Expedition 321: Pacific Equatorial Age Transect (PEAT II)

9 June 2009

Site U1337 Summary

The latest Oligocene through the middle Miocene appears to have been a time of relative warmth comparable to the latest Eocene. However, the variability in the isotopic record of the early to middle Miocene is larger than that of the Eocene and may indicate more variability in climate and in global ice volume. Site U1337 (PEAT-7C, 3°50.009'N, 123°12.352'W, 4463 m water depth) was targeted to collect an early-middle Miocene segment of the PEAT equatorial megasplice located on ~24 Ma crust between the Galapagos and Clipperton Fracture Zones, about 390 km southeast of Site U1335. In conjunction with Sites U1335 (PEAT-6C) and U1336 (PEAT-5C), it was also designed to provide a latitudinal transect for early Miocene age slices. The recovered sediment column at Site U1337 represents a nearly complete and continuous Neogene sedimentary section.

Operations

Four holes were cored at Site U1337. In Hole U1337A, APC cores were taken from the seafloor to 195.5 m DSF (U1336A-1H to 21H). Non-magnetic core barrels were used for all APC cores except for core 21H. FLEXIT core orientation was conducted for all cores except 1H. In addition, five successful APCT3 temperature measurements were taken with cores 5H, 7H, 9H, 11H, and 13H. XCB coring continued with XCB cores 22X through 48X. The sediment/basement contact was recovered at the base of core 48X. Three logging strings (triple combo, vertical seismic imager [VSI], and FMS-sonic) were deployed in Hole U1337A.

In Hole U1337B, APC cores were taken from the seafloor to 245.2 m DSF (U1336A-1H to 27H). Non-magnetic core barrels were used through Core 20H. The FLEXIT core orientation system was deployed successfully for all but two APC cores (17H and 18H). APCT3 temperature measurements were obtained with Cores 15H, 17H, and 19H. Coring continued with a single XCB Core 28X to a depth of 251.9 m DSF, however this barrel could not be recovered, and Hole U1337B was abandoned prematurely.

Hole U1337C was cored to recover sections that were missing from Holes U1337A and U1337B. APC cores were taken from the seafloor to 11.4 m DSF (U1336A-1H to 2H) using non-magnetic core barrels and the FLEXIT core orientation system. A wash barrel (3W) was then deployed and the hole was washed to a depth of 169.4 m DSF. APC coring resumed at that depth and continued through Core 9H to a depth of 221.3 m DSF and switched to steel core barrels. Coring with the XCB system continued with Cores 10X through 33X. Basement was recovered in Core 33X.

Hole U1337D was planned to target the few remaining areas that had yet to be fully recovered and to duplicate recovery through those sections of the formation already recovered to provide additional sample material. The most troublesome material encountered in the previous holes was the large diatom mats located directly above and below a hard ~0.4 m thick porcellanite (“baby chert”) layer. In Hole U1337D, APC cores were taken from the seafloor to 237.7 m DSF (U1337D-1H to 26H). Non-magnetic core barrels were used through Core 20H. The first XCB Core 27X was designed to only core through the hard ~0.4 m thick “baby chert” layer. The APC was once again deployed and

Cored 28H through 30H up to 267.0 m DSF. At this point the XCB coring system was again deployed for Cores 31X through 49X to a total depth of 442.9 m DSF. The FLEXIT core orientation system was deployed successfully with all APC cores. The Sediment Temperature Tool (SET) was deployed for the first time from the *JOIDES Resolution* after Core 17X at a depth of 298.1 m DSF.

Lithostratigraphy

At Site U1337, latest Oligocene seafloor basalt is overlain by about 450 m of nannofossil and biosiliceous oozes and nannofossil chalks that are divided into three lithologic units. The Pleistocene through uppermost Miocene sediments of Unit I are characterized by multicolored (various hues of white, brown, green and gray) nannofossil oozes, diatom oozes and radiolarian oozes that alternate on meter scales, with a general downsection increase in siliceous microfossils relative to nannofossils. Green and gray biosiliceous lithologies, interbedded on meter scales with white and light greenish gray nannofossil ooze comprise the dominant sedimentary constituents in the uppermost Miocene to middle Miocene Unit II, which includes regular diatom mat deposits. Meter-scale color alternations in Units I and II are associated with variations in lithology and physical properties. However, similar to the common mm- and cm-scale color banding that do not mark compositional changes, they are likely associated with sediment redox conditions. White, pale yellow and pale green nannofossil oozes and chalks dominate the sediments of middle Miocene to latest Oligocene age, although diatoms and radiolarians remain present in low abundances. Latest Oligocene seafloor basalt (Unit IV) was recovered at the base of the sedimentary section.

Biostratigraphy

At Site U1337, planktic foraminifers are rare to abundant and with poor to good preservation throughout most of the succession, but absent or extremely rare in the interval from the lower part of the late Miocene and upper early Miocene. Biozones PT1b to O6 are recognized, with the exception of zones PL4, M12, and M3. The calcareous nannofossils at Site U1337 are moderately to poorly preserved and some samples with high silica content are barren. Nannofossil Zones NN1 to NN21 are present, indicating an apparently complete sequence. The radiolarian stratigraphy at Site U1337 spans the interval from the uppermost part of Zone RN16-17 (upper Pleistocene) to RN1 (lower Miocene). The radiolarian assemblages of Pleistocene to upper Miocene tend to have good preservation, whereas middle to lower Miocene assemblages show moderate preservation. In the lowermost part of the section, above the basement, the sediments are barren of radiolarians. The high resolution diatom stratigraphy at Site U1337 spans the interval from the *Fragilariopsis* (*Pseudoeunotia*) *doliolus* Zone (upper Pleistocene) to the lowermost part of the *Craspedodiscus elegans* Zone (lower Miocene). The diatom assemblage is generally well to moderately preserved throughout the recovered section; however, there are several intervals in which valve preservation becomes moderate to poor. The base of the sediment column is barren of diatoms. The nannofossil, foraminiferal, radiolarian, and diatom datums and zonal schemes generally agree, though some discrepancies occur in the lowest part of the core. Benthic foraminifers occur continuously throughout the succession recovered in Hole U1337A, and show good to moderate preservation. The overall assemblage composition indicates lower bathyal to abyssal paleodepths. Marked variations in downcore abundance and species distribution reflect major changes in global climate linked to fluctuations in ice volume and re-organization of Pacific circulation during the Neogene.

Stratigraphic Correlation

Stratigraphic correlation provided a complete spliced record to a depth of approximately 220 m CCSF-A. Several gaps (perhaps 3) were encountered over the next 50 m CCSF-A. Comparison of GRA density records with well logging density data suggests that no more than a meter of section was lost in any of the gaps. Correlation between the holes was broken again several times between 440 m CCSF-A and basement at 490 m CCSF-A. Growth factor for the correlation was 1.12. The linear sedimentation rate decreases from approximately 21 m/m.y. in the middle Miocene to 17 m/m.y. in the late Miocene.

Paleomagnetism

Paleomagnetic measurements were conducted on archive half sections of 20 APC cores and 14 XCB cores from Hole U1337A, 27 APC cores from Hole U1337B, 8 APC cores from Hole U1337C, and 30 APC cores from Hole U1337D. The FLEXIT core orientation tool was deployed in conjunction with all APC cores, and we conclude that the FLEXIT orientation data are generally reliable. Measurements of natural remanent magnetization (NRM) above ~93 m CSF-A indicate moderate magnetization intensities (on the order of 10^{-3} A/m) with a patchy but generally weak viscous (VRM) or isothermal remanent magnetic (IRM) coring overprint, and polarity reversal sequences from the Brunhes to the bottom of the Gilbert Chron are recognized. Below ~93 m CSF-A, remanence intensities after alternating-field (AF) demagnetization of 20 mT are reduced to values close to magnetometer noise level in the shipboard environment (~$1x10^{-5}$ A/m). In this zone, sediment magnetizations have been partly overprinted during the coring process, and remanence inclinations are occasionally steeply negative after AF demagnetization at peak fields of 20 mT. Nonetheless, polarity reversals are apparently recorded down to ~200 m, and they are provisionally correlated to the GPTS from to Chron C3An to C5n (~ 6 to 11 Ma). Magnetic polarity interpretation was impossible for APC cores taken with steel core-barrel and XCB cores due to severe magnetic overprint during coring.

Physical Properties

Physical properties measurements on whole-round sections and samples from split cores display a strong lithology dependent variation at Site U1337. The variations in the abundances of nannofossils, radiolarians, diatoms, and clay in Unit I account for high amplitude, high frequency variations of all physical properties. The general pattern is that intervals enriched in biogenic silica and clay display lower grain density and bulk density and higher porosity, magnetic susceptibility, and natural gamma radiation. Velocity is generally directly related to bulk density; however, it commonly is higher in low density siliceous-rich sediments than it is in more calcareous intervals. Wet bulk density is low in Unit I, ranging from 1.12 to 1.46 g/cm^3. Porosity is as high as 92% in this unit. Velocity also is low, averaging 1525 m/s. The natural gamma record, as at the previous Expedition 320 and 321 sites is marked by an anomalously high near surface peak (~65 cps). Magnetic susceptibility varies between 4 and 18 x 10^{-5} SI. The color of Unit I is characterized by the lowest luminance (L*) and high and variable a* and b* values. Unit

II is characterized by a continued high variability in grain density. Together, the grain density in Units I and II averages 2.51 g/cm^3 and ranges from 2.17 to 2.85 g/cm^3. All other physical properties display less variability in Unit II than in Unit I, reflecting a less variable lithology. Wet bulk density increases and porosity decreases with depth in Unit II; however, in both Units II and III these trends are interrupted by low density, high porosity diatom- and radiolarian-rich intervals. Unit II is slightly lighter colored (lower L*) and distinctly more blue (lower a*) and green (lower b*) than Unit I. Unit III is characterized by more uniform physical properties that accompany the high and uniform carbonate composition of the unit. The nannofossil oozes and chalks of this unit are characterized by a uniform grain density that averages 2.67 g/cm^3. The bulk density and porosity trends of Unit II continue in Unit III. The transition from ooze to chalk is marked by a change in gradient of these properties to a more rapid decrease in wet bulk density and increase in porosity with depth. The wet bulk density and porosity at the base of the sediment section are 1.95 g/cm^3 and 47%, respectively. The increase in velocity with depth also changes to a higher gradient in Unit III with values increasing from 1510 at ~340 m CSF-A to ~1800 m/s near the base of the hole. Magnetic susceptibility and natural gamma radiation values remain low in Unit III, but do vary in response to small changes in lithology. The sharp color change from greenish gray to pale yellow at ~410 m CSF-A is marked by a sharp increase in a* and b*. The change in color to pale brown chalk immediately above basement is marked by an increase in both a* and b* and a decrease in L*.

Downhole Logging

Downhole logging consisted of deploying three tool strings in Hole U1337A. Two tool strings took downhole measurements of natural gamma ray radioactivity, bulk density, electrical resistivity, elastic wave velocity, and borehole resistivity images in the depth interval 77-442 m WSF (wireline depth below seafloor). The third tool string measured seismic waveforms in a vertical seismic profile (VSP) experiment in the depth interval 214-439 m WSF. Measurement depths were adjusted to match across different logging runs, obtaining a wireline matched below seafloor (WMSF) depth scale. The downhole log measurements were used to define three logging units: Unit I (77-212 m WMSF) and Unit II (212-339 m WMSF) have average densities of ~1.3 and ~1.6 g/cm^3, respectively, that do not show any trend with depth, while in Unit III density increases with depth (339-442 m WMSF) reaching 1.85 g/cm^3 at the base of the hole. Resistivity and P-wave velocity follow a pattern similar to that of density, suggesting that the major control on these physical properties are variations in sediment porosity. Natural gamma ray measurements are low throughout the logged interval (~5 degrees API), except for two pronounced peaks due to uranium, one at the seafloor and the other at 240 m WMSF. The gamma-ray peak at 240 m WMSF corresponds to the ~40 cm-thick "baby chert" layer that has only been recovered as rubble in the cores but can be clearly identified in the downhole logs and borehole images as an interval of high density and resistivity. The VSP logging measured arrival time of the seismic pulse from the sea surface at 16 stations. Together with the travel time to the seafloor, the VSP measurements are the basis for a travel time-depth conversion that allows seismic reflectors to be correlated to stratigraphic events. Downhole temperature measurements and thermal conductivities of core samples were combined to estimate a geothermal gradient of 32.4 °C/km and a heat flow of 28.4 mW/m^2 at Site U1337.

Geochemistry

The shipboard geochemical analyses of the interstitial water and bulk sediment samples reflect the large variations in the sediment composition resulting from shifts in carbonate versus opal primary production. The large scale redox state and diagenetic processes of the sediment column are related to the overall changes in sediment composition. The interstitial water chemistry is also influenced by the "baby chert" layer forming a diffusive boundary at around 240 m CSF-A and seawater circulation in the basement. The basement itself appears to exert little influence on the geochemistry of the sediments and interstitial waters.

Highlights

Diatom mat deposition

Unit II at Site U1337 is mostly comprised of biosiliceous lithologies, notably diatoms. The abundance of diatoms in the middle and upper Miocene section at Site U1337 is much higher than encountered in any interval at Sites U1331 to U1336. Several dm- to m-scale intervals of diatom ooze are laminated, and smear slide analyses indicate that the diatom assemblage is composed primarily of pennate taxa, with abundant 'needle-like' *Thalassiothrix* spp., indicating diatom mat deposition. The lowermost laminated diatom mat is in the upper portion of Unit III at ~15 Ma, then much larger intervals are present in

Unit II at roughly 10 Ma, and shorter intervals at around 4.5 Ma. The ages of laminated diatom mats at this site are similar to those found at Leg 138 sites farther to the east (Mayer, Pisias and Janecek, Init Repts ODP, 138) which have been interpreted to reflect regional bursts of export silica production in the eastern equatorial Pacific (Kemp and Baldauf, 1993). No laminated diatom oozes were recorded during Exp 320 drill sites farther to the northwest, however, near 10 Ma at Site U1335, drilling recovered clayey diatom ooze and clayey radiolarian ooze containing no carbonate at all suggesting that dissolution may also play an important role in the deposition of laminated diatom mats.

Oligocene–Miocene transition

The Oligocene/Miocene boundary (O/M) was recovered in Holes U1337A, U1337C and U1337D. In Hole U1337A, the O/M boundary is estimated to fall between Samples U1337A-48X-2, 85-87 cm and -48X-3, 55 cm (445.56 - 446.75 m CSF-A; 490.92 - 492.11 CCSF-A). It occurs in white (2.5Y 8/1) nannofossil chalk with foraminifers, interbedded and heavily mottled with pale yellow (2.5Y 7/4) to very pale brown (10YR 7/4) nannofossil chalk. Abundant mm-scale dendritic manganese grains composed of manganese oxide occur throughout this interval. The lower 15 cm of the core catcher of this core represents basement. No prominent change in lithology, GRA bulk density, reflectance or magnetic susceptibility is seen through the O/M transition.

Neogene Carbonate Dissolution

The CCD of the Neogene is much more stable than that of the Eocene, but there are intervals of lower carbonate deposition at Site U1337 that probably represent significant changes of the Neogene CCD. In the early Miocene, a significant carbonate low reaches its minimum at about 17 Ma (340 m CSF-A in U1337A), when the site was at a depth of about 3500 mbsl. This early Miocene interval marks a strong minimum at Site U1334 as well, on crust with a depth of about 4000 m at that time. Highly variable carbonate is also characteristic of the late-middle Miocene boundary, but the role of carbonate dissolution vs elevated deposition of bio-silica need to be sorted out.

References

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Mayer, L., Pisias, N., Janecek, T. et al., 1992. Proceedings of the Ocean Drilling Program, Initial Reports, 138: College Station, TX (Ocean Drilling Program). Doi:10.2973/odp.proc.ir.138.1992