IODP Expedition 385: Guaymas Basin Tectonics and Biosphere

Site U1549 Summary

Background and Objectives

Site U1549 (proposed Site GUAYM-16A) is located ~9.5 km northwest from the northern axial graben of Guaymas Basin, and ~780 m northwest of a mound-shaped seafloor feature where active cold-seep communities have been documented. In addition, seismic data at this location image an underlying sill at ~450 mbsf and indicate gas movement along and around a pipe structure. This association of a relatively deep sill, active gas venting, and seafloor communities connects multiple components of the carbon budget of a sill-driven vent/seep system. The sedimentary setting at Site U1549 is intermediate between the almost exclusively biogenic sedimentation of Sites U1545 and U1546 and the dominantly terrigenous deposition southeast of the northern axial graben. The primary objectives for Site U1549 are thus to characterize the physical, chemical, and microbial properties of this sedimentologically intermediate setting and to assess the influence of the underlying sills and altered sediments on carbon cycling in the subseafloor.

Operations

Two holes were cored at Site U1549 (proposed Site GUAYM-16A). Hole U1549A is located at 27°28.3317′N, 111°28.7844′W in a water depth of 1840.1 m. In Hole U1549A, we used the advanced piston corer (APC) coring system to advance from the seafloor to a final depth of 168.0 mbsf with a recovery of 166.9 m (99%). We made formation temperature measurements at several depths using the advanced piston corer temperature tool (APCT-3). In Hole U1549B, located at 27°28.3383′N, 111°28.7927′W in a water depth of 1841.2 m, we deployed the APC coring tool. Cores penetrated from the seafloor to a final depth of 166.9 mbsf and recovered 164.4 m (99%). Hole U1549B 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 51.1 h, or 2.1 d, were spent at Site U1549.

Principal Results

Lithostratigraphy

The sediments recovered at Site U1549 are Holocene to Middle Pleistocene in age, and are mostly biogenic (mainly diatom ooze) with a significant (~10%) proportion of sand- to silt-sized

siliciclastic components that occur either mixed with the biogenic component or concentrated in discrete laminae and beds. No major diagenetic changes were observed, probably because of the relatively shallow subseafloor depth reached at this site, leading to the characterization of a single lithostratigraphic unit (Unit I). The most common lithology observed is olive gray, clay- to silt-rich diatom ooze. Unlike what was observed at the northwestern (U1545/U1546) and Ringvent (U1547/U1548) sites, the diatom ooze is primarily nonlaminated. The terrigenous-dominated, depositional layers that intercalate with diatom ooze range from a few centimeters to a meter thick and show sharp bases, locally marked by a coarser basal lamina of silt- to sand-sized bioclasts (foraminifers, small bivalves). The thickest beds occasionally exhibit a base of laminated, bioclastic sand with a few coarse siliciclastic particles. Other coarse siliciclastic (silt to sand-sized) depositional layers were also recognized, and they range from a few millimeter-thick laminae to beds as thick as ~6 m. The thickest of these beds are normally graded and are associated with basal sand to silty sand that shows scouring at the base. Four exceptionally thick, normally graded terrigenous depositional layers were noted within the lithological succession. Three of these beds were clearly correlated between Holes U1549A and U1549B and show a characteristic increase in natural gamma radiation (NGR), magnetic susceptibility (MS), and color parameter b*. The depositional layers composed of homogenous biogenic and siliciclastic components can be interpreted as the products of slope instability. The gray fining-upward silty to sandy terrigenous layers may be the result of hybrid flows.

Structural Geology

Structural information was obtained from sedimentary sequences at Site U1549. None of the samples were sufficiently lithified to be measured independently as whole-round (WR) pieces. Tilted laminae seen in Cores U1549A-2H and 3H suggest small-scale slump folds, but the rest of Holes U1549A and U1549B mostly have laminae that are roughly perpendicular to the axis of the hole. One chevron fold with a horizontal fold axis was found in the interval 385-U1549A-3H-1A, 42–47 cm. Tilted bedding was noted starting in Section 385-U1549A-16H-1 (at 139.5 mbsf) and continues to deeper levels in Cores 385-U1549A-17H and 18H with values typically from 10° to 15°. A few brittle faults were seen at different depths in the section, but overall there is much less faulting in the sedimentary section here, compared to Ringvent Sites U1547/U1548, northern Guaymas rift Site U1550, and northwestern Guaymas Basin Sites U1545/U1546.

Biostratigraphy

Calcareous nannofossils are abundant to common with good/moderate preservation throughout the entire sampled sequence at Site U1549, and the barren interval seen at Sites U1545, U1546, U1547, and U1548 is not present at this site. Reworked nannofossils include a significant component of Miocene taxa with a greatly reduced contribution of reworked Cretaceous specimens. In general, marine diatoms are dominant to abundant with good/moderate preservation throughout Hole U1549A, except for 63.62 and 71.23 mbsf where diatoms have a

common abundance. Freshwater diatoms in Hole U1549A are much more frequent than at the northwestern and Ringvent sites, particularly at similar depths. This suggests strong influence of terrestrial input. No evidence of diagenetic alteration of diatoms is present in Hole U1549A. The occurrence of *Emiliania huxleyi* from the top to the bottom of the hole dates the entire sediment sequence to Holocene–Middle Pleistocene (0–0.29 Ma; Hole U1549A: 0–168.35 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 examined samples. The estimated average sedimentation rate is >580 m/My (>58.0 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 U1549A (APC cores). The drilling-induced overprint was successfully removed from all cores (from the seafloor to ~168 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 U1549A shows that the drilling-induced overprint is removed by 10 mT and the characteristic remanent magnetization is in agreement with the SRM measurements. Natural remanent magnetization (NRM) of archive-half sections is higher at ~16–19, ~69.5–70, and 79.5–80 mbsf. These intervals correspond to sandy layers that contain more detrital material. We assigned Hole U1549A cores to the normal Brunhes Chron C1n (<0.78 Ma).

Inorganic Geochemistry

A total of 65 interstitial water (IW) samples were collected by hydraulic squeezer (35 IWs from the seafloor to 160 mbsf) and by Rhizon samplers (30 IWs from the seafloor to 30 mbsf in Hole U1549A) at Site U1549. Based on sulfate profile, the sulfate/methane transition zone (SMTZ) is estimated at 30 mbsf in Hole U1549A and at 25 mbsf in Hole U1549B. Below the SMTZ, alkalinity shows a high maximum value of 85 mM. High values at depth suggest that the alkalinity production is not only due to organic matter mineralisation, as biogenic methanogenesis pathways at these depths do not produce any alkalinity. Mg^{2+} has higher concentration than in seawater (53.5 mM) and its maximum value reaches 65 mM below the SMTZ. In addition, downhole concentration profiles of Li^{+}, B, and $H_4SiO_4^{+}$ generally display an increasing trend, with higher values than those of seawater. The IW chemical signatures at Site U1549 may be predominantly influenced by organic matter degradation related to microbial processes and by sediment-water interactions associated with silicate weathering and mineral precipitation/dissolution processes.

Organic Geochemistry

At Site U1549, organic geochemists performed sampling and analysis of gas and solid phase samples. In Hole U1549A, one headspace gas sample was analyzed per 9.5 m advance for

routine hydrocarbon safety monitoring, void gases were quantified and sampled for hydrocarbon content, and the carbon, nitrogen, and sulfur contents of particulate sediment were characterized. In Hole U1549B, hydrocarbon analyses were performed on headspace gas, H_2 and CO contents were measured, sediment carbon, nitrogen, and sulfur contents were characterized, and a comprehensive suite of gas and sediment samples was taken for postexpedition analyses. Methane appears below ~25 mbsf, and C_2–C_6 hydrocarbons are all detectable at depths below 60 mbsf. No anomalous C_1/C_2 values were observed. From elemental analysis, we inferred that the primary source of organic matter is marine in origin. In Hole U1549B, H_2 and CO are present in low concentrations, implying that biological cycling is the dominant control on these gases.

Microbiology

Hole U1549B samples represent horizons that inform our understanding of the cycle of carbon driven by fluid flow occurring in the subseafloor of Guaymas Basin. In contrast to the other Expedition 385 sites, Site U1549 is effectively a cold seep site characterized by mass-gravity flows. Thus, the site has a relatively high proportion of terrigenous material, and an attenuated thermal gradient that indicates very moderate hydrothermal warming. As such, it provides an opportunity for microbiologists to examine the influence of these gravity flows on in situ microbial diversity and activities within a hydrothermal setting distal to the immediate influences of emplaced sills and/or extremely hot hydrothermal fluids. 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. 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 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 six distinct horizons. Cell abundance for selected samples was determined by direct counting with an epifluorescence microscope. Cell abundance was 0.94×10^6 cells/cm^3 in bottom seawater and 6.3×10^8 cells/cm^3 in seafloor sediments. Below the seafloor, cell abundance gradually decreased to below the detection limit of the protocol that we used for shipboard measurements.

Physical Properties

Physical properties measured on WR and working-half core sections were compared between Holes U1549A and U1549B for lithostratigraphic characterization and correlation of visual core description with physical properties. Four in situ formation temperature measurements were taken with the APCT-3 and SET2 tools for the calculation of the geothermal gradient and heat flow. Conductivity measurements show a similar trend with depth in Holes U1549A and U1549B. We have identified one main interval that correlates to lithostratigraphic Unit I. However, NGR and MS peaks at ~70 to 100 mbsf can be correlated with four depositional subunits. These physical properties along with density and *P*-wave velocity values have a negative correlation with porosity. Thus, porosity derived from MAD measurements shows a

general decrease with depth. In contrast, shear strength measurements show a linear increase due to the presence of indurated sediments.