore-based as well as shipboard analyses.

A fully automated wavelength-dispersive ARL8420 XRF system equipped with a Rh target X-ray tube was used to determine the major oxide and trace-element abundances of whole-rock samples (see



Figure 2. Section configuration and depth range of recovery for the two bit recoveries and four junk basket recoveries of Core 142-864A-1M.

ing: texture, grain size, mineral occurrence and abundance, rock composition, or rock clast type. For each lithologic unit and section, the following information was recorded in the database system:

1. The leg, site, hole, core number, core type, and section number.

2. The unit number (consecutive downhole), position in the section, number of pieces of the same lithologic type, the rock name, and the identification of the describer.

The color of the dry rock and the presence and character of any structural fabric.

4. The number of mineral phases visible with a hand lens and their distribution within the unit, together with the following information for each phase: (1) abundance (volume percentage); (2) size range in millimeters; (3) shape; (4) degree of alteration; and (5) further comments.

5. The groundmass texture: glassy, fine-grained (<1 mm), medium-grained (1-5 mm), or coarse-grained (>5 mm). Grain size changes within units were also noted.

The presence and characteristics of secondary minerals and alteration products.

7. The abundance, distribution, size, shape, and infilling material of vesicles (including the proportion of vesicles that are filled by alteration minerals).

8. The rock structure, including the determination of whether the flow is massive, pillowed, thin or sheetlike, brecciated, or a hyaloclastite.

9. The amount of rock alteration, expressed both in the description and next to the graphic description of the archive half. Alteration was graded as fresh (<2%); slightly altered (2%–10%); moderately altered (10%–40%); highly altered (40%–80%); very highly altered (80%– 95%); and completely altered (95%–100%). The type, form, and distribution of alteration was also noted.



Figure 3. Crystallites, radial spherules, and plagioclase crystals in glass, interval 142-864A-1M-2, 0-35 cm. Field of view is 5.6 mm across.

Table 1 for analytical conditions). Analyses of the major oxides were conducted on lithium borate glass disks doped with lanthanum as a "heavy absorber" (Norrish and Hutton, 1969). The disks were prepared from 500 mg of rock powder that had been ignited for 2 hr at about 1030°C and mixed with 6.000 g of preweighed (on shore) dry flux consisting of 80% lithium tetraborate and 20% La_2O_3 . This mixture was then melted in air at 1150°C in a Pt-Au crucible for about 10 min and poured into a Pt-Au mold using a Claisse Fluxer. The 12:1 flux-to-sample ratio and the use of the lanthanum absorber made matrix effects insignificant over the normal range of igneous rock compositions. Hence, the relationship between X-ray intensity and concentration becomes linear and can be described by:

$C_i = (I_i \cdot m_i) - b_i,$

where C_i = concentration of element *i* (weigh percentage, or wt%); I_i = peak X-ray intensity of element *i*; m_i = slope of calibration curve for element *i* (wt%/counts per second); and b_i = apparent background concentration for element *i* (wt%). Analytical conditions for the XRF analyses are given in Table 1.

The slope m_i was calculated from a calibration curve derived from the measurement of well-analyzed reference rocks (BHVO-1, G-2, AGV-1, AII-92-29-1, BE-N, BIR-1, DR-N, GH, JB-1a, JB-2, JB-3, JGB-1, JP-1, BR, MRG-1, NBS-688, RGM-1, STM-1, UB-N, BAS-111, DRN, and SiO₂). Standardization curves typically gave correlation coefficients for the major elements between 0.995 and 1.000. The background b_i was determined by regression analysis from the calibration curves. The differences in expected vs. analyzed major element composition for these standards derived from the calibration curves are given in Table 2, and represent an estimation of the accuracy of the analysis procedure. Systematic errors resulting from short-term or long-term fluctuations in X-ray tube intensity and instrument temperature were addressed by counting an internal standard between no more than six unknowns in any given run. The intensities of this standard were normalized to its known values, providing correction factors to the measured intensities of the unknowns. To reduce shipboard weighing errors, two glass disks were prepared for each sample. Accurate weighing was difficult on board the moving platform of the *JOIDES Resolution*, and was performed with particular care, as weighing errors could be a major source of imprecision in the final analysis. Loss on ignition was determined by drying the sample at 110°C for 8 hr, and then by weighing before and after ignition at 1030°C in air.

Trace-element determinations were made on pressed-powder pellets prepared by pressing (with 7 tons of pressure) a mixture of 5.0 g of dry rock powder (dried at 110°C for >2 hr) and 30 drops of polyvinyl alcohol binder into an aluminum cap. A minimum of 5 g for sample size ensures that the sample will be infinitely thick for Rh K-series radiation (20 keV). A modified Compton scattering technique based on the intensity of the Rh Compton peak was used for matrix absorption corrections (Reynolds, 1967). The analyses of the standard BHVO derived from the calibration curves used are given in Table 3.

An internal analytical standard was produced by pooling glass fragments collected by the junk basket during reaming of the uppermost portion of Hole 864A (Sample 142-864A-1M-3, 0–100 cm; BAS142). This sample was used to examine whether the alumina grinding barrel produced significant contamination of the sample. Results of repeated analysis of BAS142 (size fraction 0.1 to 0.5 cm, with grinding times of 3.5 to 7 min) and quartz sand show no significant relative contamination of any element with respect to the grinding barrel used (Table 4). In particular, the difference in average Al_2O_3 of the BAS142 standard ground in alumina ceramic vs. tungsten carbide



Figure 4. Spherulitic texture: coalesced radial spherules, sheaf spherule, and acicular plagioclase microlites, interval 142-864A-1M-6, 0–76 cm. Field of view is 5.6 mm across.

is within the analytical uncertainty of the analysis method. Replicate analyses of this internal standard and the international rock standard BHVO (Tables 3 and 4) are consistent with previous experience, showing that the major-element data are precise to within 0.2 to 2.5 relative percent, and are considered accurate to $\approx 1\%$ for Si, Ti, Al, Fe, Mg, Ca, and K, and between 3% and 5% for Al, Na, and P. Precision is within 0.5%–6% for Zr, Y, Sr, Zn, Cu, Ni, Cr, and V for the rocks analyzed, with precision for Rb, Ce, and Ba much lower (from about 10% to 50%, dependent upon concentration). Only Rb, Ce, and Ba maxima are reported here.

Carbon and Water Analyses

The total carbon and structural water of sampled rock was determined using a Carlo Erba NA 1500 CHNS analyzer. Nitrogen and sulfur concentrations were usually below detection limit of the CHNS analyzer on board. Fifty to 80 mg of dried (110°C) bulk-rock samples were combusted at 1010°C under an oxygen atmosphere in tin-foil sample holders, converting organic and inorganic carbon into CO₂ and thermally releasing H₂O. Following gas-chromatographic separation of the gases, CO₂ and H₂O⁺ were quantitatively determined using a thermal conductivity detector. The bias factor "K" of the CHNS analyzer was calculated by measuring the USGS reference rock sample MRG-1 (CO₂ = 1.00 wt%; H₂O⁺ = 0.98 wt%; Gladney and Roelandts, 1988b).

Analyzed samples were typically splits from the XRF powders, and at least three replicates were performed on each. During Leg 142, carbon and hydrogen analysis techniques originally designed for sediments were applied to rock samples, and accuracy was checked with five international reference rocks (Gladney and Roelandts, 1988a, 1988b; Terashima and Ando, 1987) and was considered adequate. Reproducibility was tested by analyzing several shipboard basalt samples, and samples AII92 29-1 and BAS140. The relative standard deviation of multiple replicates is listed in Table 5; approximate precision is 10% for CO₂ and H₂O⁺.

MAGNETISM

Natural remanent magnetization (NRM) and other rock magnetic measurements were performed on discrete minicore samples taken from the working half of the material recovered during Leg 142. At least one minicore sample was taken per lithological unit when recovery permitted. Bulk magnetic susceptibility and NRM were measured on discrete samples and their coercivity was investigated after stepwise alternating field (AF) and thermal demagnetization. Studies of the acquisition and subsequent demagnetization of anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM) were also conducted to investigate the characteristics of the magnetic phases carrying the NRM.

Measurement of Remanent Magnetization and Coercivity

Two magnetometers, a Molspin spinner magnetometer, and a 2-G Enterprises (Model 760R) pass-through cryogenic rock magnetometer, were available for measurement of remanent magnetization of the cores.

Discrete samples from the working half of the core were measured with the Molspin magnetometer controlled semiautomatically by the



Figure 5. Microlitic texture: sample is dominated texturally by acicular plagioclase microlites, some intergrown in radial or bow-tie arrangements. Individual euhedral to skeletal olivine grains and anhedral clinopyroxene grains occur singly or intergrown with plagioclase microlite clusters; plumose and sheaf clinopyroxene also occurs. Interval 142-864A-1M-4, 9–20 cm; field of view is 5.6 mm across.

ODP-developed Macintosh application, "Mol Mac." AF demagnetization was performed with a single-axis Schonstedt Geophysical Specimen Demagnetizer (Model GSD-1) at steps of 5, 10, 15, 20, 25, and 30 mT and upward in 10-mT steps until the specimen decreased to below 10% of the NRM intensity. In addition, thermal demagnetization was performed on selected samples using a Schonstedt Thermal Specimen Demagnetizer (Model TSD-1) at steps of 50°, 100°, 150°, 200°, 250°, 300°, 350°, 400°, 450°, 500°, 550°, 600°, 650°, and 700°C. Magnetic susceptibility was measured before each reheating to detect any changes in susceptibility that may have been caused by chemical alteration of minerals.

Rock Magnetic Measurements

Bulk magnetic susceptibility (χ) was measured using a Bartington Magnetic Susceptibility Meter (Model MS1) using a 36-mm dual-frequency loop in the low-frequency mode. Values of initial susceptibility were used in conjunction with the values of the intensity of NRM to calculate the *Q* ratio (Koenigsberger ratio) of the samples. A field value of 0.037 mT was assumed for Site 864 so that $Q = \text{NRM}/(\chi \times 0.037)$.

Measurements of ARM and IRM were made on a representative set of minicores from during Leg 142. Most of this additional work was done after the physical property measurements had been completed.

ARM is an artificial remanence known to have magnetic characteristics that are similar to thermoremanent magnetization (TRM). The ARM measurements were made using the Schonstedt AF demagnetizer and a DTECH, Inc., double-coil device, which allowed a steady, unidirectional field of 0.1 mT to be applied during each AF step. For demagnetizing the ARM the procedure used was the same as that for the NRM.

The IRM acquisition experiments were accomplished using the ASC Scientific Impulse Magnetometer (Model IM-10). Samples were subjected to a steady magnetic field along the +X axis and measured with the Molspin spinner magnetometer. The coercivity of IRM was then determined by applying a progressively increasing steady field in the opposite direction, until the IRM intensity in the sample was reduced to zero.

PHYSICAL PROPERTIES

Introduction

Compressional wave velocities and index properties (bulk density, grain density, porosity, and water content) were measured on basalts recovered during Leg 142 at the East Pacific Rise (EPR). These measurements were coordinated with other shipboard sampling programs so that a maximum amount of information could be derived from the limited amount of core material available. Details of the experimental procedures used can be found below and also in the cited references.

Velocity Measurements

The pulse transmission technique was used to determine the compressional wave velocities of samples using piezoelectric transducers as sources and receivers in a screw-press Hamilton frame velocimeter (Boyce, 1976). To determine the zero-length time delay inherent in



Figure 6. Intergranular texture: sample is dominated texturally by skeletal, elongate plagioclase, some intergrown in radial or bow-tie arrangements, and by anhedral to subhedral clinopyroxene. Clinopyroxene forms elongate, radiating crystal clusters as well as more equidimensional grains; euhedral to skeletal olivine crystals also occur. Sample 142-864A-5Z-1, 15–19 cm; field of view is 3.2 mm across.

the measuring system, calibration measurements were performed on aluminum and leucite minicores whose lengths were measured using digital calipers. Traveltimes through a range of different lengths of each material were measured and plotted on a time-distance graph (Fig. 7). An average of the intercept at zero length for both materials gives the delay time for the particular set of transducers. This technique has been shown to be more accurate than taking a single reading at zero length (Dick, Erzinger, Stokking, et al., 1992). Flatness and parallelness of the ends of the samples determine the accuracy and reproducibility of the measurements. Therefore, minicores were prepared so both ends were flat and parallel to within .1 mm. This resulted in sharply defined first arrivals of the direct *P*-wave mode.

Due to the fact that only small, unoriented samples were obtained during coring operations, no determinations of velocity anisotropy could be made. Measurement uncertainties in minicore length (± 0.1 mm, or $\pm 0.4\%$ of length) and timing uncertainties (± 0.035 seconds, or 0.1\%) yielded nominal uncertainties in V_p of about 1.0%. Calibration against standards (leucite $V_p = 2.745$ km/s) were reproduced to within 2.7%. Heterogeneity of the rock samples and irregularities in minicore shapes and finishes further degrades the experimental accuracy by an undetermined factor.

Index Properties

Bulk densities, grain densities, porosities, and water contents of samples were determined using motion-compensated microbalance measurements of mass and Penta-pycnometer measurements of sample volume. Samples collected for index property measurements were first saturated in seawater for 48 hr and then weighed, with a precision of ±0.02 g, using a calibrated Scitech 202 electronic balance. The Penta-pycnometer is designed to measure the volume and densities of the samples by employing Archimedes' principle of fluid displacement. The displaced fluid is helium, which assures penetration into microcracks and pores approaching one angstrom (10-10 m) in dimension. Preliminary tests indicated measurements of wet sample volume using the pycnometer were erratic at best, probably due to the diffusion of helium into pore water. Thus, volumes of saturated samples were not determined by this method. After measuring saturated weights, the samples were dried at 110°C for 24 hr. The samples were then re-weighed and their volume determined using a purge time of 5 min in the pycnometer. Bulk sample density and porosity were calculated using the difference between wet and dry sample weights, dry sample volume, and seawater density. Overall accuracies of bulk and grain densities are about 0.2% or 6×10^{-3} g/cm³. Porosities were determined to probably no better than $\pm 0.2\%$.

REFERENCES

- Boyce, R.E., 1976. Definitions and laboratory determination of compressional sound velocity parameters and wet-water content, wet-bulk density and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S.O., Jackson, E.D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931–958.
- Bryan, W.B., 1972. Morphology of quench crystals in submarine basalts. J. Geophys. Res., 77:5812–5819.
- Dick, H.J.B., Erzinger, J., Stokking, L.B., et al., 1992. Proc. ODP, Init. Repts., 140: College Station, TX (Ocean Drilling Program).

- Gladney, E.S., and Roelandts, I., 1988a. 1987 Compilation of elemental concentration data for USGS BHVO-1, MAG-1, QLO-1, RGM-1, SCo-1, SDC-1, SGR-1, and STM-1. Geostand. Newsl., 12:253–362.
- ——, 1988b. 1987 Compilation of elemental concentration data for CCRMP reference rock samples SY-2, SY-3, and MRG-1. *Geostand. Newsl.*, 14:373–458.
- Natland, J.H., 1978. Crystal morphologies in basalts from DSDP Site 395 23°N, 46°W, Mid-Atlantic Ridge. *In* Malson, W.G., Rabinowitz, P.D., et al., *Init. Repts. DSDP*, 45: Washington (U.S. Govt. Printing Office), 423–445.
- Norrish, K., and Hutton, J.T., 1969. An accurate X-ray spectrographic method for the analysis of a wide range of geological samples. *Geochim. Cosmochim. Acta.*, 33:431–453.
- Reynolds, R.C., 1967. Estimation of mass absorption coefficients by Compton scattering: improvements and extensions of the method. Am. Mineral., 48:1133–1143.
- Staudigel, H., 1979. Chemical analyses of inter-laboratory standards. In Donnelly, T., Francheteau, J., Bryan, W., Robinson, P., Flower, M., Salisbury, M., et al., Init. Repts. DSDP, 51, 52, 53: Washington (U.S. Govt. Printing Office), 1331–1333.
- Terashima, S., and Ando, A., 1987. Elemental concentrations in nine new Japanese rock reference samples. *Geostand. Newsl.*, 11:75–78.

Ms 142IR-103

Table 1. Leg 135 XRF analytical conditions.

| Goniometer | Oxide/Element | Line | Crystal | Detector | Collimator | Peak angle (degrees 20) | Background offset (degrees 2θ) | Count time on peak (s) | Count time on background (s) |
|------------|--------------------------------|-----------------|-----------|----------|------------|----------------------------|-----------------------------------|---------------------------|---------------------------------|
| 2 | SiO ₂ | K-alpha | PET | FPC | Coarse | 109.009 | ±0.00 | 40 | 0 |
| 1 | TiO ₂ | K-alpha | LiF (200) | FPC | Coarse | 86.167 | ± 0.00 | 100 | 0 |
| 2 | Al ₂ O ₃ | K-alpha | PET | FPC | Coarse | 144.437 | ±0.00 | 100 | 0 |
| 2 | Fe ₂ O ₃ | K-alpha | LiF (200) | FPC | Fine | 57.514 | ±0.00 | 40 | 0 |
| 1 | MnO | K-alpha | LiF (200) | KrSc | Fine | 63.039 | ±0.00 | 40 | 0 |
| 2 | MgO | K-alpha | TLAP | FPC | Coarse | 44.883 | ±0.80 | 200 | 400 |
| 1 | CaO | K-alpha | LiF (200) | FPC | Coarse | 113.144 | ± 0.00 | 40 | 0 |
| 1 | Na ₂ O | K-alpha | TLAP | FPC | Coarse | 54.631 | -1.20 | 200 | 200 |
| 2 | K ₂ Ō | K-alpha | LiF (200) | FPC | Coarse | 136.677 | ± 0.00 | 100 | 0 |
| 1 | P ₂ O ₅ | K-alpha | Ge (111) | FPC | Coarse | 140.983 | ±0.00 | 100 | 0 |
| 1 | Rh | K-alpha Compton | LiF (200) | Scint | Fine | 18.623 | ±0.00 | 60 | 0 |
| 1 | Nb | K-alpha | LiF (200) | Scint | Fine | 21.426 | ±0.35 | 200 | 200 |
| 1 | Zr | K-alpha | LiF (200) | Scint | Fine | 22.578 | ±0.35 | 100 | 100 |
| 1 | Y | K-alpha | LiF (200) | Scint | Fine | 23.823 | ±0.40 | 100 | 100 |
| 1 | Sr | K-alpha | LiF (200) | Scint | Fine | 25.165 | ±0.41 | 100 | 100 |
| 1 | Rb | K-alpha | LiF (200) | Scint | Fine | 26.629 | ±0.60 | 100 | 100 |
| 1 | Zn | K-alpha | LiF (200) | Scint | Coarse | 41.791 | ±0.55 | 100 | 100 |
| 1 | Cu | K-alpha | LiF (200) | Scint | Coarse | 45.021 | ±0.55 | 100 | 100 |
| 1 | Ni | K-alpha | LiF (200) | Scint | Coarse | 48.716 | ±0.60 | 100 | 100 |
| 1 | Cr | K-alpha | LiF (200) | FPC | Fine | 69.385 | ±0.50 | 100 | 100 |
| 1 | Fe | K-alpha | LiF (220) | FPC | Fine | 85.757 | ±0.70 | 40 | 40 |
| 1 | V | K-alpha | LiF (220) | FPC | Fine | 123.232 | -0.50 | 100 | 100 |
| 1 | Ti | K-alpha | LiF (200) | FPC | Fine | 86.185 | ±0.50 | 40 | 40 |
| 1 | Ce | K-alpha | LiF (220) | FPC | Coarse | 128.390 | ±1.50 | 100 | 100 |
| 1 | Ba | K-alpha | LiF (220) | FPC | Coarse | 128.965 | ± 1.50 | 100 | 100 |

Notes: All elements analyzed under vacuum, with generator power settings of 60 kV and 50 mA. $Fe_2O_3^*$ is the total iron expressed as Fe_2O_3 . FPC = flow proportional detector (Ar₉₀CH4₁₀ detector gas); KrSC = sealed gas detector (Kr gas); scint = scintillation detector (NaI-TI).

| | SiO ₂ | TiO ₂ | Al_2O_3 | Fe ₂ O ₃ | MnO | MgO | CaO | Na ₂ O | K ₂ O | P_2O_5 |
|---------------|------------------|------------------|-----------|--------------------------------|------|-------|-------|-------------------|------------------|----------|
| Goniometer 1 | | | | | | | | | | |
| AGV-1 | 0.18 | 0.02 | 0.10 | 0.02 | 0.00 | 0.04 | -0.01 | 0.13 | 0.05 | 0.24 |
| AII-92-29-1 | -0.07 | 0.02 | 0.10 | 0.01 | 0.00 | -0.01 | -0.06 | 0.12 | 0.00 | 0.31 |
| BE-N (BR) | 0.42 | 0.00 | -0.24 | -0.24 | 0.00 | -0.01 | 0.08 | -0.09 | 0.02 | 0.13 |
| BHVO-1 | -0.02 | 0.02 | -0.09 | -0.01 | 0.00 | -0.01 | 0.07 | 0.14 | 0.00 | 0.23 |
| BIR-1 | 0.27 | 0.00 | 0.03 | 0.12 | 0.00 | 0.05 | 0.10 | -0.07 | 0.01 | 0.31 |
| BR | 0.21 | 0.03 | -0.47 | 0.09 | 0.00 | -0.44 | -0.18 | -0.07 | 0.00 | 0.17 |
| DR-N | -0.13 | -0.01 | -0.06 | -0.03 | 0.00 | -0.13 | -0.06 | -0.06 | 0.03 | 0.31 |
| G-2 | -0.66 | 0.01 | -0.06 | -0.04 | 0.00 | 0.15 | -0.01 | 0.04 | 0.01 | 0.30 |
| GH | 0.13 | 0.00 | 0.32 | 0.04 | 0.00 | 0.21 | 0.02 | 0.17 | 0.01 | 0.30 |
| IB-1a | 0.25 | -0.03 | -0.15 | -0.16 | 0.02 | 0.13 | 0.02 | -0.10 | -0.06 | 0.27 |
| IB-2 | -0.18 | -0.03 | 0.01 | 0.00 | 0.06 | -0.17 | -0.04 | 0.04 | -0.01 | 0.31 |
| IB-3 | -0.40 | -0.02 | 0.40 | 0.06 | 0.03 | -0.09 | -0.08 | -0.10 | -0.02 | 0.24 |
| IGB-1 | 0.11 | -0.03 | -0.16 | 0.05 | 0.02 | -0.01 | -0.14 | 0.03 | 0.00 | 0.32 |
| IP-1 | 0.03 | 0.01 | 0.17 | 0.00 | 0.00 | 2.65 | 0.02 | -0.01 | 0.00 | 0.34 |
| MRG-1 | 0.35 | 0.00 | 0.19 | 0.00 | 0.00 | 0.01 | 0.02 | _0.02 | 0.00 | 0.20 |
| NRS-688 | 0.04 | 0.00 | 0.12 | 0.00 | 0.00 | 0.01 | 0.07 | -0.13 | 0.00 | 0.29 |
| PGM-1 | 0.50 | 0.00 | 0.12 | -0.04 | 0.00 | -0.05 | 0.07 | -0.13 | 0.00 | 0.32 |
| STM I | 0.12 | 0.00 | 0.02 | -0.11 | 0.00 | 0.10 | 0.02 | -0.05 | 0.01 | 0.32 |
| UP N | 0.20 | 0.00 | -0.08 | 0.01 | 0.01 | 2.01 | -0.01 | -0.00 | -0.01 | 0.2/ |
| SiO | -0.20 | 0.00 | -0.04 | 0.05 | 0.00 | -2.91 | 0.02 | 0.15 | 0.00 | 0.34 |
| 3102 | 0.00 | 0.02 | 0.17 | 0.10 | 0.00 | 0.24 | 0.05 | -0.05 | 0.00 | 0.52 |
| Average | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.28 |
| 1σ | 0.33 | 0.02 | 0.20 | 0.09 | 0.01 | 0.16 | 0.08 | 0.09 | 0.02 | 0.05 |
| Goniometer 2 | | | | | | | | | | |
| AGV-1 | 0.11 | 0.02 | 0.08 | 0.07 | 0.00 | 0.06 | -0.01 | 0.11 | 0.04 | 0.00 |
| АП-92-29-1 | 0.01 | 0.01 | 0.12 | 0.01 | 0.00 | -0.12 | -0.08 | 0.17 | 0.00 | 0.02 |
| RE-N (BR) | 0.46 | 0.00 | -0.23 | 0.01 | 0.00 | -0.12 | 0.06 | -0.15 | 0.02 | -0.01 |
| BHVO-1 | _0.12 | 0.03 | -0.08 | 0.02 | 0.00 | -0.15 | 0.00 | 0.11 | -0.05 | -0.04 |
| BIR-1 | 0.23 | 0.00 | -0.03 | 0.02 | 0.00 | -0.05 | 0.00 | 0.12 | 0.01 | 0.00 |
| BR | 0.23 | 0.00 | 0.04 | 0.15 | 0.00 | -0.05 | 0.12 | -0.12 | 0.01 | 0.02 |
| DR-N | -0.16 | 0.02 | -0.03 | 0.01 | 0.00 | 0.12 | -0.15 | _0.04 | 0.02 | 0.02 |
| G-2 | -0.67 | 0.01 | 0.07 | 0.05 | 0.00 | 0.26 | 0.01 | 0.03 | 0.01 | 0.01 |
| GH | 0.15 | 0.01 | 0.20 | 0.02 | 0.00 | 0.20 | 0.01 | 0.21 | 0.02 | -0.01 |
| IB-1a | 0.23 | 0.03 | 0.11 | 0.15 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 |
| 10.2 | 0.12 | 0.03 | 0.05 | -0.15 | 0.00 | 0.02 | 0.00 | 0.11 | 0.00 | 0.00 |
| 10.2 | 0.12 | 0.03 | 0.40 | 0.00 | 0.02 | -0.22 | -0.02 | 0.12 | 0.00 | 0.00 |
| JCP 1 | -0.42 | -0.02 | 0.40 | 0.07 | 0.02 | -0.11 | -0.07 | -0.12 | -0.02 | -0.04 |
| JOD-1 | 0.15 | -0.05 | -0.15 | 0.07 | 0.02 | -0.12 | -0.14 | 0.05 | 0.00 | 0.02 |
| JF-1 MDC 1 | 0.10 | 0.02 | 0.18 | 0.06 | 0.00 | 2.12 | 0.02 | -0.00 | 0.01 | 0.02 |
| MRG-I | 0.28 | 0.00 | -0.18 | -0.00 | 0.00 | -0.12 | 0.12 | -0.04 | 0.01 | -0.02 |
| ND3-068 | -0.05 | 0.00 | 0.11 | -0.03 | 0.00 | -0.10 | 0.05 | -0.15 | 0.00 | -0.01 |
| RGM-1 | -0.45 | 0.01 | 0.15 | -0.12 | 0.00 | 0.37 | 0.01 | -0.12 | -0.04 | 0.01 |
| SIM-I | -0.48 | 0.00 | -0.07 | 0.00 | 0.01 | 0.35 | -0.01 | -0.05 | -0.01 | -0.02 |
| UB-N | -0.14 | 0.01 | -0.03 | 0.07 | 0.00 | -2.76 | 0.02 | 0.11 | 0.01 | 0.03 |
| 5102 | 0.67 | 0.01 | 0.16 | 0.09 | 0.00 | 0.37 | 0.03 | 0.03 | 0.01 | 0.00 |
| Average | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.33 | 0.02 | 0.19 | 0.09 | 0.01 | 0.25 | 0.07 | 0.11 | 0.02 | 0.02 |

Table 2. Difference between accepted analysis of major element standards and analysis derived from calibration curves.

Notes: Standard deviation shown for each element is derived from entire standard population. Analyses of standards from Terashima and Ando (1987), Staudigel (1979), and Gladney and Roelandts (1988a, 1988b).

| Analysis | SiO_2 | TiO ₂ | Al_2O_3 | Fe ₂ O ₃ | MnO | MgO | CaO | Na ₂ O | K ₂ O | P_2O_5 | Total | | |
|----------------|---------|------------------|-----------|--------------------------------|--------|------|-------|-------------------|------------------|----------|------------------|--------|-----|
| 1 | 49.72 | 2.73 | 13.57 | 12.22 | 0.18 | 7.13 | 11.35 | 2.33 | 0.54 | 0.23 | 99.99 | | |
| 2 | 49.62 | 2.73 | 13.55 | 12.27 | 0.18 | 7.09 | 11.38 | 2.47 | 0.54 | 0.22 | 100.04 | | |
| 3 | 49.77 | 2.73 | 13.63 | 12.24 | 0.18 | 7.21 | 11.35 | 2.41 | 0.54 | 0.23 | 100.29 | | |
| 4 | 49.66 | 2.73 | 13.58 | 12.24 | 0.18 | 7.13 | 11.35 | 2.35 | 0.54 | 0.23 | 99.97 | | |
| 5 | 49.40 | 2.72 | 13.35 | 12.20 | 0.17 | 6.84 | 11.28 | 2.22 | 0.53 | 0.23 | 98.94 | | |
| 6 | 49.59 | 2.74 | 13.52 | 12.24 | 0.17 | 6.87 | 11.39 | 2.40 | 0.54 | 0.23 | 99.68 | | |
| 7 | 49.66 | 2.73 | 13.58 | 12.24 | 0.18 | 7.13 | 11.35 | 2.35 | 0.54 | 0.23 | 99.97 | | |
| 8 | 49.71 | 2.73 | 13.66 | 12.20 | 0.18 | 7.03 | 11.36 | 2.37 | 0.54 | 0.24 | 100.03 | | |
| 9 | 49.59 | 2.74 | 13.60 | 12.20 | 0.17 | 7.08 | 11.35 | 2.34 | 0.54 | 0.24 | 99.85 | | |
| Average | 49.63 | 2.73 | 13.56 | 12.23 | 0.18 | 7.06 | 11.35 | 2.36 | 0.54 | 0.23 | 99.86 | | |
| lσ | 0.11 | 0.01 | 0.09 | 0.02 | < 0.01 | 0.12 | 0.03 | 0.07 | < 0.01 | 0.01 | | | |
| Accepted value | 49.62 | 2.68 | 13.67 | 12.23 | 0.17 | 7.21 | 11.32 | 2.17 | 0.53 | 0.27 | 99.87 | | |
| Analysis | Nb | Zr | Y | Sr | Rb | Zn | Cu | Ni | Cr | v | TiO ₂ | Ce (%) | Ba |
| 1 | 18.5 | 183 | 26.4 | 398 | 7.2 | 112 | 145 | 123 | 284 | 326 | 2.90 | 32 | 145 |
| 2 | 18.5 | 184 | 26.9 | 396 | 8.4 | 110 | 144 | 118 | 285 | 333 | 2.87 | 42 | 122 |
| 3 | 18.7 | 182 | 26.5 | 395 | 7.8 | 110 | 144 | 120 | 286 | 324 | 2.88 | 41 | 128 |
| 4 | 18.1 | 182 | 26.6 | 397 | 7.3 | 110 | 144 | 122 | 287 | 325 | 2.88 | 33 | 141 |
| 5 | 18.5 | 184 | 26.9 | 396 | 8.4 | 110 | 144 | 118 | 285 | 333 | 2.87 | 42 | 122 |
| 6 | 18.7 | 182 | 26.5 | 395 | 7.8 | 110 | 144 | 120 | 286 | 324 | 2.88 | 41 | 128 |
| 7 | 18.7 | 182 | 25.6 | 399 | 7.6 | 111 | 145 | 121 | 287 | 331 | 2.89 | 39 | 125 |
| Average | 18.5 | 182 | 26.5 | 397 | 7.8 | 110 | 144 | 120 | 286 | 328 | 2.88 | 39 | 130 |
| lσ | 0.2 | <1 | 0.4 | 1 | 0.5 | <1 | <1 | 2 | 1 | 4 | 0.01 | 4 | 9 |
| Accepted value | 19.0 | 180 | 26.0 | 420 | 10.0 | 113 | 140 | 120 | 306 | 310 | 2.68 | 38 | 127 |

Table 3. Major element analysis of rock reference standard BHVO-1 following Leg 142 calibration.

Notes: Fe₂O₃* is total amount of iron expressed as Fe₂O₃. Reference value is from Gladney and Roelandts (1988a).

Table 4. Results of grinding tests for determining whether grinding vessels contaminated samples.

| Grinding | Testing | Time ground | | | | | | | | | | | | | |
|-----------------------|---------|----------------|---------------|------------------|---------------|--------------------------------|--------------|--------------|---------------|-------------------|------------------|-----------|----------------------|----|----|
| vessel | date | (min.) | SiO_2 | TiO ₂ | Al_2O_3 | Fe ₂ O ₃ | MnO | MgO | CaO | Na ₂ O | K ₂ O | P_2O_5 | Total | | |
| Quartz sand: | | | | | | | | | | | | | | | |
| Agate | 11 Feb | 10.0 | 99.54 | 0.01 | 0.18 | 0.12 | 0.00 | 0.31 | 0.03 | -0.06 | 0.00 | 0.01 | 100.13 | | |
| *Agate | 19 Feb | 10.0 | 99.94 | 0.00 | -0.04 | 0.02 | 0.00 | 0.08 | 0.00 | 0.01 | 0.00 | -0.04 | 99.97 | | |
| Tungsten | 11 Feb | 2.0 | 99.53 | 0.00 | 0.17 | 0.10 | 0.02 | 0.38 | 0.03 | -0.05 | 0.00 | 0.04 | 100.22 | | |
| *Tungsten | 19 Feb | 2.0 | 100.36 | 0.00 | -0.04 | -0.01 | 0.00 | 0.10 | 0.00 | 0.05 | 0.00 | -0.02 | 100.44 | | |
| Alumina | 11 Feb | 3.5 | 98.12 | 0.01 | 0.48 | 0.11 | 0.01 | 0.83 | 0.03 | -0.05 | 0.00 | 0.06 | 99.60 | | |
| Alumina | 15 Feb | 3.5 | 100.06 | 0.01 | 0.25 | 0.09 | 0.00 | 0.60 | 0.03 | -0.05 | 0.01 | -0.02 | 100.96 | | |
| Alumina | 15 Feb | 7.0 | 100.09 | 0.01 | 0.24 | 0.10 | 0.00 | 0.57 | 0.03 | -0.08 | 0.01 | -0.03 | 100.94 | | |
| *Alumina | 19 Feb | 3.5 | 100.81 | 0.00 | 0.06 | -0.02 | 0.01 | 0.08 | 0.00 | 0.02 | 0.00 | -0.03 | 100.94 | | |
| *Alumina | 19 Feb | 7.0 | 100.39 | 0.00 | 0.07 | 0.00 | 0.00 | 0.11 | 0.00 | 0.05 | 0.00 | -0.02 | 100.62 | | |
| BAS142 standard: | | | | | | | | | | | | | | | |
| Tungsten | 21 Feb | 7.0 | 49.79 | 1.63 | 14.06 | 11.68 | 0.20 | 7.36 | 11.68 | 2.52 | 0.13 | 0.11 | 99.15 | | |
| Tungsten | 28 Feb | 7.0 | 49.75 | 1.64 | 14.26 | 11.65 | 0.20 | 7.19 | 11.68 | 2.65 | 0.14 | 0.10 | 99.25 | | |
| **Tungsten | 28 Feb | 1.0 | 49.77 | 1.64 | 14.19 | 11.66 | 0.20 | 7.19 | 11.65 | 2.58 | 0.14 | 0.11 | 99.14 | | |
| **Tungsten | 28 Feb | 1.0 | 49,79 | 1.64 | 14.24 | 11.64 | 0.19 | 7.24 | 11.71 | 2.60 | 0.14 | 0.11 | 99.30 | | |
| Tungsten average | | | 49.78 | 1.64 | 14.19 | 11.66 | 0.20 | 7.24 | 11.68 | 2.59 | 0.14 | 0.11 | 99.21 | | |
| 1σ | | | 0.02 | 0.01 | 0.09 | 0.02 | 0.00 | 0.08 | 0.02 | 0.05 | 0.00 | 0.00 | | | |
| | | | | | | | | | | | | | | | |
| Alumina | | | 50.09 | 1.64 | 14.38 | 11.63 | 0.20 | 7.52 | 11.75 | 2.56 | 0.13 | 0.10 | 100.00 | | |
| Alumina | 21 Feb | 12.0 | 49.91 | 1.63 | 14.26 | 11.53 | 0.20 | 7.46 | 11.68 | 2.61 | 0.14 | 0.10 | 99.51 | | |
| **Alumina | 28 Feb | 12.0 | 49.84 | 1.64 | 14.21 | 11.69 | 0.20 | 7.35 | 11.66 | 2.55 | 0.14 | 0.10 | 99.38 | | |
| **Alumina | 28 Feb | 10.0 | 49.86 | 1.64 | 14.34 | 11.59 | 0.20 | 7.37 | 11.64 | 2.53 | 0.14 | 0.12 | 99.41 | | |
| Alumina average 1σ | 28 Feb | 10.0 | 49.92 0.11 | 1.64 0.01 | 14.30 0.07 | 11.61 0.07 | 0.20 0.00 | 7.42 0.08 | 11.68 0.05 | 2.56 0.03 | 0.14 0.00 | 0.10 0.01 | 99.57 | | |
| | | Time | | | | | | | | | | | | | |
| Grinding | Testing | ground | | | | | | | | | | | | | |
| vessel | date | (min.) | Nb | Zr | Y | Sr | Rb | Zn | Cu | Ni | Cr | v | TiO ₂ (%) | Ce | Ba |
| Quartz sand: | | | | | | | | | | | | | | | |
| Agate | 11 Feb | 10.0 | 0.8 | 0 | -0.6 | -I | -I | -7 | 0 | -1 | 0 | -2 | 0.00 | -3 | 8 |
| Tungsten | 11 Feb | 2.0 | 1.4 | 1 | -0.5 | 0 | 0 | -9 | 0 | -6 | 4 | -1 | 0.00 | 22 | 14 |
| Alumina | 11 Feb | 3.5 | 1.0 | 1 | -0.2 | 0 | 0 | -7 | 1 | -1 | 1 | -1 | 0.00 | 4 | 4 |
| Alumina | 15 Feb | 3.5 | 0.9 | 1 | 0.3 | 0 | 0 | -7 | 0 | -1 | 1 | -4 | 0.00 | 0 | -1 |
| Alumina | 15 Feb | 7.0 | 1.2 | 1 | 0.5 | 0 | 0 | -8 | -1 | -1 | 3 | 1 | 0.00 | -1 | -1 |
| BAS142 standard: | | | | | | | | | | | | | | | |
| Tungsten | 21 Feb | 7.0 | 4.2 | 111 | 35.6 | 121 | -1 | 102 | 81 | 73 | 245 | 359 | 1.79 | 15 | 13 |
| Tungsten | 27 Feb | 7.0 | 4.0 | 111 | 36.5 | 120 | -1 | 101 | 79 | 73 | 241 | 366 | 1.78 | 20 | 11 |
| Tungsten | 27 Feb | 1.0 | 4.1 | 112 | 36.3 | 122 | -1 | 119 | 85 | 76 | 262 | 374 | 1.80 | 22 | 10 |
| Tungsten | 27 Feb | 1.0 | 3.7 | 112 | 37.1 | 121 | -1 | 122 | 82 | 75 | 248 | 365 | 1.78 | 16 | 19 |
| Tungsten average | | | 4.0 | 112 | 36.4 | 121 | n.d. | 111 | 82 | 74 | 249 | 366 | 1.79 | 18 | 13 |
| 1σ | | | 0.2 | 1 | 0.5 | 1 | | 11 | 3 | 1 | 9 | 6 | 0.01 | 3 | 4 |
| Alumine | 01.224 | 10.0 | | | 26.5 | 100 | 6 | 100 | | 70 | 242 | 250 | 1.77 | 10 | |
| Alumina | 21 Feb | 12.0 | 5.1 | 111 | 30.5 | 122 | 0 | 108 | 114 | 19 | 242 | 338 | 1.77 | 10 | 3 |
| Alumina | 27 Feb | 12.0 | 2.3 | 112 | 35.5 | 122 | -1 | 111 | 100 | 80 | 242 | 300 | 1.77 | 9 | 17 |
| Alumina | 27 Feb | 10.0 | 3.6 | 111 | 35.6 | 122 | -1 | 134 | 83 | 70 | 246 | 357 | 1.77 | 10 | 12 |
| Alumina | 27 Feb | 10.0 | 3.4 | 112 | 36.0 | 123 | $^{-1}$ | 119 | 88 | 11 | 252 | 352 | 1.79 | 14 | 21 |
| Alumina average | | | 3.0 | 112 | 35.9 | 122 | n.d. | 118 | 96 | 80 | 245 | 357 | 1.78 | 12 | 14 |
| 10 | | | 0.6 | 0 | 0.5 | 1 | | 12 | 14 | 5 | 4 | 4 | 0.01 | 3 | 1 |

Notes: Spec-pure quartz sand and an internal standard BAS142 (from Section 142-864A-1M-5, 0–100 cm). *Calibration factor changed to quartz standard range. **Testing performed on the same date but at different times.

Table 5. ${\rm CO}_2$ and ${\rm H}_2{\rm O}^+$ values of international and shipboard reference standards.

| | $\mathrm{CO}_2(\%)$ | H ₂ O (%) |
|------------|---------------------|----------------------|
| AII92 29-1 | 0.073 | 0.920 |
| AII92 29-1 | 0.076 | 0.997 |
| AII92 29-1 | 0.073 | 0.947 |
| AII92 29-1 | 0.080 | 0.959 |
| AII92 29-1 | 0.080 | 0.989 |
| AII92 29-1 | 0.077 | 0.884 |
| AII92 29-1 | 0.070 | 0.926 |
| AII92 29-1 | 0.070 | 0.815 |
| AII92 29-1 | 0.080 | 0.801 |
| AII92 29-1 | 0.073 | 0.881 |
| AII92 29-1 | 0.073 | 0.955 |
| AII92 29-1 | 0.068 | 0.793 |
| AII92 29-1 | 0.066 | 0.621 |
| AII92 29-1 | 0.066 | 0.714 |
| AII92 29-1 | 0.072 | 0.806 |
| AII92 29-1 | 0.074 | 0.924 |
| AII92 29-1 | 0.067 | 0.973 |
| AII92 29-1 | 0.067 | 1.020 |
| Average | 0.072 | 0.885 |
| 1σ | 0.005 | 0.107 |
| Reference | 0.07 | 0.92 |
| BAS-140 | 0.038 | 1.378 |
| BAS-140 | 0.044 | 1.411 |
| BAS-140 | 0.040 | 1.420 |
| BAS-140 | 0.055 | 1.337 |
| BAS-140 | 0.043 | 1.150 |
| BAS-140 | 0.047 | 1.319 |
| Average | 0.045 | 1.336 |
| 1σ | 0.006 | 0.100 |
| Reference | 0.03 | 1.25 |

Notes: Reference values are from Staudigel (1979) and Dick, Erzinger, Stokking, et al. (1992).



Figure 7. Calibration plot for the Hamilton frame velocimeter.