IODP Expedition 366: Mariana Convergent Margin

Site U1496 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1496 (proposed Site MAF-11A) is located on the summit of Asùt Tesoru Seamount (informally called Big Blue Seamount in the Scientific Prospectus and previous publications) at 18°6.61′N, 147°6.10′E, in 1244 m of water. The site lies on multichannel seismic (MCS) reflection profile EW0202 42-44.

Asùt Tesoru Seamount is a serpentinite mud volcano that lies about 72 km from the trench axis, and is the farthest from the trench of the three seamounts targeted on this expedition. The subducting slab lies approximately 18 km below its base according to interpretation of MCS data (Oakley, et al., 2007). This mud volcano is the largest so far discovered on the Mariana forearc. It is about 50 km in diameter and over 2 km high. It may have been active since the Eocene because nearby DSDP Site 459 recovered two intervals of sediment immediately above Eocene basement that contained about 50% serpentine (Despraires et al., 1981).

An MCS line EW0202 42-44, collected in 2002 with the R/V *Ewing,* across Asùt Tesoru Seamount traversed the 2 km wide, 150 m high mound that tops the seamount. Gravity and piston cores taken at this mound in 2003 on a cruise with the R/V *Thomas G. Thompson* recovered serpentinite muds that oozed out of the core catcher, suggesting that the muds in the mound contain gas (Fryer et al., in prep.). The MCS profile shows reflectors below the surface that may represent a previous surface of the summit area that deflated since eruption and formed a depression that was subsequently refilled by the mound.

The summit mound is itself topped by three smaller circular mounds, the largest of which is about 400 m in diameter and about 40 m high. The two others are about 250 m in diameter and 20 m high. A dive by ROV *Jason-2* at the summit of the 500 m mound revealed serpentinite mud at the surface with no sediment overlying it. A transect of push cores using *Jason-2* from west to east across the low-backscatter patch found the highest fluid flow rate to be in the center of the transect. The holes drilled at Site U1496 run perpendicularly south from the middle of the *Jason-2* transect.

Drilling was expected to recover recently erupted serpentinite muds along with serpentinized peridotite clasts and perhaps other lithologies from the conduit system of the seamount, as has been documented from the gravity and piston cores taken earlier (Fryer et al., 2006). It was also expected to recover pore fluids with a pristine signal from slab-derived fluids, because of the active fluid flow. The screened-casing hole at this site was planned for the area of highest fluid flow, to provide the foundation for future experiments and sampling with the aid of a CORK-Lite structure to be installed postcruise.

Coring at this location was chosen to: 1) intersect mudflows emanating from the spring; 2) potentially date discrete mud flows paleontologically, should there be sediment layers between them; 3) determine variability of mudflow composition and thickness; 4) investigate potential systematic variability in degree of serpentinization; 5) examine transport conditions; 6) provide a measure for the scale of potential fluid flux and composition characteristics (e.g., diffuse vs. channelized), and 7) collect samples for microbiological studies.

Operations

Hole U1496A (18°6.5936'N, 147°6.0999'E, water depth 1244 m)

Coring at Hole U1496A (proposed Site MAF-11A) began at 0045 h on 8 January, after a 1 nmi transit from Site U1495. We started with half-length advanced piston corer (HLAPC) coring, and switched to extended core barrel (XCB) coring after Core U1496A-9F did not achieve a full stroke. The penetration rate slowed, and after reaching 44.8 mbsf we ended the hole. Hole U1496A penetrated to 44.8 mbsf and recovered 38.7 m (86%).

Hole U1496B (18°6.6210'N, 147°6.1000'E, water depth 1240 m)

Hole U1496B was started at 1915 h on 8 January, 50 m to the north of Hole U1496A. Coring proceeded well until a clast-rich zone starting at about 28 mbsf slowed coring. To try to pass through the zone we took XCB Core U1496B-8X, then drilled ahead to 34.3 mbsf and took Core U1496B-10F which contained only rock clasts, so we ended the hole at this point. Hole U1496B penetrated to 36.0 mbsf and recovered 22.1 m (74%). To reach the target depth of about 110 mbsf at this site, we pulled the drill pipe back up to the ship to switch to rotary core barrel (RCB) coring in a new hole.

Hole U1496C (18°6.6074'N, 147°6.1000'E, water depth 1244 m)

Hole U1496C started at 2320 h on 9 January at a location midway between the first two holes at the site. Coring progressed quickly, penetrated 105 m, and recovered 8.52 m (8%). The low levels of core recovery were anticipated for rotary coring in this material, and the coring did its intended job of reaching 105 mbsf, the depth to which casing would be emplaced in the hole. The hole was swept and reamed, the reentry cone was deployed, and the drill pipe was raised back to the ship. To further prepare the hole for casing, it was reentered at 2340 h on 10 January with a 14.75 inch bit, and widened by drilling and reaming to 120 mbsf. The drill pipe was raised up to the drill floor and the 105 m long casing was assembled.

The casing for Hole U1496C consisted of two regular 10.75 inch casing joints, three screened casing joints, and three further regular casing joints, connecting to a 16 inch casing hanger at the top. The underreamer and mud motor bottom-hole assembly (BHA) was assembled and lowered through the casing, and the running tool on the BHA was attached to the casing hanger on the casing. The bit extended about 4 m below the base of casing. The casing and bit/underreamer assembly reentered Hole U1496C at 0130 h on 12 January, and reached the target depth of 109 mbsf at 1100 h. Downward progress was fairly rapid, apart from taking a few hours to pass through a hard zone at ~40 mbsf. The casing was latched to the reentry cone and the bit/underreamer assembly was pulled inside the casing. The ~4 m diameter circular ROV platform was deployed and landed slightly off-center, by about 1 ft, but is still functional. Hard fill was found in the casing at a depth of 99 mbsf, indicating that formation material had come up about 6 m inside the casing. The drill pipe was raised up to the ship and the rig floor was secured for transit to Site U1497 (proposed Site MAF-9B).

We returned to Hole U1496C on 21 January at 1525 h after a 144 nmi, 13.4 h transit from Hole U1492D. The aim was to take a water sample using the water-sampling temperature probe (WSTP), remove the fill, and cement the bottom of the casing. The drill pipe was lowered to the seafloor and reentered Hole U1496C without difficulty, despite having to pass through the 32 inch diameter central aperture in the ROV landing platform. The drill pipe was lowered to 42 mbsf, within the upper joint of screened casing, where the WSTP was deployed to sample borehole fluids and take temperature measurements. Initial geochemical measurements of the ~1 L WSTP fluid sample indicate that it was mostly formation water, mixed with some drilling water (seawater). We used a 9.825 inch polycrystalline diamond compact (PDC) coring bit because it was narrow enough to fit inside the casing. The drill pipe was lowered and we found fill at 99 mbsf, ~7 m above the base of casing, a depth similar to where it was when the casing was installed on 12 January. We sampled the material inside the casing with Cores U1496C-12G and 13G, which recovered 7.7 m serpentinite mud with lithic clasts from this previously cored depth interval. Five barrels of 14 ppg cement were pumped with the aim of sealing the base of casing. The drill pipe was raised above the seafloor and flushed to remove any residual cement, then raised back to the ship, concluding operations at Site U1496.

Principal Results

Holes U1496A and U1496B from the summit of Asùt Tesoru Seamount are characterized by a dominance of pale green serpentinite mud with a low proportion of lithic clasts compared to the sites on the flank of the seamount. The pale green serpentine mud is typically soupy or very soft due to its high gas content, and often continued to outgas well after the cores were split. Zones of dark blue serpentine mud are present but uncommon, and are characterized by higher clast counts. The most common clasts are ultramafic, typically highly serpentinized harzburgites with less common dunite and orthopyroxenite. There are rarer occurences of mafic metavolcanic clasts, which include dolerites. Clasts also include a fossiliferous limestone that may be pre-Eocene in age.

Pore waters and gas samples were extracted from cores from each of the three boreholes, including two sediment cores and one WSTP sample in the water column within the casing.

Dissolved gas data indicate high concentrations of methane and hydrogen, and high methane/ethane ratios, consistent with a deep-sourced origin. The methane to hydrogen ratio did not change with depth, indicating that microbial processes, while present and active, are not sufficient to alter the deep-sourced fluid composition as it upwells from depth. Many of the ions in the pore fluid show a rapid increase or decrease of concentration within the first meter, followed by a quick leveling off at a consistent concentration level, suggesting that there is significant upflow of deep-sourced fluids on the order of tens of centimeters per year. The pattern of cation and anion enrichments and depletions in pore waters at Asùt Tesoru Seamount are markedly different from those observed at Yinazao Seamount, and are also different from those measured at South Chamorro and Conical Seamounts (Mottl et al, 2003).

Samples were collected for shore-based microbiological samples. To assess possible artifacts from drilling operations, tracers were pumped into the drill string prior to and during core recovery. Tracer analyses indicate that most of the whole-round samples for microbiology are suitable for continued shore-based analyses.

Bulk density and porosity ranged from 1.6 to 2.0 g/cm^3 and 60% to 30%, respectively, similar to those measured at the summit of other active seamounts of the Mariana forearc, Site U1492 at Yinazao Seamount, Conical Seamount (Fryer et al., 1992), and South Chamorro Seamount (Salisbury et al., 2002). There is a slight increase in bulk density with depth in Hole U1496A, but no trend is observed in Hole U1496B. These results may suggest that Hole U1496B is likely closer to the main upwelling zone than Hole U1496A. Average physical property values of Site U1496 differ significantly from those obtained along the three-site transect on the southern flank of Asùt Tesoru Seamount (Sites U1493 to U1495), which have higher bulk density and lower porosity.

Downhole measurements included three formation temperature measurements (APCT-3) and one borehole water sample (WSTP). Two of the APCT-3 deployments were of sufficient quality to calculate formation temperature, which, together with the bottom water temperature, yielded a thermal gradient of 14°C/km. Using the average thermal conductivity of 1.26 W/(m·K) measured at this site, the estimated heat flow is 18 mW/m^2. WSTP temperature data in the borehole fluid inside the casing were collected during the reoccupation of the hole 9.5 d after circulation of drilling fluids ceased. This was a sufficiently long period such that the temperature in the borehole would nearly (~90%) equilibrate to pre-drilling temperatures. Fluid chemical data also indicate discharge of a deep-sourced fluid into the borehole during this period, likely warming the formation. Further analysis may discern the rate of discharge from the open borehole.

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