IODP Expeditions 367 and 368: South China Sea Rifted Margin

Site U1505 Summary

Background and Objectives

Site U1505 (proposed Site SCSII-3D) is located in a water depth of 2916.6 m on a broad regional basement high. It was an alternate to Site U1501, should time be left for drilling following completion of the high-priority sites included in the *Scientific Prospectus*. Both Sites U1505 and U1501 are located on the same structural high with similar water depths and are 10.5 km apart. The two sites are believed to have similar tectonic background. The seismic section at Site U1505 generally shows a more horizontal orientation of the seismic reflectors and concordant relationship of the strata than at Site U1501, indicating the sediment sequence here should be more complete. The key objective at Site U1505 was to sample the stratigraphic record above the seismic unconformity T80 (inferred to be ~38 Ma), with the specific goals of constraining both the sediment responses to the tectonic events and basin evolution since the Eocene, and Neogene paleoceanographic and paleoclimatological changes along the northern South China Sea (SCS) margin.

The relatively shallow water depth of 2916.6 m at Site U1505 makes it one of the few ODP/IODP sites above the modern carbonate compensation depth (CCD) of the SCS. Its hemipelagic deposits, rich in calcareous microfossils, enable the application of stable isotopes, faunal analyses, and other multi-disciplinary methods. Key objectives are to reconstruct the East Asian monsoonal climate record in the SCS, and upper and deep-water variations in the western Pacific. Site U1505 will provide an almost continuous sequence of paleoceanographic proxies (oxygen and carbon isotopes, etc.) at orbital and millennial timescales since the late Eocene in the SCS for the first time. We advanced piston corer (APC) cored two holes at this site to obtain a continuous record for the Pliocene to Pleistocene interval for high-resolution paleoceanographic studies.

Operations

Four holes were APC/XCB cored at Site U1505. In Hole U1505A (18°55.0560′N, 115°51.5369′E, water depth 2916.6 m) Core 1H misfired and recovered only 0.3 m. At Hole U1505B (18°55.0562′N, 115°51.5370′E, water depth 2918.6 m) a 3.23 m long mudline core was recovered for future education and outreach activities. Hole U1505C (18°55.0570′N, 115°51.5370′E, water depth 2917.4 m) was cored to 480.2 m and recovered 480.15 m (100%). Hole U1505D (18°55.0485′N, 115°51.5501′E, water depth 2917.5 m) was cored to 184.5 m and recovered 191.43 m (104%). Downhole logging with a modified triple combo was conducted in Hole U1505C.

Principal Results

Lithostratigraphy

The sediment succession recovered at Site U1505 extends from the Late Eocene to the Pleistocene. Two sedimentary units (Units I and II) were observed. Lithostratigraphic Unit I is dominated by nannofossil ooze with varying amounts of foraminifers and clay, and with biogenic silica in the upper interval of the hole. Lithostratigraphic Unit I is divided into three subunits (Subunits IA to IC). Subunit IA (Hole U1505C, 0.00–27.76 m) comprises dark greenish gray and greenish gray biosiliceous-rich clay with nannofossils, nannofossil-rich clay with biogenic silica, and nannofossil-rich biosiliceous ooze with clay. The abundance of biogenic silica decreases downhole. There is a pinkish gray, ~6 cm thick, slightly fining upward ash layer at 20.8 m (Hole U1505C) and ash pods at 20.3 m in Hole U1505D. Subunit IB (Hole U1505C, 27.76–273.39 m) comprises gray to brown nannofossil ooze with minor silty intervals. The color change reflects the varying abundance of foraminifers and clay. Subunit IC (Hole U1505C, 273.39–403.79 m) comprises gray, greenish gray, and light brownish gray clay-rich nannofossil ooze (with foraminifers), and foraminifer-rich nannofossil ooze with clay and minor amounts of nannofossil-rich clay. Unit II (Hole U1505C, 403.50–480.54 m) is dominated by dark greenish gray, well-consolidated silty clay, and clayey silt (with nannofossils). The amount of nannofossils increases downhole.

Biostratigraphy

All core catcher samples from Holes U1505A, U1505B, and U1505C were analyzed for calcareous nannofossils, planktonic foraminifers, and diatoms. Additional samples were taken from intervals within the working-half cores when necessary to refine the ages. Hole U1505D was not sampled continuously for biostratigraphic analyses because of time constraints at the end of the expedition, but the sequence recovered spans from the late Miocene to the present. Preservation of calcareous microfossils is good in Cores U1505C-1H to 48X, and moderate to poor in Cores U1505C-49X to 64X. Planktonic foraminifers are abundant or common in Cores U1505C-1H to 56X and 59X to 62X, and rare in Cores U1505C-57X, 58X, 63X, and 64X. Calcareous nannofossils are generally abundant to common in most samples of Hole U1505C, except for those from the upper part of Core U1505C-57X.

Forty-five biostratigraphic datums identified in Hole U1505C suggest a continuous succession of Early Oligocene to the Holocene. The Pleistocene/Pliocene boundary is placed within Core U1505C-7H, the Pliocene/Miocene boundary between Cores U1505C-11H and 13H, and the Miocene/Oligocene boundary between Cores U1505C-54X and 55X. Sedimentation rates are ~7 mm/ky in the Oligocene, ~15 mm/ky during the Miocene-Pliocene, and ~24 mm/ky during the Pleistocene.

Relatively low abundances of planktonic foraminifers below Core U1505C-57X indicates bathyal depths during the Early Oligocene, while much higher abundances of planktonic

foraminifers above Core U1505C-56X suggests a deeper water environment since the Late Oligocene.

Paleomagnetism

Only natural remanent magnetization (NRM) was measured with the superconducting rock magnetometer (SRM) for Hole U1505C (except for sections U1505C-1H-1 to U1505C-3H-1 that were in-line alternating field (AF) demagnetized in three steps). Most of the 55 AF demagnetized discrete samples show a very soft magnetic behavior responsible for the acquisition of a strong, vertical drilling overprint (average inclination ~81°) that is removed by demagnetization to 10–15 mT. This soft behavior shows that magnetic remanence is dominated by multidomain to pseudosingle domain titanomagnetite or magnetite. The drilling overprint appears to impact discrete samples far less than core sections. The lower part of the hole (Cores U1505C-48X to U1505C-64X) is characterized by severe drilling disturbance that causes a large scatter of NRM directions and inclinations.

Magnetostratigraphic data is based on the polarity assigned to the archive-half cores and corroborated by directions obtained from oriented discrete samples. The lower boundary of the Brunhes (C1n) normal Chron is at 37.4 m (0.781 Ma). The lower boundary (57.4 m) of the reverse polarity r1 is the base of subchron C1r.3r with an age of 1.778 Ma.

The anisotropy of magnetic susceptibility (AMS) shows a moderate degree of anisotropy and a strongly oblate symmetry, most likely of depositional origin. The Fisher distribution of AMS principal axes also suggests an oblate fabric with a nearly horizontal planar fabric, consistent with deposition in a calm, pelagic environment with very limited traction on sedimentary particles.

Geochemistry

Low, but measurable, hydrocarbon gases were detected only in Cores U1505C-53X to 60X (371–438 m). The base of the hole has methane distributions similar to Site U1499, while the top section is similar to Site U1501 in being barren of methane. Except for the shallowest 30 m of sediment, total organic carbon, nitrogen, and sulfur contents were mostly low in Lithostratigraphic Unit I, but sulfur and TOC were slightly higher in Unit II but in all cases typically <1%. Interstitial water chemistry has two important features. The upper part exhibits similar patterns to Site U1501 with inhibited sulfate reduction, and low chlorine, bromine, and salinity suggest the presence of freshwater at depth. Freshwater at >400 mbsf coincides with the presence of low quantities of methane and the T60 regional seismic unconformity.

Physical Properties and Downhole Measurements

Physical property data were acquired on cores from Holes U1505C (0–480.5 m) and U1505D (0–184 m), including density, magnetic susceptibility (MS), *P*-wave velocity, natural gamma ray (NGR), color reflectance, and thermal conductivity. The trends of physical properties allow us to

define two petrophysical units: PP Unit 1 (0–403 m) and PP Unit 2 (403–480 m). The boundary between PP Units 1 and 2 displays a distinct color change from greenish and light brownish gray to dark greenish gray. This boundary, which corresponds to seismic stratigraphic unconformity T60, is associated with a sharp change in the physical properties. In PP Unit 1 (0–403 m), sediments are composed of foraminifer-rich nannofossil ooze with clay in the upper part, gradually changing to clay-rich nannofossil ooze in lower part of the unit. This is well reflected in the NGR, which exhibits an increasing trend with depth. The higher NGR values in PP Unit 2 are related to sediment that primarily consists of silty clay. The MS shows an overall gradual decreasing trend with depth. The boundary between PP Units 1 and 2 shows that density and *P*-wave velocity drop sharply from ~2.2 g/cm^3 to ~1.8 g/cm^3 and from ~2250 m/sec to 1750 m/sec respectively. Porosity abruptly increases from ~35% to ~50%. Thermal conductivity also shows a sharp change at the boundary. Reflectance (L*) and RGB data are well correlated with carbonate content.

Wireline logging was conducted in Hole U1505C using the triple combo with the Dipole Sonic Imager (DSI) tool added to it. The tool string included the Hostile Environment Natural Gamma Ray Sonde (HNGS), Hostile Environment Litho-Density Sonde (HLDS), Dipole Sonic Imager Tool (DSI), and magnetic susceptibility sonde (MSS). This logging string collected good data from 341.2 m (139.1 m above the bottom of Hole U1505C), and allows definition of six logging units, which mostly correlate with the Lithostratigraphic Units and core petrophysical data. Logging Unit 1 extends from the seafloor to the base of the drill pipe at 78 m. The NGR is highly attenuated inside the drill pipe. Logging Unit 2 (base of drill pipe to 96 m) exhibits NGR that is ~50% lower than the underlying Logging Unit 3. In Logging Unit 3 (96–136 m), NGR increases with depth. Logging Unit 4 (136–220 m) exhibits relatively constant V_p and V_s. In Logging Unit 5 (200–296 m), resistivity increases with depth, while most of other physical properties are relatively constant. Logging Unit 6 (296–341.2 m) has higher MS than Logging Unit 5.

Four downhole temperature measurements were conducted at Hole U1505C using the advanced piston corer temperature tool (APCT-3). The temperature values ranged from 4.7°C at 36.7 m to 11.7°C at 122.8 m mbsf, giving a geothermal gradient of 84.6°C/km. A heat flow of 94.0 mW/m^2 was obtained from the linear fit between temperature and thermal resistance. The geothermal gradient and heat flow at Site U1505 are comparable to the relatively high values observed in a number of ODP and IODP sites in this part of the South China Sea.