IODP Expedition 385: Guaymas Basin Tectonics and Biosphere

Site U1550 Summary

Background and Objectives

Site U1550 (proposed Site GUAYM-06B) is located within the axial graben of the northern Guaymas Basin spreading segment. This site was chosen to lie very close to DSDP Site 481 to take advantage of the known presence, depth, and characteristics of sills and indurated sediments at Site 481, and to improve what is known about that site by redrilling it with improved coring tools and sampling approaches. Substantially improved recovery was expected relative to Site 481, leading to increased sampling resolution of downhole changes and enabling the use of modern microbiological approaches. The fault-bounded setting of Site U1550 provides the potential for high-flux fluid circulation in response to sill intrusion, leading to rapid cooling and potentially enhanced alteration due to the rapid removal of dissolved phases and gases. The primary objectives for Site U1550 are to characterize the physical, chemical, and microbial responses to sill intrusion into sediments at a high-flux end-member location.

Operations

We cored two holes at Site U1550 (proposed Site GUAYM-06B). Hole U1550A is located at 27°15.1602′N, 111°30.4163′W in a water depth of 2000.8 m. In Hole U1550A, we used the advanced piston corer (APC), half-length APC (HLAPC), and extended core barrel (XCB) coring systems to advance from the seafloor to a final depth of 207.0 mbsf with a recovery of 190.9 m (92%). We made formation temperature measurements at several depths using the advanced piston corer temperature tool (APCT-3) and Sediment Temperature 2 (SET2) tool. In Hole U1550B, located at 27°15.1704′N, 111°30.4451′W in a water depth of 2001.2 m, we deployed the APC/HLAPC/XCB coring tools. Cores penetrated from the seafloor to a final depth of 174.2 mbsf and recovered 160.8 m (92%). Hole U1550B was dedicated to extensive microbial and biogeochemical sampling that required the deployment of perfluorocarbon tracers (PFTs) downhole on all cores to monitor drilling fluid (seawater) contamination. The pacing of coring in Hole U1549B was adjusted to accommodate the complex microbial sampling program conducted on the core receiving platform. A total of 72.0 h, or 3.0 d, were spent at Site U1550.

Principal Results

Lithostratigraphy

At Site U1550, a succession of sediments, sedimentary rocks, and igneous rocks was recovered. The sediments recovered can mainly be ascribed to two lithologic types: (1) a biogenic-

dominated type, in which more or less laminated olive gray diatom clays occur mixed with various proportions of nannofossils and silt-sized siliciclastic particles; and (2) a siliciclastic-dominated type in which coarse-grained siliciclastic components (sand and silt), clay minerals, and subordinate diatoms occur either mixed in homogenous layers or segregated in depositional layers often characterized by graded bedding and scoured bottoms. Most of the thickest graded terrigenous layers identified can be traced between holes. Vertical changes in the character of the dominant lithology, the style of bedding and/or deformation, and diagenetic boundaries prompted the subdivision of Unit I into three subunits. Subunit IA includes three thick event beds and shows evidence of soft-sediment deformation. The bottom of the subunit is marked by a lithologically complex correlative interval that includes a large concentration of silt- to granule-sized fragments of scoria. Subunit IB is mainly composed of varying proportions of diatoms, clay, and silt, with sand occurring principally as a minor component. The upper part of the subunit contains a very distinctive, ~18 m thick, homogenous interval composed of olive green diatom clay. Subunit IC shows pronounced differences between holes. In Hole U1550A, the top of this subunit corresponds to the first appearance of carbonates (micrite/nodules). The latter occur scattered in diatom clay or coarser grained, sand- to silt-sized cement grains. Folding and tilting are common as well as the presence of coarser grained beds, including event bed T4. Low diatom abundance and preservation indicate silica diagenesis and the transition from opal-A to opal-CT. In Hole U1550B, Subunit IC was identified in only three cores that are mainly composed of organic-rich, yellowish-brown homogenous diatom clay showing evidence of soft-sediment deformation. The sediments recovered at Site U1550 display a variety of sedimentary features, including graded beds with scoured bases ranging from a few centimeters to several meters in thickness, tilted and/or folded beds or laminae, and chaotic fabric that together are direct evidence that deposition at this site occurred mainly by means of mass-gravity flows.

Igneous Petrology and Alteration

The dominant igneous lithology recovered at the bottom of both Hole U1550A (top margin at ~204 mbsf with ~1.2 m recovered) and Hole U1550B (top margin at ~174 mbsf with ~1.6 m recovered) is dolerite, but minor sparsely to highly plagioclase-phyric basalt occasionally occurs in different intervals. Notably, there is a gradational change in grain size transitioning from basaltic to doleritic texture within a distance of few centimeters, indicating slower magma solidification. Nevertheless, there are also angular fragments of dolerite entrapped within basalt intervals in Hole U1550B. The slightly to moderately altered, nonvesicular to sparsely vesicular igneous rocks also contain multiple, slightly dipping calcite veins running parallel to each other.

Structural Geology

Both Holes U1550A and U1550B exhibit folding and tilted bedding at levels starting at 15 mbsf and continuing intermittently below. These are attributed to soft-sediment deformation and slumping because they are variable on a small spatial scale. Significant faults are seen in both holes at about 130 to 140 mbsf, where sets of parallel faults with apparent dips of about 60°

displace the sediment. These faults have a spacing of 0.2 to 1 m in the cores, but the amount and direction of displacement is unknown. The faults indicate an episode of deformation that occurred prior to the time of deposition of sediments that are now found at about 130 mbsf.

Biostratigraphy

Calcareous nannofossils are abundant and common downhole to 123.08 mbsf, rare/barren from 131.06 to 135.6 mbsf, and resume to abundant and common occurrences from 142.02 to 187.66 mbsf. Nannofossil preservation is good/moderate throughout the entire sedimentary sequence. Marine diatoms are dominant to abundant with good/moderate preservation in the upper interval of Hole U1550A (0–72.51 mbsf). They alternate between abundant, common, and few with moderate to poor preservation at an intermediate depth range (81.02–123.08 mbsf), and range from few to rare and barren with poor preservation in the lowermost interval (131.06–200.55 mbsf). Apparent diagenetic alteration of diatoms is present in samples with rare diatoms at the bottom of Hole U1550A. The diatom assemblages are obviously different from Sites U1545, U1546, U1547, and U1548, possibly suggesting strong disturbance of sedimentation sequences by underwater mass-flow events. The occurrence of calcareous nannofossil *Emiliania huxleyi* from the top to the bottom of both holes dates the entire sediment sequence to Holocene–Middle Pleistocene (0–0.29 Ma; Hole U1550A: 0–200.55 mbsf). This age assignment is consistent with the absence of *Pseudoemiliania lacunosa* (last appearance datum [LAD]: 0.44 Ma) and *Fragilariopsis reinholdii* (LAD: 0.62 Ma) in all samples examined. The estimated average sedimentation rate is >692 m/My (>69.2 cm/ky).

Paleomagnetism

We conducted alternating field (AF) demagnetization on archive-half sections up to 20 mT with the superconducting rock magnetometer (SRM) on all sediment cores from Hole U1550A (Cores U1550A-1H to 29X). The drilling-induced overprint was successfully removed on APC and HLAPC cores (from the seafloor to ~130 mbsf) upon demagnetization. Inclination values after demagnetization at 20 mT cluster around 46°, which is comparable to the expected geocentric axial dipole (GAD) inclination at the latitude of the site (46.4°). A detailed analysis of the remanence of discrete samples from Hole U1550A shows that the drilling-induced overprint was removed by 10 mT and the characteristic remanent magnetization is in agreement with the SRM measurements. Unfortunately, XCB cores were overprinted and too disturbed to yield reliable paleomagnetic data. Nevertheless, three discrete samples were collected in XCB cores and their inclination value is consistent with what is expected. Thus, Hole U1550A cores were assigned to the normal Brunhes Chron C1n (<0.78 Ma). Sedimentary discrete samples taken in Hole U1550A predominantly show prolate behavior through the hole with the K_{max} (maximum) principal axis of anisotropy of magnetic susceptibility distributed in the horizontal plane. We measured only the natural remanent magnetization (NRM) of archive-half sections containing igneous rocks (Cores U1550A-30X to 32X) because AF demagnetization treatment was not effective.

Inorganic Geochemistry

A total of 42 interstitial water (IW) samples were collected at Site U1550, which is located 50–100 m from DSDP Site 481. The sulfate/methane transition zone (SMTZ) at this site is located at ~10 mbsf. The IW chemical properties show spatial and vertical heterogeneities. They exhibit a slight difference between Holes U1550A and U1550B (e.g., alkalinity, Mg^{2+}, Li^{+}, and B) and significantly change between the upper and lower parts of the sediment succession throughout both holes. In the upper part of Site U1550 (0–40 mbsf), alkalinity reaches very high values up to 90 mM, and Mg^{2+} accumulates to values higher than seawater concentration, while Ca^{2+} shows a decreasing trend due to authigenic carbonate precipitation. Below 100 mbsf, alkalinity and Mg decrease with depth, while Ca^{2+}, Li^{+}, Sr^{2+}, and $H_4SiO_4^{+}$ concentrations increase with depth. These elements show remarkable excursions above the sill. Thus, the IW chemical properties in this interval are likely to be influenced by the sill, as previously evidenced at DSDP Site 481.

Organic Geochemistry

At Site U1550, organic geochemists performed sampling and analysis of gas and solid-phase samples. In Hole U1550A, one headspace gas sample was analyzed per 9.5 m of advance for routine hydrocarbon safety monitoring; void gases were quantified and sampled for hydrocarbon, H_2, and CO contents; and the carbon, nitrogen, and sulfur contents of particulate sediment were characterized. In Hole U1550B, hydrocarbon, H_2, and CO analyses were performed on headspace and void gas samples. Carbon, nitrogen, and sulfur contents of sediment were characterized, and a comprehensive suite of gas and sediment samples were taken for postcruise analyses. Methane and C_2–C_6 hydrocarbons are detectable at depths below ~7 mbsf. Low C_1/C_2 values that displayed an anomalous relationship with temperature were observed in both Holes U1550A and U1550B. The lowest ratios occurred between ~100 and ~130 mbsf, but the concentrations of higher hydrocarbon were low and C_1/C_2 values returned to normal further downhole. From elemental analysis, we infer that the primary source of organic matter is marine in origin, although some samples indicate terrestrial organic matter input, and others are ambiguous due to the influence of mineral-associated nitrogen. In Hole U1550B, H_2 and CO are present at nanomolar concentrations.

Microbiology

Hole U1550B is located in the northern axial graben, ~51 m from DSDP Site 481 where past studies included enrichments for hydrogenotrophic methanogens and detected living methanogens in shallow cores. Due to its cool temperatures, this site presents an opportunity for microbiologists to examine the microbial abundance and community structure in sediments with a lower temperature gradient compared to the other sites of Expedition 385. Syringe samples for cell counts, 3D structural imaging, and RNA analyses were taken on the core receiving platform, preserved or frozen, and stored for further analyses. Whole-round (WR) core samples were either stored in a −80°C freezer or temporarily stored in 4°C cold room and processed further for shore-based analyses. WR core sample processing was conducted either inside a Coy Laboratory

Products anaerobic chamber or on the bench with a KOACH open clean zone system in order to maintain as sterile conditions as possible. Samples for PFT measurements were taken on the core receiving platform by syringe at nine distinct horizons. Cell abundance for selected samples was determined by direct counting with an epifluorescence microscope. Cell abundance was 3.1×10^6 cells/cm^3 in bottom seawater, while seafloor sediments showed 1.1×10^9 cells/cm^3. Below the seafloor, cell abundance gradually decreased to below the detection limit of the protocol that we used for shipboard measurements.

Physical Properties

Measurements of physical properties made on WR and working-half core sections were compared between Holes U1550A and U1550B for lithostratigraphic characterization and correlation of visual core description with physical properties. Four in situ formation temperature measurements were conducted using the APCT-3 and SET2 tools for the calculation of the geothermal gradient and heat flow. Conductivity measurements between Holes U1550A and U1550B show a similar increasing trend with depth. Three main depth intervals are identified by the strength measurements between the seafloor and 43 mbsf, from 43 to 86.5 mbsf, and below 96.5 mbsf. The general rheology trend shows an increase of shear and compressive strength downhole while porosity strongly decreases due to the presence of a sill at the bottom of both holes. Strength and porosity measurements can be correlated with three lithologic subunits (IA, IB, and IC) and are negatively correlated with the rest of the physical properties (e.g., bulk density). Physical properties in Holes U1550A and U1550B show good correlation with depth except at ~80–90 mbsf where the peaks of natural gamma radiation, magnetic susceptibility, and *P*-wave velocity show an offset of 10 m between the two holes (at ~80 mbsf in Hole U1550A and ~90 mbsf in Hole U1550B). Also, these physical properties reveal the presence of a sill in both holes, (at 204 mbsf in Hole U1550A and at 173 mbsf in Hole U1550B).