IODP Expedition 385: Guaymas Basin Tectonics and Biosphere

Site U1551 Summary

Background and Objectives

Site U1551 (proposed Site GUAYM-15A) is located ~29 km southeast of the axial graben of the northern Guaymas Basin spreading segment. The type of sediment, the depositional environment, and the type, size, and presumably age of sill intrusions all differ in the southeastern side of the spreading segment relative to the northwest. The sediment here is predominately terrigenous, deposited as gravity flows ranging from landslides to turbidites, and the underlying sills are larger and more saucer-shaped than those in the northwest. The physical and chemical properties of sediments may impact alteration in response to sill intrusion, with consequences for carbon cycling. The size and shape of the sills beneath Site U1551 may be influenced by the physical properties of the sediments, which in turn may also impact permeability evolution with enhanced induration, ultimately affecting the efficiency of alteration. The greater presence of terrestrial organic carbon and metals in these sediments relative to the northeast may also affect sediment alteration and its products. The primary science objective at Site U1551 was to constrain the influence of sediment type, an important factor controlling alteration and carbon cycling, by studying the response of predominantly terrigenous sediments to sill intrusion.

Operations

Two holes were cored at Site U1551 (proposed Site GUAYM-15A). Hole U1551A is located at 27°12.3887′N, 111°13.1943′W in a water depth of 1844.1 m. In Hole U1550A, we used the advanced piston corer (APC) and half-length APC (HLAPC) coring systems to advance from the seafloor to a final depth of 120.3 m below seafloor (mbsf) with a recovery of 122.1 m (101%). We made formation temperature measurements at several depths using the advanced piston corer temperature tool (APCT-3). Coring was terminated because unconsolidated sand layers prevented us from reaching the deeper drilling objectives. In Hole U1551B, located at 27°12.3832′N, 111°13.1841′W in a water depth of 1843.9 m, we deployed the APC coring system. Cores penetrated from the seafloor to a final depth of 48.5 mbsf and recovered 50.0 m (103%). Hole U1551B 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 U1551B was at times adjusted to accommodate the complex microbial sampling program conducted on the core receiving platform. A total of 28.8 h, or 1.2 d, were spent at Site U1551.

Principal Results

Lithostratigraphy

The sediments recovered at Site U1551 are assigned to Lithostratigraphic Unit I. They represent a combination of biogenic (diatom ooze to diatom clay) and terrigenous (sand/silt/clay grade) components with the highest overall proportion of silty to sandy intervals (~60%) cored during Expedition 385. Macroscopic core description and microscopic smear slide analysis show that two main types of components are clustered in four different stratigraphic intervals. These lithologic patterns are reflected in the natural gamma radiation (NGR), magnetic susceptibility (MS), and color reflectance (CR) data, forming the basis of the division of Unit I into four subunits, with Subunits IA and IC being more biogenic rich and Subunits IB and ID being more siliciclastic rich. Lithologies in which the content of diatoms is very high (>85%) are mainly found in Subunit IA. Succeeding Subunit IB includes authigenic carbonates that occur in small patches of micrite, partly cemented sandstone intervals, or carbonate concretions. This subunit also contains thick sand beds and, overall, it is dominated by coarser grained siliciclastic sediments that correspond to higher MS and NGR values. Subunit IC is composed of silt-rich diatom clay and clay-rich, mainly homogenous, diatom ooze alternating with beds of gray sand and silty sand. Subunit ID is mainly composed of medium-grained sand, which is partially interpreted to represent coring-induced flow in rather than in situ deposition. Although Site U1551 and the previously drilled Site U1549 share many similarities, Site U1551 contains larger proportions of siliciclastic (terrigenous) material. The predominance of siliciclastic components over biogenic ones and the presence of terrigenous depositional layers characterized by coarse-grained mass-gravity deposits suggest that the deposition at this site was more influenced by terrigenous sources than at the other sites drilled in Guaymas Basin during Expedition 385. This may be related to the more proximal location of Site U1551 to the Yaqui River delta.

Structural Geology

At Site U1551, Holes U1551A and U1551B penetrated Lithostratigraphic Unit I, recovering a sedimentary sequence of diatom ooze, diatom clay, sand, and silt. Bedding and lamination in the sedimentary succession are similar to those described for Sites U1545 to U1550. However, Site U1551 has intervals of massive sand in which the lack of stratification prevented any deformation structures from being identified. Folds are seen in Subunit IB in both holes, where contortion and soft-sediment deformation produced steep to overturned bedding below ~15 mbsf. The folded strata are cut by a single set of faults with subparallel orientations and apparent dips of 45°–70°. Faults were found in some deeper intervals. The differences in depths characterizing the folded strata in Holes U1551A and U1551B may have been partly caused by faulting prior to the deposition of Subunit IA. No faulting is inferred in Subunit IA at Site U1551, based on the stratigraphic similarity between the two drill holes.

Biostratigraphy

In Hole U1551A, calcareous nannofossils are abundant to rare down to 96.8 mbsf with two barren intervals around 24.8 and 25.1 mbsf. Downhole, nannofossils are barren in the interval 102.14–116.19 mbsf and abundant in the bottom sample from 119.01 mbsf. Nannofossil preservation is good and moderate throughout the entire sedimentary sequence except for two samples with poor preservation at 22.0 and 25.8 mbsf. The barren intervals correspond to recovered sections of predominantly sandy lithology. Marine diatoms are abundant with good preservation only in the uppermost part of Site U1551. Then they decrease in abundance with moderate to poor preservation from the seafloor to 36.9 mbsf, followed by an interval without diatoms from 36.9 to 61.22 mbsf. Diatoms vary from common to rare from 71 to 108.28 mbsf, with moderate to poor preservation, and are barren at the bottom of Hole U1551A. Diatoms are abundant but poorly preserved in a spot sample from 119.0 mbsf at the bottom of Hole U1551A. The occurrence of *Emiliania huxleyi* from the seafloor downhole to the bottom dates the entire sediment sequence to Holocene–Middle Pleistocene or 0–0.29 Ma in age (Hole U1551A: 0–119.01 mbsf). This age assignment is consistent with the absence of *Pseudoemiliania lacunosa* (Top: 0.44 Ma) and *Fragilariopsis reinholdii* (Top: 0.62 Ma) in all examined samples. The estimated average sedimentation rate is >410.4 m/My (>41.04 cm/ky).

Paleomagnetism

We conducted alternating field (AF) demagnetization up to 20 mT with the superconducting rock magnetometer (SRM) on all sediment archive-half core sections from Hole U1551A (Cores U1551A-1H to 19F). The drilling-induced overprint was successfully removed on APC and HLAPC cores (from the seafloor to ~120 mbsf) upon demagnetization. Inclination values after demagnetization at 20 mT cluster around 47°, which is comparable to the expected geocentric axial dipole (GAD) inclination at the latitude of the site (46°). A detailed analysis of the remanence of discrete samples from Hole U1551A shows that the drilling-induced overprint is removed by 10 mT and the characteristic remanent magnetization is in agreement with the SRM measurements. Thus, we assigned Hole U1551A cores to the normal Brunhes Chron C1n (<0.78 Ma). Sedimentary discrete samples taken in Hole U1551A predominantly show prolate behavior throughout the hole, with the K_{max} (maximum) principal axis of anisotropy of magnetic susceptibility distributed in the horizontal plane.

Inorganic Geochemistry

In Holes U1551A and U1551B, a total of 18 interstitial water (IW) samples were taken from all lithologies except for unconsolidated sands. Thus, it is challenging to decipher the IW properties due to the limited number of collected IW samples as a consequence of the abundance of sand. However, as demonstrated by the nearly complete sulfate depletion that coincides with a concentration peak for dissolved sulfide, the sulfate/methane transition zone (SMTZ) is located at ~25 mbsf. Authigenic carbonate precipitation was also observed visually, and the precipitation depth coincides with a sharp decrease in Ca^{2+} concentrations.

Organic Geochemistry

At Site U1551, organic geochemists sampled and analyzed gas and solid-phase samples. In Hole U1551A, one headspace gas sample was analyzed per 9.5 m of advancement for routine hydrocarbon safety monitoring, and the carbon, nitrogen, and sulfur contents of particulate sediment were characterized. In Hole U1551B, hydrocarbon analyses on headspace gas were performed at high resolution (two per 9.5 m of core), H_2 and CO contents were measured, and carbon, nitrogen, and sulfur contents of sediment were characterized. Hydrocarbon gases are detectable below ~30 mbsf and are primarily composed of methane and ethane. C_3–C_6 hydrocarbons were detected in only a few intervals at very low concentrations. Gas concentration with depth is strongly influenced by the presence of sand. From elemental analysis, we infer that the primary source of organic matter in organic-rich intervals is marine in origin. The presence of mineral nitrogen in the organic-poor levels prevents interpreting the C/N values in terms of organic source. H_2 and CO are present at nanomolar concentration levels and exhibit no trend with depth.

Microbiology

Site U1551 is located on the southeastern flanking region of Guaymas Basin in an area of low heat flow and is influenced by terrigenous sedimentation derived from the Yaqui River, which drains the Sierra Madre Occidental and coastal Sonora. As such, this site presents an opportunity for microbiologists to examine microbial abundance and community structure in organic carbon–depleted sediments with more moderate temperature gradients compared to the other sites drilled during 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 a 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 to maintain as sterile conditions as possible. Samples for PFT measurements were taken on the core receiving platform by syringe at five distinct horizons. Cell abundance for selected samples was determined by direct counting with an epifluorescence microscope. Cell abundance in bottom seawater was 1.1×10^6 cells/cm^3, and 0.9×10^9 cells/cm^3 in seafloor sediments. Below the seafloor, cell abundance gradually decreased but stayed above the detection limit of the protocol that we used for shipboard measurements at the deepest sample obtained from Hole U1551B.

Physical Properties

Physical properties at Site U1551 were measured on WR and split-core sections. Two holes were cored to depths of ~120 mbsf (Hole U1551A) and ~49 mbsf (Hole U1551B), respectively. The acquired data were compared between holes for lithostratigraphic characterization and correlation of core description information with the physical properties data. Four in situ formation temperature measurements were made with the APCT-3 tool for the calculation of

geothermal gradient and heat flow. Hole U1551A conductivity measurements show an increase of values with depth according to the composition of the sediment. Four distinct depth intervals can be identified in all petrophysical parameters: from the seafloor to 15 mbsf, between ~15 and ~65 mbsf, from ~67 to 92 mbsf, and below 92 mbsf. Shear strength consistently increases with depth, coinciding with higher values in compressive strength. Porosity and density values derived from the moisture and density measurements show a strong negative correlation at all depths. The other measured physical properties (density, NGR, MS, and *P*-wave velocity) show a positive correlation with depth that is in accordance with the corresponding presence of diatom ooze, clay, and sand beds. The general trend of these physical properties shows maximum peak values between 15 and 65 mbsf and below 92 mbsf.