Expedition 320: Pacific Equatorial Age Transect (PEAT I)

19 April 2009

Site U1333 Summary

Three holes were cored at Site U1333 (10º30.996'N, 138º25.159'W, 4853 m water depth). At Site U1333, Eocene age seafloor basalt is overlain by ~183 m of pelagic sediment, dominated by nannofossil and radiolarian ooze with varying amounts of clay.

In Hole U1333A, APC cored sediments were recovered from approximately 3 m below the mudline (~4850 m water depth) to 95 m CSF-A (Core U1333A-10H). XCB coring advanced to 184.1 m DSF, through an approximately 60 m thick sequence of lowermost Oligocene carbonate oozes and nannofossil-bearing Eocene sediments. Near the basal section, Core U1333A-20X recovered a 30 cm long interval of lithified carbonate. The following Core U1333A-21X contained a dolostone basalt breccia. Core U1333A-22X recovered a 6 cm piece of basalt.

Coring in Hole U1333B started 5 m shallower than Hole U1333A to recover the mudline and to span the core gaps from the first hole. Core U1333B-1H recovered 7.73 m of carbonate bearing ooze overlain by a few meters of clay. Since the cores recovered from Hole U1333A showed that there were no significant porcellanite or chert layers, we used the APC drill-over strategy in Hole U1333B to obtain APC cores across and below the EO transition down to 162.7 m CSF-A. We then XCB cored to basement and a total depth of 180.3 m CSF-A.

Hole U1333C was designed to provide stratigraphic overlap and confirm stratigraphic correlations made between Holes U1333A and U1333B. APC coring in Hole U1333C started 2.75 shallower than Hole U1333B and reached to 163.2 m CSF-A before we had to switch to XCB coring. No downhole logging was conducted at Site U1333.

The sediment column at Site U1333 has a strong resemblance to that of ODP Site 1218 (Lyle et al., 2002a), but with notably more carbonate bearing sediments in the Eocene portion. The ~183 m of pelagic sediments have been divided into four major lithological units. Unit I is about 7 m thick and contains an alternating sequence of clay, clayey radiolarian ooze, radiolarian clay, clayey nannofossil ooze, and nannofossil ooze from the early Miocene period. Unit II is approximately 112 m thick and composed of alternating very pale brown nannofossil ooze and yellowish brown nannofossil ooze with radiolarians of early Miocene to latest Eocene age. Unit III is approximately 60 m thick and composed of Eocene biogenic sediments comprising clayey nannofossil ooze, nannofossil radiolarian ooze, nannofossil ooze, radiolarian nannofossil ooze, and porcellanite of latest Eocene to middle Eocene age (Unit III). Unit III is divided into two subunits, based on the absence (subunit IIIa) or occurrence of porcellanite (subunit IIIb). Porcellanite is a third lithology in Unit III between approximately 168 and 174 m CSF-A. Unit IV is a ~3.3 thin unit of lithified carbonate (partly dolostone) and dolomitized nannofossil ooze, overlying basalt of Eocene age (Unit V).

All major microfossil groups have been found in sediments from Site U1333, and provide a consistent, coherent and high resolution biostratigraphic succession from basement up to the top of lithological Unit II. Shipboard biostratigraphy indicates that sediments recovered at Site U1333 span a near continuous succession from around the lower Miocene boundary to the middle Eocene. Radiolarians are common and well preserved in the Eocene succession but less well preserved in the Oligocene sediments. A complete sequence of radiolarian zones from RN2 down to RP14 (middle Eocene) was described. Initial assessment of the radiolarian assemblages across the EO boundary interval indicates a significant loss of diversity through this apparently complete succession. Although a few species from the Eocene carry through to the Oligocene, only one stratigraphic marker species (*Lithocyclia angusta*) first appears near the Eocene/Oligocene boundary. Calcareous nannofossils are present and moderately to well preserved through most of the succession, although there are some short barren intervals in the middle to late Eocene. The succession spans a complete sequence of nannofossil zones from the early Miocene zone NN1 to the middle Eocene zone NP15. The Oligocene/Miocene boundary are bracketed by the base *Sphenolithus disbelemnos* in Sample 320-U1333A-2H-5, 70 cm (16.20 m CSF-A) and the occurrence of rare *Sphenolithus delphix* in Sample 320-U1332A-2H-CC-PAL (9.57 m CSF-A). Discoasters are very rare in the basal assemblages, indicative of a eutrophic environment, consistent with the paleolatitude of this site in the early middle Eocene within the equatorial upwelling zone. Planktic foraminifers are relatively abundant and well preserved from the lowest part of the Miocene to the lower Oligocene. The Oligocene fauna is characterized by the common occurrence of *Catapsydrax* spp., *Dentoglobigerina* spp., and *Paragloborotalia* spp. In contrast the upper Eocene sediments contain poorly preserved specimens or are barren of planktic foraminifers. Preservation and abundance slightly increased in some intervals of the middle Eocene, which is recognized by the presence of acarininids and clavigerinellids. The absence of the genera *Globigerinatheka* and *Morozovella* makes precise age determination of individual samples problematic. The high abundance of *Clavigerinella* spp. has been linked to high-productivity environments, consistent with the paleogeographic location of this site. Benthic foraminifers were almost continuously present and indicate lower bathyal to abyssal depths. The Oligocene fauna is characterized by calcareous hyaline forms, such as *Nuttallides umbonifer*, *Oridorsalis umbonatus* and *Cibicidoides mundulus*. *Nuttallides truempyi* and *Oridorsalis umbonatus* often dominate the Eocene fauna. Benthic foraminifers are present through most of the section apart from an interval in the middle Eocene equivalent to radiolarian zone RP16. They indicate lower bathyal to abyssal paleodepths. Diatoms have been observed throughout the column, but will have to await analysis by specialists not onboard Expedition 320.

Sedimentation rates at Site U1333 are about 6 m/m.y. in the upper sediment column from the early Miocene to the late Oligocene. In the early Oligocene linear sedimentation rates increase to ~12 m/m.y. Between about 31 Ma (the earliest Oligocene) and the earliest late Eocene they are about 4 m/m.y., increasing slightly in the middle Eocene section (~39–45 Ma) to ~ 5 m/m.y..

Paleomagnetic results from measurements made along split-core sections and on small discrete samples from Site U1333 provide a well-resolved magnetostratigraphy. Shipboard analyses suggest that a useful magnetic signal is preserved in most APC cored intervals after removal of the drilling-induced overprint by partial alternating-field (AF) demagnetization at 20 mT. The overprint was nearly absent in those cores collected in non-magnetic core barrels at Site U1333 whereas it was quite prominent for cores recovered in the standard steel core barrels. Paleomagnetic directions from discrete samples agree well with those from split cores, confirming that AF demagnetization at 20 mT is generally sufficient to resolve the primary paleomagnetic direction regardless of which type of core barrel was used. The cleaned paleomagnetic data provide a series of distinct ~180° alternations in the declination and subtle changes in inclination, which when combined with biostratigraphic age constraints, allow a continuous magnetostratigraphy to be constructed that correlates well with the geomagnetic polarity timescale. The magnetostratigraphic record extends from the base of Chron C6n (19.722 Ma) at 1.7 m CSF-A in Hole U1333C down to the top of Chron C20r (43.789 Ma) at 161.6 m CSF-A in Hole U1333C. Highlights include very high-quality paleomagnetic data across Chrons C13r and C13n, which span the latest Eocene and earliest Oligocene, and a newly recognized cryptochron within Chron 18n.1n.

Geochemistry results indicate that samples from the uppermost ~4 m of Site U1333 have modest $CaCO_3$ concentrations of 26% to 69%, with frequent variations between 58% and up to 93% in the interval between 4–35 m CSF-A. Carbonate concentrations are consistently high (75.5% to 96%) from 35 m to 111 m CSF-A, while in the Eocene (between 111 to 171 m CSF-A), $CaCO_3$ concentrations vary rapidly between less than 1% and 74%. The lowermost lithified carbonate rocks between 173 and 180 m CSF-A have high $CaCO_3$ concentrations between 76% and 90%. Total organic carbon concentrations, as determined using an acidification method, are generally very low or below the detection limit (<0.1%, apart from samples in the top most 5 m, which reached ~ 0.17%). Porewater alkalinity values are never elevated, but alkalinity and dissolved strontium values are somewhat higher near the Eocene–Oligocene transition; these are generally consistent with carbonate dissolution or recrystallization processes. Dissolved silicates increase with depth, with values always less than 1000 µM.

A full physical property program was run on cores from Holes U1333A, U1333B, and U1333C comprising whole-round multisensor core logger measurements of magnetic susceptibility (MS), bulk density, P-wave velocity, non-contact resistivity, natural gamma radiation, and measurements of color reflectance, followed by discrete measurements of moisture and density properties, sound velocities and thermal conductivity on cores from Hole U1333A only. All track data show variability throughout the section, allowing a detailed correlation between holes primarily using magnetic susceptibility and density (MS varies around ~24×10^{-5} SI in radiolarian ooze dominated sections, and ~3×10^{-5} SI in more carbonate-rich intervals). MS values gradually increase uphole. Natural gamma (NGR) measurements are elevated by an order of magnitude in the uppermost clays and show an increase near the lower Oligocene at around 115 m CSF-A (from 5 to 8 counts per second). P-wave velocity shows a gradual increase downhole, as we move from carbonate- to radiolarian-dominated successions. P-wave velocity generally varies between 1490 and 1560 m/s depending on lithology, with lower velocities corresponding more to carbonate-rich sections. Bulk density and grain density show a marked decrease around 112 m CSF-A (~1.704 to 1.313 g/cm^3 in bulk density) and occurs where carbonate content decreases rapidly. Porosity values are generally high in the radiolarian rich sediments (80%), and decrease within the carbonate-rich section (~60%). Thermal conductivity measurements show increased values in carbonate rich intervals, and range from around 0.8 W/(K m) in lithological Unit I to 1.2-1.3 W/(K m) in lithological Unit II.

Stratigraphic correlation indicated that a composite section was recovered down to a depth of ~130 m CSF in the upper Eocene, equivalent to a composite depth of ~150 m CCSF. For Site U1333, a growth factor of 15% is estimated from the ratio between the CCSF and CSF (formerly mcd and mbsf) depth scales. Stratigraphic correlation with ODP Site 1218 suggest a complete stratigraphic section in the Oligocene to uppermost Eocene interval.

Five formation temperature measurements were conducted in Hole U1333B with the APCT3 tool. These temperature measurements, when combined with the thermal conductivity values obtained from the cores, indicate that Site U1333 has a heat flow of about 43 mW/m^2, and a thermal gradient of 38°C/km.

Highlights

1) High carbonate fluctuations in middle Eocene sediments

Coring at Site U1333 was designed to capture a time period when the carbonate compensation depth (CCD) was slightly deeper, within the middle Eocene interval that showed prominent fluctuations of carbonate content (Lyle et al., 2005). This interval occurs during the cooling that took place after the Eocene Climatic Optimum (“EECO”, Zachos et al. 2001a) and before the Eocene–Oligocene transition (e.g., Coxall et al., 2005). Unlike ODP Site 1218, Site U1333 sediments show carbonate concentrations of over 75% in this interval at a deeper water depth, and apparently co-eval with the CCD cycles described by Lyle et al., 2005. The basal lithological Unit IV recovered partially lithified carbonates.

2) Middle Eocene Climatic Optimum (MECO), Eocene/Oligocene and Oligocene/Miocene transitions and depth transects

Site U1333 forms the third oldest and deepest component of the PEAT depth transect, and can be directly compared with ODP Site 1218, which will allow the study of critical intervals (such as the Eocene–Oligocene transition, see Coxall et al., 2005) and variations of the equatorial CCD. Site U1333 is estimated to have been approximately 3.8 km deep during the Eocene–Oligocene transition, approximately 1 km shallower than today, and 200 m shallower at that time than Site U1332. Sediments do not change carbonate content as rapidly as at the deeper and older Sites U1332 and U1333. They appear to contain Eocene–Oligocene transition sediments that are suitable for palaeoceanographic studies using carbonate based geochemical proxies, and thus are an improvement over ODP Site 1218. Of note Site U1333 also contains high carbonate content bearing sediments around the Middle Eocene Climatic Optimum event (Bohaty and Zachos, 2003; Bohaty et al., 2009), allowing a detailed study of the sequence of events linking carbonate preservation cycles (Lyle et al., 2005) with climatic oscillations.

Site U1333 also recovered carbonate bearing sediments across the Oligocene–Miocene transition (e.g., Zachos et al., 2001b), adding important data to the study of this time interval in the context of the PEAT Oligocene–Miocene depth transect.

3) An age transect of sea-floor basalt

Site U1333 recovered what appear to be fresh fragments of seafloor basalt, aged between 45 and 46 Ma. This material will, when combined with other PEAT basalt samples, provide important sample material for the study of seawater alteration of basalt.

References

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