IODP Expedition 330: Louisville Seamount Trail

Site U1375 Summary

Background and Objectives

Background

Site U1375 (Primary Site LOUI-2B) on Achernar Guyot was the fourth drill site targeted during Integrated Ocean Drilling Program (IODP) Expedition 330. This seamount has an estimated age of ~59-63 Ma and knowledge about this feature will fill in an important gap in the age *vs.* distance relationship of the Louisville Seamount Trail and it will provide pivotal information in the reconstruction of past plate motions and the motion of the Louisville hotspot. Compared to Rigil Guyot and Canopus Guyot to the northwest, this seamount is two times smaller, 29 km long and 27 km wide, and it is part of a trail of seven small guyots and seamounts that starts with Burton Guyot at the northern end. Site U1375 was targeted in the middle of this small edifice, away from its shelf edges and away from any thick packages of dipping volcaniclastics on its flanks, the latter which preferentially were targeted at Sites U1372, U1373 and U1374. Achernar Guyot shows no evidence of tilting and Site U1375 was placed on its summit plain at ~1259 m water depth. Sidescan sonar reflectivity survey and 3.5 kHz sub-bottom profiling data indicate that Site U1375 is covered with less than 15 m of pelagic sediment and seismic reflection profiles show that this central part of Achernar Guyot is typified by a less than 44 m of volcaniclastics overlaying igneous basement.

The original drilling plan was to recover the soft sediment using a gravity push approach with little or no rotation using a Rotary Core Barrel (RCB), followed by standard coring into the volcaniclastic materials and 350 m into igneous basement. A short downhole logging series was planned including the standard Triple Combo and FMS-Sonic tool strings, and the third-party Göttingen Borehole Magnetometer (GBM) tool.

Objectives

Drilling during ODP Leg 197 provided the first compelling evidence for the motion of mantle plumes by documenting a large ~15° shift in paleolatitude for the Hawaiian

hotspot (Tarduno et al., 2003; Duncan et al., 2006). This lead to two geodynamical end-member models that are being tested during Expedition 330, namely that the Louisville and Hawaiian hotspots moved coherently over geological time (Wessel and Kroenke 1997; Courtillot et al. 2003) or, quite the opposite, that these hotspots show considerable inter-hotspot motions, as predicted by mantle flow models (Steinberger, 2002; Steinberger et al., 2004; Koppers et al., 2004; Steinberger and Antretter, 2006; Steinberger and Calderwood, 2006). The most important objective of Expedition 330 therefore was to core deep into the igneous basement of four Louisville seamounts in order to sample a large number of in situ lava flows ranging in age between 80 and 50 Ma. With a sufficiently large number of these independent cooling units high-quality estimates of their paleolatitude can be determined, and any recorded paleolatitude shift (or lack thereof) can be compared with seamounts in the Hawaiian-Emperor seamount trail. For this reason Expedition 330 mimicked the drilling strategy of ODP Leg 197 by drilling Louisville guyots equivalent in age to Detroit (76-81 Ma), Suiko (61 Ma), Nintoku (56 Ma) and Koko (49 Ma) in the Emperor seamounts, with Achernar Guyot being equivalent to Suiko Seamount. Accurate paleomagnetic inclination data are required for the drilled seamounts in order to establish a record of the past motion of the Louisville hotspot, and together with high-resolution $^{40}Ar/^{39}Ar$ age dating of the cored lava flows, these data will help us to constrain the paleolatitudes of the Louisville hotspot between 80 and 50 Ma.

Expedition 330 also aimed to provide important insights into the magmatic evolution and melting processes that produced and constructed Louisville volcanoes while progressing from their shield to post-shield, and maybe post-erosional, volcanic stages. Existing data from dredged lavas suggest that the mantle source of the Louisville hotspot has been remarkably homogeneous for as much as 80 m.y. (Cheng et al., 1987; Hawkins et al., 1987; Vanderkluysen et al., 2011). In addition, all dredged basalts are predominantly alkalic and possibly represent a mostly alkalic shield-building stage, which is in contrast to the tholeiitic shield-building stage of volcanoes in the Hawaiian-Emperor seamount trail (Hawkins et al., 1987; Vanderkluysen et al., 2011). Therefore, the successions of lava flows cored during Expedition 330 will help us to characterize the Louisville

seamount trail as the product of a *primary* hotspot and to test the long-lived homogeneous geochemical character of its mantle source. Analyses of melt inclusions, volcanic glass samples, primitive basalts, high-Mg olivines and clinopyroxene phenocrysts will provide further constraints on the asserted homogeneity of the Louisville plume source, its compositional evolution between 80 and 50 Ma, potential mantle plume temperatures, and its magma genesis, volatile outgassing and differentiation. Finally, basalts and sediments cored at Site U1375 were planned to be used for a range of secondary objectives such as searching for active microbial life in the old seamount basements and to find fossil traces of these microbes left behind in volcanic glasses and biofilms on the rocks.

Operations

The 322 nmi voyage to Site U1375 (Prospectus Site LOUI-2B) on Achernar Guyot was accomplished at an average speed of 10.2 knots and the vessel arrived on site at 0330 hr on 25 January.

The bit tagged seafloor at a depth of 1269.0 mbrf (= 1258 mbsf). Hole U1375A was spudded with the rotary core barrel (RCB) assembly at 1345 hr on 25 January. Almost immediately the driller experienced erratic high torque indicating that we were attempting to core though loose rocks and boulders. Frequent overpulls of up to 90 kip were required to keep the drill string rotating freely. At 2130 hr coring of Hole U1375A was terminated at a depth of 11.5 mbsf because of unstable hole conditions. The average recovery for the two cores was 13%.

The vessel was offset 300 m at 315 degrees and a second attempt at coring this site was initiated when Hole U1375B was spudded at 2345 hr. After penetrating 8.5 m with increasing difficulty and constantly fighting unstable hole conditions, operations at this site were terminated as well. The lone core retrieved had an average recovery of 7%. It was concluded that the formation on the top of this seamount consisted of a sedimentary breccia loosely held together in a "soft" carbonate matrix that quickly disintegrated during drilling, leaving mainly loose pebbles behind. The vessel departed for an approved

alternate site located 91 nmi NNW from Site U1375 at 1945 hr on 26 January. The total time spent on Site U1375 was 34.3 hours or 1.4 days.

Scientific Results

Sedimentology

Sediment at Site U1375 was mostly restricted to Hole U1375A, and represents a pelagic cap and an older sediment cover of Achernar Guyot. Two stratigraphic units were defined on the basis of compositional and textural characteristics of the sediment at macroscopic and microscopic scales. The uppermost part of Hole U1375A (Unit I) was retrieved with only poor (~2%) recovery with few cuttings retrieved in the core catcher of Core 330-U1375A-1R. The cuttings indicate that Unit I probably contains a young (late Miocene to Holocene) sedimentary cover composed of sandy foraminiferal ooze. The sediment resembles that recovered in the uppermost parts of Sites U1372 on Canopus Guyot and U1374 on Rigil Guyot, and is interpreted to represent a pelagic cap on top of the drowned seamount. An older sedimentary cover (Unit II) in Hole U1375A occurs between 8.50 and 10.11 mbsf, which includes from top to bottom: (1) a ferromanganese-phosphate encrustation at ~8.50 mbsf; (2) an early to middle Paleocene grain-supported, poorly-sorted, multicolor basalt conglomerate between ~8.50 and 9.34 mbsf; and (3) an altered, monolithic, matrix-supported, poorly-sorted, multicolor basalt breccia between 9.34 and the bottom of the hole at 10.11 mbsf. The composition and texture of the sediment suggest that Unit II includes a hemipelagic interval probably deposited after drowning of Achernar Guyot at Site U1375, and on top of an older debris flow deposit.

Paleontology

Calcareous nannofossils and planktonic foraminifers observed in the unconsolidated sandy foraminiferal ooze of Unit I display an age range of latest Miocene-Holocene. The first core from Hole U1375A has penetrated 8.5 m of supposedly soft pelagic sediment, however, almost all sediment was flushed from the core liner during recovery. Only a small amount of disturbed sediment was retained in the core catcher in Core U1375-1R and was defined as Unit I. In contrast, calcareous nannofossils and planktonic foraminifers present in Section U1375A-2R-1 allowed for a preliminary age assignment

of early Paleocene for the Unit IIA conglomerate, indicating a more than 55 million year interval represented by the unconformity between Units I and II.

Igneous Petrology

Hole U1375A penetrated to a total depth of 11.5 mbsf and recovered 1.61 m of sedimentary rocks containing five types of volcanic clasts. The clast types found in Units IIA and IIB include aphyric basalt, moderately olivine-augite-phyric basalt, moderately augite-olivine-plagioclase-phyric basalt, and highly olivine-augite-phyric basalt. Hole U1375B penetrated to a total depth of 8.5 mbsf and recovered 57 cm of igneous rock. Unit I, the only unit to be defined for Hole U1375B, is composed of moderately olivine(-augite)-phyric microgabbro (dolerite) with olivine and augite phenocrysts that reach over 10 mm in size.

Alteration Petrology

The entire succession recovered from Holes U1375A and U1375B has undergone secondary alteration by low temperature water-rock interactions and/or weathering. The overall alteration of the volcanic clasts in sedimentary units from Hole U1375A ranges from slight to high (between 10% and 60%), whereas the moderately olivine (-augite) -phyric microgabbro (dolerite) from Hole U1375B varies from moderately to highly altered (55%). Plagioclase and augite are generally well-preserved, both as phenocrysts and in the groundmass throughout the entire igneous portion of the core. Olivine is typically completely altered to iddingsite, hematite, Fe-oxyhydroxydes and carbonates. Alteration phases are mostly carbonates (Mg-calcite), brown clay minerals and other secondary phases (iddingsite, Fe oxyhydroxides, goethite). Additionally, the microgabbro from Hole U1375B is characterized by millimeter thick veins of goethite.

Structural Geology

Structural features in Hole U1375A are veins and vein networks within sedimentary clasts, and geopetals in the surrounding sediments. The reliable geopetals are horizontal, indicating this part of Archenar Seamount has not been tilted since deposition of the geopetal infilling material. Veins and vein networks are common within the clasts, and

are up to 8 mm wide, although typically much thinner. In Hole U1375B several veins are present within the microgabbro (dolerite). Most of these veins are steeply dipping, with thinner conjugate veins at shallow dips.

Geochemistry

One sample of the Unit I microgabbro (dolerite) from Hole U1375B was analyzed chemically. It is moderately altered and highly evolved, and represents one of the most alkalic rocks recovered during Expedition 330. Data for the sample lie in the field of basanite and tephrite in a total alkalis (Na_2O+K_2O) vs. SiO_2 diagram. It appears to be the product of crystal fractionation dominated by olivine, and to a lesser extent, augite. It has slightly lower Zr and Y for its TiO_2 content than igneous rocks from Sites U1372 through U1374 and Site U1376, suggesting that it may represent a different magma type.

Physical Properties

Characterization of physical properties was conducted for material recovered at Site U1375. The data sets are mutually consistent and fall within the ranges expected based on the identified lithologies. In Hole U1375A, magnetic susceptibility, bulk density, and natural gamma ray radiation all show a moderate decrease downhole likely due to a reduction in basaltic clasts, but may also be affected by the fragmented nature of the recovered material. The 60 cm of microgabbro recovered in Hole U1375B generally has values of magnetic susceptibility and bulk density larger than observed in Hole U1375A and similar values of natural ray radiation. In Hole U1375A, values of GRA-derived bulk density, MS, and NGR each show a moderate decrease downhole, which may be related to a reduction in basaltic clasts, but may also be affected by the fragmented nature of the recovered material. Material from both holes show a color reflectance that is more yellow than blue. In terms of redness versus greenness, the sedimentary rocks of Hole U1375A are consistently more red than green, whereas the igneous rocks from Hole U1375B are more neutral.

Paleomagnetism

The single, 57 cm long microgabbro unit that may not be in situ had an average inclination of 36.3 ± 1.6° (determined from archive half-core data using Fisher statistics). A single discrete sample taken from the same unit has been interpreted as having a broadly consistent direction.

Microbiology

No microbiology samples were taken from Site U1375 samples.

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