Data report: spatial and temporal evolution of slow spread oceanic crust—graphic sections of core recovered from IODP Hole U1309D, Atlantis Massif, 30°N, MAR (including Pb/U zircon geochronology and magnetic remanence data)[1]

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Chapter contents

[1]John, B.E., Cheadle, M.J., Gee, J.S., Grimes, C.B., Morris, A., and Pressling, N., 2009. Data report: spatial and temporal evolution of slow spread oceanic crust—graphic sections of core recovered from IODP Hole U1309D, Atlantis Massif, 30°N, MAR (including Pb/U zircon geochronology and magnetic remanence data). *In* Blackman, D.K., Ildefonse, B., John, B.E., Ohara, Y., Miller, D.J., MacLeod, C.J., and the Expedition 304/305 Scientists, *Proc. IODP,* 304/305: College Station, TX (Integrated Ocean Drilling Program Management International, Inc.).
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Abstract

This contribution presents a graphical downhole log for core recovered from Integrated Ocean Drilling Program (IODP) Hole U1309D made during postcruise study at the Bremen Core Repository. More than 3500 observations of the rock composition and structural relations are presented, including igneous composition, texture and grain size variations, layering and intrusive contact orientation, and younger/older intrusive relations, together with observations of fault/shear zone thickness and orientation and alteration mineral assemblages. In addition, remanence components for 523 new specimens are shown along with shipboard magnetic susceptibility and 18 Pb/U zircon ages from evolved Fe-Ti oxide gabbro and felsic dikes from Hole U1309D. This compilation is a resource for researchers interested in the composition, construction, and deformation of slow-spreading gabbroic crust, in particular the scale/thickness of intrusive bodies and the order of intrusion.

Introduction

Integrated Ocean Drilling Program (IODP) Expedition 304/305 was a two-stage drilling program that took place in 2004–2005 at Atlantis Massif. The expedition was designed to investigate the processes that control oceanic core complex (OCC) formation and the exposure of lower oceanic crustal and upper mantle rocks in young oceanic lithosphere. Site U1309 is located on the central dome of Atlantis Massif (Fig. **F1**), ~15 km west of the Mid-Atlantic Ridge at 30°N, where the seafloor coincides with a detachment fault surface. Previous studies (Blackman et al., 1998, 2002) have shown that the footwall at Atlantis Massif is composed of lower crust and upper mantle rocks that are denuded by a detachment fault exposed over an 8–10 km wide, 15 km long area that forms an elongate, doubly plunging domal seafloor morphology. The adjacent block to the east, dominated by basalt, is interpreted as the hanging wall to the detachment fault. The detachment is inferred to continue at a gentle dip (<15°) beneath the eastern block toward the ridge axis.

Two holes were drilled at this site; here we focus on Hole U1309D, which penetrated 1415.5 meters below seafloor (mbsf) with 74% recovery (see the "Expedition 304/305 summary" chapter). The deep penetration of Hole U1309D provides an unprecedented view of the architecture of primitive slow-spreading crust (cf. Ocean Drilling Program [ODP] Hole 735B; Dick et al., 2000).

The primary rock types recovered from the Expedition 304/305 sample suite include, in decreasing abundance, gabbro, olivine gabbro, troctolite, oxide-bearing gabbro, oxide gabbro, gabbronorite, oxide- and olivine-bearing gabbro and gabbronorite, diabase, and felsic veins.

Methods

Core description and graphic logs

Core recovered from IODP Hole U1309D was evaluated to produce a uniform visual core description (VCD) in the Bremen Core Repository (BCR). Graphic logs were produced and are presented as columns in 15 m intervals. See the graphic logs in "Supplementary material."

Observations of the archive section halves of the entire core were made over a period of 15 days by B.E. John and M.J. Cheadle (at the BCR, May 2006) to maintain consistent observations over the entire core length (1415 m). Rock type and fabrics for whole-core rounds not present were determined from shipboard VCDs. Barrel sheets showing magnetic susceptibility were used during observation to identify oxide and oxide-bearing gabbro not originally noted during shipboard core description. Lithologic names were given to core intervals based on modal mineralogy observed from cut and round faces, thin section descriptions, and magnetic susceptibility logs using the classification and nomenclature outlined in the "Methods" chapter. Differences between a given interval in these logs and the shipboard VCDs likely result from new information that was not available during shipboard core description.

Each log includes the estimated depth to specific intervals based on curated depth to the top of each core section. The relative depth to an interval (contact, zone of increased grain size, mylonitic deformation, etc.) in subsequent cores may therefore have an error as large as ~20 cm (relevant for core-log integration). By IODP convention, when recovery is less than 100%, all recovered material is curated from the top of the cored interval, which produces an additional shift in the reported recovery depths. All intervals are shown based on the above. Recovery exceeding 100% is not uncommon and results in (typically minor) overlap of two core sections in depth. These intervals are indicated by gray bars in the corresponding susceptibility plots. When overlap occurs, the lithology shown is for the lower section.

Magnetic methods and data

Remanence components were determined from detailed thermal demagnetization studies conducted at the Scripps Institution of Oceanography (see Morris et al., 2009). Before being heated, all specimens were subjected to low-temperature (77 K) treatment to preferentially remove remanence carried by coarse multidomain magnetite. Best-fit remanence components were calculated by principal component analysis (Kirschvink, 1980). Because the core pieces are azimuthally unoriented, polarity was determined primarily with the inclination value along with additional information provided by the known positive inclination of the drilling-induced remanence and/or comparison of results from multiple specimens in a contiguous core piece.

Circles on the graphic logs represent locations of discrete shore-based paleomagnetic specimens; white circles represent data accepted after analysis; gray circles represent data rejected. Raw demagnetization data will soon be available from the International Magnetics Information Consortium (MagIC) database (earthref.org/MAGIC/index.html).

Magnetic component codes associated with each sample reported are as follows:

- R1 = high-temperature reversed component.
- N1 = intermediate-temperature normal component.
- R2 = low-temperature reversed component.

In several specimens a single polarity component may be curved or have two distinct linear segments that differ in either inclination or declination. When the latter occurs, the suffix ".1" or ".2" is appended to the component designation for the higher and lower temperature subsegments, respectively. Magnetization components in which the vector difference sum was reduced to <50% by either low-temperature treatment or the first heating step (100°C) or in which the maximum angular deviation of the principal component was >10° were rejected. Rejected components are indicated in brackets.

Shipboard magnetic susceptibility data were downloaded from the JANUS database; in a small number of cases we were able to correct shipboard data that were measured with incorrect section numbers. Susceptibility data were collected at 2 cm intervals; data ≥4 cm (the approximate half-width of the sensor response) from the end of a core piece are plotted in red and reflect the most robust data. The susceptibility meter used has a maximum value of 9999 × 10^{-5} SI. When susceptibility values exceed 0.1 SI, the most significant digit is not recorded (e.g., 13,000 × 10^{-5} SI is recorded as 3000 × 10^{-5} SI), leading to apparent high-amplitude fluctuations, especially in oxide-rich zones.

Pb/U zircon geochronology methods and data

Pb/U zircon ages for 18 samples of evolved Fe-Ti oxide gabbro and felsic dikes reported by Grimes et al. (2008) are plotted at sampled depths between 40 and 1415 mbsf in Hole U1309D. Stars (and associated ages) on the graphic logs represent locations of dated samples, reported as weighted mean ages (with 2σ errors) for spots on 5–14 individual zircons, analyzed with the Stanford-U.S. Geological Survey sensitive high-mass resolution ion microprobe (SHRIMP).

Summary

We present graphical downhole logs/core description for all core recovered from IODP Hole U1309D in columns representing intervals of 15 m. More than 3500 observations of the rock composition and structural relations are presented, including igneous composition, texture and grain size variations, layering and intrusive contact orientation, and younger/older intrusive relations, together with observations of fault/shear zone thickness and orientation and alteration mineral assemblages. Single or multiple components of magnetic remanence for 523 specimens are shown together with shipboard magnetic susceptibility measurements and 18 Pb/U zircon ages from evolved Fe-Ti oxide gabbro and felsic dikes from Hole U1309D. This compilation is a resource for researchers interested in the composition, construction, and deformation of slow-spreading gabbroic crust, in particular the scale/thickness of intrusive bodies and intrusive history.

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References

Blackman, D.K., Cann, J.R., Janssen, B., and Smith, D.K., 1998. Origin of extensional core complexes: evidence from the Mid-Atlantic Ridge at Atlantis Fracture Zone. *J. Geophys. Res.,* 103(B9):21315–21334. **doi:10.1029/98JB01756**

Blackman, D.K., Karson, J.A., Kelley, D.S., Cann, J.R., Früh-Green, G.L., Gee, J.S., Hurst, S.D., John, B.E. Morgan, J., Nooner, S.L., Ross, D.K., Schroeder, T.J., and Williams, E.A., 2002. Geology of the Atlantis Massif (Mid-Atlantic Ridge, 30°N): implications for the evolution of an ultramafic oceanic core complex. *Mar. Geophys. Res.,* 23(5–6):443–469. **doi:10.1023/B:MARI.0000018232.14085.75**

Dick, H.J.B., Natland, J.H., Alt, J.C., Bach, W., Bideau, D., Gee, J.S., Haggas, S., Hertogen, J.G.H., Hirth, G., Holm, P.M., Ildefonse, B., Iturrino, G.J., John, B.E., Kelley, D.S., Kikawa, E., Kingdon, A., LeRoux, P.J., Maeda, J., Meyer, P.S., Miller, D.J., Naslund, H.R., Niu, Y.-L., Robinson, P.T., Snow, J., Stephen, R.A., Trimby, P.W., Worm, H.-U., and Yoshinobu, A., 2000. A long in situ section of the lower ocean crust: results of ODP Leg 176 drilling at the Southwest Indian Ridge. *Earth Planet. Sci. Lett.,* 179(1):31–51. **doi:10.1016/S0012-821X(00)00102-3**

Grimes, C.B., John, B.E., Cheadle, M.J., and Wooden, J.L., 2008. Protracted construction of gabbroic crust at a slow spreading ridge: constraints from $^{206}Pb/^{238}U$ zircon ages from Atlantis Massif and IODP Hole U1309D (30°N, MAR). *Geochem., Geophys., Geosyst.,* 9:Q08012. **doi:10.1029/2008GC002063**

Kirschvink, J.L., 1980. The least-squares line and plane and the analysis of palaeomagnetic data. *Geophys. J. R. Astron. Soc.,* 62(3):699–718.

Morris, A., Gee, J.S., Pressling, N., John, B.E., MacLeod, C.J., Grimes, C.B., and Searle, R.C., 2009. Footwall rotation in an oceanic core complex quantified using reoriented Integrated Ocean Drilling Program core samples: *Earth Planet. Sci. Lett,* 287(1–2):217–228. **doi:10.1016/j.epsl.2009.08.007**

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Figure F1. Location of Integrated Ocean Drilling Program (IODP) Hole U1309D, along the Atlantis Transform at 30°N on the Mid-Atlantic Ridge (after Grimes et al., 2008).