IODP Expedition 385: Guaymas Basin Tectonics and Biosphere

Site U1552 Summary

Background and Objectives

Site U1552 (proposed Site GUAYM-10B) is located ~20 km northwest of the northern axial graben in Guaymas Basin. The site is adjacent to a mostly buried mound that sits atop a pipe-like blanked zone that was observed in seismic line SO-112 extending toward the edge of an interpreted sill intrusion at ~700 m below seafloor (mbsf). Cold-seep seafloor communities are known to exist in the area above the edges of the interpreted deep sill. The mound structure is similar to the surficial mound near Site U1549, where gas hydrate is present at the seafloor, and it was thus expected that massive gas hydrate can be sampled in Hole U1552A, which is situated directly adjacent the mostly buried mound. As with Site U1549, the association of a relatively deep sill, gas hydrates, and nearby seafloor communities connects multiple components of the carbon budget of a sediment deposition system that is influenced by a deep sill. The primary objectives for Site U1552 were thus to characterize the physical, chemical, and microbial properties of this environment and to assess the influence of the deep sill on interstitial water chemistry and gas hydrate stability, the role of gas hydrates as a carbon-storage buffer, the utilization of permeable pathways between the sill and the seafloor for the transport of deep thermogenic gas, and the impact of lateral gradients away from the pipe structure on microbial life.

Operations

We cored three holes at Site U1552 (proposed Site GUAYM-10B). Hole U1552A is located at 27°33.2906′N, 111°32.9665′W in a water depth of 1841.6 m. In Hole U1552A, we used the advanced piston corer (APC) tool to advance from the seafloor to a final depth of 107.5 mbsf with a recovery of 73.9 m (69%). We made formation temperature measurements at several depths with the advanced piston corer temperature tool (APCT-3). In Hole U1552B, located at 27°33.2885′N, 111°32.9640′W in a water depth of 1841.1 m, we deployed the APC coring tool. Cores penetrated from the seafloor to a final depth of 55.0 mbsf and recovered 40.0 m (73%). Hole U1552B 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. Few cores from Holes U1552A and U1552B recovered gas hydrates. In Hole U1552C, located at 27°33.2181′N, 111°32.8557′W in a water depth of 1844.3 m, we deployed the APC coring system. Cores penetrated from the seafloor to a final depth of 99.3 mbsf and recovered 78.3 m (79%). A total of 32.6 h, or 1.4 d, were spent at Site U1552.

Principal Results

Lithostratigraphy

Site U1552 provides information on the history of sedimentation near a methane-rich cold seep mound in Guaymas Basin close to the Sonora margin. The deepest hole (Hole U1552A) recovered a 105.2 m thick succession of sediments constituting Lithostratigraphic Unit I. The lithologies at this site show prominent downhole variability with three main types: diatom clay, silty clay, and sandy silt alternating at vertical scales of meters. The alternations occur throughout the recovered section without any specific trend or clustering of one lithology with respect to the others. Hence only one lithostratigraphic unit was identified. Holes U1552A and U1552C show a high level of correlation that can be observed at the scale of a single bed. The most traceable of these beds are dominated by coarse-grained siliciclastic deposits (sand and silt). The thickest beds (~5 m) exhibit scoured bases and normally graded sand that fines upward into clayey silt to silty clay. The main biogenic components in the sediment are siliceous diatoms with rare radiolarians and silicoflagellates. The silt to sand fractions consist mainly of feldspar and lithic fragments with lesser quartz, dense and micaceous minerals. Also, foraminifers are a significant component in several beds. Overall, calcareous nannofossils and foraminifers are present throughout the recovered sediments, along with organic matter and plant debris. Authigenic carbonates occur only in the upper part of the site as disseminated micrite (micrometer-sized authigenic carbonate particles) or as cements of small sandy concretions. Fossil bivalves, belonging to the Lucinidae family, were observed at the very top of all three holes. Holes U1552A–U1552B recovered gas hydrates from ~25 mbsf that decomposed quickly after the cores arrived on deck. As a consequence of hydrate dissociation and gas expansion, the sediments were often disturbed and most cores displayed gas expansion cracks and voids. Complex structures were observed in Hole U1552C, including laminated diatom clay intervals crosscut by gray clayey silt at high angle contacts that locally extend down the core for up to 1 m.

Structural Geology

Coring at Site U1552 was intended to constrain differences in seismic reflection stratigraphy that were seen on either side of a seafloor mound. In the three holes cored, the sequence has beds that are generally horizontal, with no significant tilt domains or folded strata. However, gas hydrates that disturbed the sediments were found at ~25 mbsf in Holes U1552A and U1552B. Overall, Hole U1552C revealed much more deformation than the other two holes, showing evidence for considerable injection and mobilization of sand along a high-angle conduit or clastic dike that continued through two sections of core. In some places, the clastic dike occupies a preexisting fault plane. The remobilization of sand indicates that a substantial volume of sediment may have been lost from below. Other oblique faults and fractures were found in Hole U1552C at depths below the clastic dike, being attributed to mechanical instability caused by the presence of gas hydrates.

Biostratigraphy

At Site U1552, calcareous nannofossils are well preserved with abundant to common occurrence throughout the entire sedimentary sequence, and marine diatoms are dominant/abundant to common with good/moderate preservation. No biostratigraphic datum was defined in the generally continuous succession from the Holocene to the Middle Pleistocene. The occurrence of calcareous nannofossil *Emiliania huxleyi* at the bottom of both holes dates the entire sediment sequence to Holocene–Middle Pleistocene or 0–0.29 Ma in age. 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 >362.6 m/My (>36.26 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 U1552A (Cores U1552A-1H to 12H) and Hole U1552C (Cores U1552C-1H to 11H). A small drilling-induced overprint was successfully following demagnetization. Inclination values after demagnetization at 20 mT cluster around 43°, which is comparable to the expected geocentric axial dipole (GAD) inclination at the latitude of the site (~46°). We measured only the natural remanent magnetization (NRM) of archive-half sections in Hole U1552B (Cores U1552B-1H to 6H). A detailed analysis of the remanence of discrete samples from Holes U1552A and U1552C shows that the drilling-induced overprint is removed by 5 mT and the characteristic remanent magnetization is in agreement with the SRM measurements. Thus, we assigned all Site U1552 cores to the normal Brunhes Chron C1n (<0.78 Ma).

Inorganic Geochemistry

A total of 31 interstitial water (IW) samples were collected at Site U1552. Based on the sulfate profile and a slight increase of methane, the sulfate/methane transition zone (SMTZ) is estimated at 10 mbsf. Salinity and Cl^- concentrations were measured on gas hydrate–bound water from Hole U1552C. Salinity and Cl^- values of 2 and 10.5 mM, respectively, are depleted compared to seawater (35 [salinity] and 559 mM [Cl^-]). Thus, the dissociation of gas hydrates could cause anomalies in the retrieved IW as observed in the Cl^- concentration of around 500 mM at 25 mbsf from Hole U1552C. By means of salt exclusion, gas hydrate formation could also affect the IW chemical properties at Site U1552. Below the SMTZ, high salinity and increases in many cation concentrations (K^+, Mg^{2+}, Ca^{2+}, etc.) were observed. Notably, such an increase was not observed in Cl^- concentration. Alkalinity reached values of up to 175 mM, the highest value recorded at any of the Expedition 385 sites.

Organic Geochemistry

At Site U1552, organic geochemists sampled and analyzed gas samples. In Hole U1552A, one to two headspace gas samples were analyzed per 9.5 m of advancement for routine hydrocarbon safety monitoring, and void gases were quantified and sampled for hydrocarbon content. In Hole U1552B, hydrocarbon analyses on headspace gas were performed; H_2 and CO contents in headspace vials were measured; void gases were quantified and sampled for hydrocarbons, H_2, and CO contents. In Hole U1552C, hydrocarbon analyses on headspace gas were performed and void gases were quantified and sampled for hydrocarbon content, H_2, and CO contents, as well as shore-based analyses. Due to the proximity of Site U1552 to the end of Expedition 385, no sediment samples were analyzed for carbon, nitrogen, and sulfur contents. Site U1552 featured the presence of methane hydrates in the sediment between 9 and 27 mbsf. Maximum methane concentrations in headspace gas were detected in this depth interval. C_2–C_6 hydrocarbons were detectable at depths below ~25 mbsf without a clear trend downhole. The abundance of dissolved gas in the sediment was marked by an abundance of voids in the cores, which could represent more than 100% of the sediment recovery. Methane was dominant in these voids. H_2 and CO were detected in the void gases, but showed no clear trend downhole.

Microbiology

Site U1552 provided access to hydrate-rich sediments overlying cooler, deep sills on the northern flank of Guaymas Basin near the transition to the Sonora margin. This site presented an opportunity for microbiologists to examine microbial abundance and community structure changes throughout the gas hydrate stability zone in the sediment. 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. Cell abundance for selected samples was determined by direct counting with an epifluorescence microscope. Cell abundance in bottom seawater was 6.6×10^6 cells/cm^3, and 1.2×10^9 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 U1552B.

Physical Properties

Physical properties of cores were measured on WR and split-core sections. The acquired data were compared between Holes U1552A and U1552C for lithostratigraphic characterization and correlation of core description information with physical properties data. Seven in situ formation temperature measurements were taken with the APCT-3 tool for the calculation of the geothermal gradient and heat flow. Hole U1552A thermal conductivity values indicate that temperatures increase with depth. Two different intervals can be identified in all petrophysical

parameters. From the seafloor to ~12 mbsf and at 18–87 mbsf, density, natural gamma radiation (NGR), and magnetic susceptibility (MS) are mainly constant. Peaks observed at ~18, ~58, and ~93 mbsf show increases in density, NGR, and MS values and decreases in porosity and strength values. Porosity measured on discrete moisture and density samples generally outlines a trend that mirrors the bulk density measurements. The shear and compressive strength trends increase with depth. For *P*-wave velocities from 12 mbsf to the bottom of both Holes U1552A and U1552C, erratic data that are typically related to voids and cracks in the cores predominate.