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ODP Site 1218 was cored in the equatorial Pacific Ocean during Leg199. The 270 m of sediments from the site yielded an excellent record of the geomagnetic polarity reversals for the entire Miocene and most of the Oligocene. Nannofossils and radiolarians indicate that the section is biostratigraphically complete with no apparent hiatuses. The top 165 m of Site 1218 was cored using the Advanced Piston Corer and sediment cores could be azimuthally oriented preserving the declination information. The high-resolution magnetostratigraphic record has been obtained by measurements made on u-channel samples, augmented by about 300 discrete samples. U-channel samples were measured at 1cm interval and stepwise demagnetized in alternating field up to a maximum peak field of 80 mT. The Characteristic Remanent Magnetization directions were determined each 1 cm by principal component analysis for demagnetization steps in the 20 mT to 50mT peak field range. A similar treatment was carried out on the discrete samples, that gave results compatible with u-channel measurements. . Magnetostratigraphy from u-channel samples are compared with shipboard data that was based on blanket demagnetization at peak AF fields of 20 mT. U-channel measurements add more detail to the magnetostratigraphic record and allow identification of short polarity zones especially in the upper part of the section were the sedimentation rates are very low (2m/Ma) The component magnetization directions determined from u-channel measurements also gave more reliable and precise estimates of inclination (paleolatitude). Although the calculation of the paleomagnetic pole is hindered by the low precision of the cores azimuth orientation, the excellent data from both u-channel and discrete samples allow determining of the paleolatitude of the Site for different ages with relatively high precision. Paleomagnetic data indicate that the paleolatitude of Site 1218 is increasing with time form nearly equatorial in the Oligocene to its present latitude. Within the precision given by the paleomagnetic method, this is in agreement with current predictions of plate motion.

PP21D-10 1105h

Paleomagnetism of ODP Leg 199 Sediments: Implications for Paleogene and Neogene Magnetic Stratigraphy and Paleolatitudes

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ODP Leg 199 was designated to collect sediments along a latitudinal transect in the Pacific Ocean to better understand Paleogene sedimentation patterns and the system of equatorial currents. At ODP Sites 1218 through 1220, the magnetic record of the Paleogene Equatorial sediments extends back to Polarity Chron C20r (Middle Eocene), providing an unprecedented record of Paleogene magnetostratigraphy in Equatorial Pacific sediments. Paleomagnetic data were acquired on the JOIDES-Resolution pass-through cryogenic magnetometer from archive halves of core sections. Ongoing analysis on u-channels corroborates the polarity pattern obtained on the shipboard magnetometer. Natural Remanent Magnetization was measured at 5-cm intervals for each core section, and was followed by four to five steps of alternating field demagnetization up to a maximum of 15 or 20 mT. In addition, shipboard and shore-based measurements of discrete samples were also carried out, including alternating field and thermal demagnetization. All measured lithologies, including an upper red clay, radiolarian ooze and nannofossil ooze/chalk yield reproducible results and have a moderate magnetization intensity, well above the noise level of the cryogenic magnetometer. Stepwise demagnetization of discrete samples indicates that the Characteristic Remanent Magnetization (ChRM) is stable and well defined for the most part of the sedimentary record. The obtained high-resolution magnetic stratigraphy allows to cross-calibrate magnetic reversal stratigraphy with biostratigraphy, including the placement of the Eocene-Oligocene and Oligocene-Miocene boundaries. Overall, results from Leg 199 provide the first complete magnetobiostratigraphic record for the Middle Eocene through the Pliocene in the Equatorial Pacific Ocean. A particularly important aspect of Leg 199 was to establish the latitudinal plate motion of the Equatorial Pacific, based on paleomagnetic data. ChRM directions for the demagnetized discrete samples are used to construct the paleolatitudinal evolution of Leg 199 sites. A progressive northward displacement of the Pacific Plate in the Paleogene, which places the equatorial mound of biogenic sediment in northern latitudes and moves sediments out of the high sediment flux area, is established from the analysis of paleomagnetic inclinations.

PP21D-11 1120h

Correlation and Astronomical Calibration of Pacific Sediments From ODP Leg 199

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One of the great successes of Leg 199 was the recovery of a high-resolution ($\sim 1 - 2cm/ky$) biogenic sediment record from the late Paleocene to the early Miocene. These sediments were found to contain an uninterrupted set of geomagnetic chrons, as well as a detailed record of calcareous and siliceous biostratigraphic datum points. In addition, lithological measurements revealed clearly recognisable cycles that can be attributed to climatic change, driven by Milankovitch style orbital variations of the Earth. Discovering drill sites with a well-defined magneto- and biostratigraphic record that also show clear lithological cycles is rare and valuable, and opens the opportunity to develop a detailed stratigraphic inter-site correlation, as well as providing the data to refine and extend the astronomical time calibration for parts of the Cenozoic.

The basis for stratigraphic correlation and time scale calibration is a complete and representative sedimentary record with a high signal-to-noise ratio in the lithological data. Shipboard work allowed the generation of a continuous spliced record, formed by correlation of at least two holes drilled at the same site. However, differential stretching and squeezing of sedimentary features, due to both coring and geological processes, result in events that are not aligned in the depth domain. We present the results of extensive postcruise work that resulted in the generation of a revised composite depth stack that puts data from all holes of sites 1218 and 1219 into a common depth framework. It was possible to extrapolate magneto- and biostratigraphic datum points between these two sites (separated by $\sim$ 750 km). This procedure allowed the generation of a site composite record, which provides smaller uncertainty intervals for bio- and magnetostratigraphic zones, as well as giving refined and more detailed preliminary age models for either site.

We then use the aligned and stacked lithological data from sites 1218 and 1219 to develop a preliminary astronomical time scale calibration that also spans the Eocene-Oligocene (E/O) boundary. First results indicate that (1) all main orbital frequencies (long & short eccentricity, obliquity and climatic precession) are present in the record, but (2) the dominant cyclicity changes across the (E/O) as well as within the Oligocene, possibly related to the evolution of the CCD. (3) A plateau in a step-like transition observed across the E/O from Site 1218 can be constrained to approximately one eccentricity cycle, and (4) distinct eccentricity cycles ($\sim$ 400 ky and 100 ky) in the Oligocene can be matched to amplitude modulation cycles of climatic precession observed from Atlantic ODP cruise Leg 154, which was astronomically calibrated by Shackleton et al. (1999).

PP21D-12 1135h

The Os isotope record of the Eocene-Oligocene transition

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Osmium (Os) isotope analyses of bulk sediments from the South Atlantic (DSDP 522), Equatorial Pacific (DSDP 574C), and the Italian Apennines yield a coherent pattern of $^{187}Os/^{188}Os$ variation across the Eocene-Oligocene transition. This record has potentially important implications for our understanding of (1) the causative factors responsible for the first major glaciation of the Oligocene, and (2) the interplay between glaciation, chemical weathering and global climate. The two most prominent features of the Os isotope record are a pronounced minimum in $^{187}Os/^{188}Os$ (0.22 to 0.27) in the late Eocene, between 34 and 34.5 Ma, and a subsequent rapid increase in $^{187}Os/^{188}Os$, to approximately 0.6, that coincides with the growth and decay of the first major Antarctic ice sheet. The timing of the local minimum in the Os record is significant in that it immediately precedes the growth of the first major Antarctic ice sheet. Two alternative hypotheses for the late Eocene $^{187}Os/^{188}Os$ minimum are presented: (1) an ultramafic erosional event, or (2) an episode of increased influx of extraterrestrial particles to the Earth. Either event has the potential to influence on the evolution of Earths climate system.

Comparison of the $^{187}Os/^{188}Os$ to benthic foram oxygen isotope records indicates that enhanced release of radiogenic Os followed the termination of the first major Antarctic glaciation. This association suggests that exposure of freshly eroded material during deglaciation enhanced chemical weathering rates, and may have contributed to ice sheet stabilization by drawing down atmospheric carbon dioxide. This observation supports analogous interpretations of the Eocene-Oligocene portion of the marine Sr record (Zachos et al. Chem. Geol. 1999) The improved temporal resolution and age control of the refined Eocene-Oligocene Os isotope record also makes it possible to illustrate the use of late Eocene Os isotope excursion as a tool for global correlation of marine sediments.

PP22A MCC: Hall D Tuesday 1330h

The Paleogene and Cretaceous Pacific: Results From ODP Drilling II Posters *(joint with GP, OS, GC)*

Presiding: **M Lyle,** Boise State University**; J Zachos,** University of California, Santa Cruz

PP22A-0344 1330h POSTER

Paleomagnetic Paleolatitude of Early Cretaceous Ontong Java Plateau Basalts: Implications for Pacific Apparent and True Polar Wander

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We present paleomagnetic data from basaltic pillow and lava flows drilled at four Ocean Drilling Program (ODP) Leg 192 sites through the Early Cretaceous ($\sim$120 Ma) Ontong Java Plateau (OJP). Altogether 270 samples (out of 331) yielded well-defined characteristic remanent magnetization components all of which have negative inclinations, i.e. normal polarity, consistent with an OJP formation shortly after the onset of the Cretaceous normal polarity superchron. Dividing data into inclination groups we obtain 5, 7, 14 and 15 independent inclination estimates for the four sites. Statistical analysis suggests that paleosecular variation have been sufficiently sampled and site-mean inclinations therefore represent time-averaged fields. Of particular importance is the finding that all four site-mean inclinations are statistically indistinguishable, strongly supporting indirect seismic observation from the flat-lying sediments blanketing the OJP, that the studied basalts have suffered little or no tectonic disturbance since their emplacement. Moreover, the corresponding paleomagnetic paleolatitudes agree excellently with paleomagnetic data from a previous ODP site (Site 807) drilled into the northern portion of the OJP. Two important conclusions can be made based on presented dataset: (i) the Leg 192 combined mean inclination (Inc= -41.4°, N= 41, k= 66.0, a95= 2.6°) is inconsistent with the Early Cretaceous part of the Pacific apparent polar wander path indicating that previous paleomagnetic poles derived mainly from seamount magnetic anomaly modelling must be used with care. (ii) The Leg 192 paleomagnetic paleolatitude for the central OJP is 20° north of the paleogeographic location calculated from Pacific hot spot tracks assuming the hot spots have remained fixed. The difference between

paleomagnetic and hot spot calculated paleolatitudes cannot be explained by true polar wander estimates derived from other lithospheric plates and our results are therefore consistent with and extend recent paleomagnetic studies of younger hot spot features in the northern Pacific Ocean that suggest Late Cretaceous to Eocene motion of Pacific hot spots.

PP22A-0345 1330h POSTER

A Record of the Philippine Sea Plate Motion Since the Eocene (ODP Site 1201)

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ODP Site 1201 (Leg 195) was drilled in the west Philippine Basin, about 100 km west of the inactive Palau-Kyushu Ridge and 450 km north of the extinct Central Basin Fault (19° 17.8'N/135° 5.9' E). A Miocene to Eocene sedimentary sequence (509 m) overlying middle Eocene (Chron C21n, $\sim$ 48Ma) basalts (cored to 90 m below the sediment/basalt interface) was recovered. Using paleomagnetism, this site provides a superb opportunity to constrain the paleolatitude of the Philippine Sea Plate throughout the last 45-50 m.y.. Although plate motion models for the Philippine Sea Plate are now fairly well established (Hall et al., 1995), data gaps exist both in time and geographical spread. The sediments at Site 1201 consist of a lower sequence of volcaniclastic material transported into the basin by turbidity currents flowing from Palau-Kyushu Ridge and a upper succession (early Pliocene to late Oligocene) of red deep-sea clays. Paleolatitudes derived from the sedimentary sequence support the model of northward movement of the plate since the Eocene (Hall et al., 1995). Analysis of 37 samples from the basaltic basement indicates that this part of the plate lay about 7$\pm$ 3.5° from the equator in the middle Eocene. Using the samples' VRM to align the ChRM, the declination data record a clockwise rotation of 62$\pm$ 18°, which is broadly consistent with the Hall et al. (1995) model. In the context of this model, we suggest that in the middle Eocene ODP Site 1201 was located in the Northern Hemisphere.

PP22A-0346 1330h POSTER

Paleoceanographic events in the Shatsky Rise from core-log-seismic data integration

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Shatsky Rise, a medium-sized Large Igneous Province (LIP) in the western Pacific, has been the target of four previous DSDP/ODP legs. In 2001, ODP Leg 198 drilled in the area to address the causes and consequences of Cretaceous and Paleogene global warmth or "greenhouse" climate as well as abrupt climatic events.

Onboard interpretation of downhole log data from Sites 1207 and 1213 not only defined log-based stratigraphic units, but also found the nature and distribution of the chert layers, and established the thickness of the early Aptian black shale. Chert layers are a fundamental part of Cretaceous stratigraphy in the area and are poorly recovered in cores. Formation MicroScanner (FMS) micro-resistivity logs successfully imaged the cherts at Site 1207. Between 210-375 mbsf the chert layers occur on average every 83 cm and have an average thickness of 9 cm. The cherts typically appear as layers rather than nodules. The early Aptian black shales are apparent in the logs as high natural gamma-radiation and Uranium values, revealing the exact depth and thickness of the shales at Sites 1207 and 1213. Density logs were used to estimate the organic carbon content of the shales, based on the relatively low density of organic carbon, giving values similar to those measured on the core itself.

Post-cruise research is continuing on high-resolution stratigraphy of the area based on core-log-seismic data integration. Characterization of the logging data set from the Northern High helped to understand the formation and occurrence of the chert in the region, at least in local scale. For regional scale correlation in the Southern High, paleoceanographic events, which are distinct on core and physical properties results as thick as 90cm, are traced on seismic profiles through integration of logging data and reprocessed seismic with the sequence aiming to achieve highest resolution.

PP22A-0347 1330h POSTER

Is There a Relationship Between the Caribbean Large Igneous Province and Ocean Anoxic Event 2 (OAE2) of the Late Cretaceous?

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It has been recently recognized that the formation of Large Igneous Provinces (LIPs), in particular oceanic plateaus, correlates closely in time with a number of rapid, global oceanographic changes including the long recognized and well documented ocean-wide anoxic events of the mid to late-Cretaceous. Hydrothermalism associated with large-scale submarine volcanism (e.g. event plumes) may have been responsible for the periodic exhaustion of water column O2 , resulting in anoxic conditions and increased preservation of organic carbon. However, a causal relationship between these two, if it exists, is still unclear.

In order to determine a specific link between anoxic events and event plume hydrothermalism associated with ocean plateau eruptions, we are determining the distribution of major, minor and trace element abundances in pelagic carbonate and black shale sequences from a number of sites around the world. An important aspect of event plume hydrothermalism is that the chemical exchange of elements to seawater is controlled by volatility rather than solubility and therefore the abundance pattern of elements released to seawater are different than those derived from typical steady-state hydrothermal vents. Specifically, we are examining for evidence of event plume activity, in the form of appropriate trace metal anomalies, before, during and after the Livello Bonarelli Ocean Anoxic Event (OAE2) at the Cenomanian/Turonian boundary. This prominent black shale layer has been correlated with the formation of the Caribbean ocean plateau ($\sim$ 90Ma).

Recently, we have measured 30 trace, minor and major element abundances in whole rock samples by ICP-MS and ICP-AES analyses from three sites; Rock Creek Canyon section, Pueblo, CO, ODP Site 1138 from the central Kerguelen Plateau and, Bass River, NJ (ODP Leg174AX). After normalizing element concentrations to Zr to remove the effect of terrestrial sediment, distinct prominent trace metal abundance anomalies can be seen at Rock Creek Canyon and ODP Site 1138 preceding the C/T boundary. Faint metal anomalies can be seen at Bass River, NJ. Elements with shorter residence times, such as Co and Sc, are enriched 7-10 times background levels at Rock Creek and 2-5 times background at ODP Site 1138. Elements with longer residence times, such as W and Ag, are enriched 5-10 times background at ODP Site 1138 and 2-5 times background at Rock Creek. Location of anomalies, within the OAE2 and preceding the C/T boundary, suggests that event plume activity may play a major role in leading up to ocean conditions before the C/T boundary.

We also will be measuring trace, minor and major element abundances for the Baranca el Canon section from Mexico and the Totumo-3 well core from Venezuela. We are expecting to find distinct trace metal anomalies, abundant in shorter residence time elements, in both these sections. Complete and detailed results from all five sites will be presented at this conference.

PP22A-0348 1330h POSTER

Using Core (mcd) to log (mbsf) Depth Miss-Matches as a Basis for Interpreting Core Elastic Rebound and Re-calculating Core Physical Properties. Results From ODP Leg 199.

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Leg 199 drilled a series of sites in the equatorial Pacific in order to investigate the paleoceanography of the Paleogene Pacific Ocean. The two deepest cored sites, (1218 and 1219) have provided continuous/near continuous spliced sedimentary sections and in situ wireline log data. Comparison of core to log data sets shows the familiar non-linear, increasing with depth, miss-match between the core (metres composite depth - mcd) and log (mbsf) depths and concomitant offset between core and log physical property data sets e.g. porosity, density, velocity. The depth miss-matches represent core expansion due to elastic rebound experienced by the sediments upon unloading i.e. removal of overburden stress, which is a function of the sediment void ratio and log of the effective in situ stress. The increasing depth offset observed between the 1218 core and log data is used to calculate an expansion index (C_r) for continuous discrete measurement intervals, down the core. The C_r values are used to re-compress the core (mcd) depth scale and as expected provide a good match with the log (mbsf) depths. The C_r values are also used to correct the core index property data, to in situ values. The quality of the corrected core index property data is good when compared with the in situ measured log data. C_r values are dependent upon the sediment composition (especially the quantity of clay) and core light absorption spectroscopy (LAS) data collected on Leg 199, provides a continuous down-core record of sediment composition, in terms of the percent clay, carbonate and opal. A relationship between the C_r values and the sediment LAS composition is established and is then applied to the Site 1219 core LAS data, allowing appropriate C_r values to be assigned to continuous, discrete core intervals. These composition based C_r values are then used to re-calculate the core (mcd) depths and correct the index property data to in situ values. The quality of the depth and index property corrections are checked by comparison with the in situ measured log data, and provide encouraging results.

PP22A-0349 1330h POSTER

Sediment Density and Velocity Trends at ODP Pacific Paleogene Transect Sites

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Variation of sediment wet bulk density and compressional wave velocity at the eight sites that comprise the ODP Leg 199 Pacific Paleogene transect was examined to determine the paleoceanographic significance of the regional seismic reflectors. At these sites the thickness of sediment drilled ranges from 62 to 274 m, sediment age ranges from Holocene to Paleocene, and dominant lithologies are clay, nannofossil ooze/chalk, and radiolarian ooze.

The extent to which core values of density and velocity vary as a function of sediment composition was tested with shipboard ICP bulk chemistry measurements and estimates of illite, smectite, calcite, and opal percentages provided by light absorption spectroscopy. Multiple regression results indicate that most of the variance in bulk density, as determined for discrete samples and by gamma ray attenuation techniques, is explained by differences in the abundance of calcareous constituents. Depth and clay abundance contribute to a lesser extent to the variation in density. Similar analyses of velocity, as determined for discrete samples and by the P-wave logger, indicate little compositional control and only a weak relationship with depth.

The relationship between velocity and density (or porosity) varies with lithology. Low wet bulk density characterizes clays (1.1-1.5 g/cm^3) and radiolarian oozes (1.1-1.4 g/cm^3), and a relationship between velocity and bulk density is lacking. Velocities of the clays and radiolarian oozes are 1475-1575 m/s and 1500-1590 m/s, respectively. Nannofossil oozes are characterized by a larger range in density (1.15-1.75 g/cm^3) and lower velocities that vary over a narrower range (1480-1560 m/s). Velocity increases with increasing density for nannofossil oozes with bulk densities greater than 1.4 g/cm^3. As a result of the lack of consistent trends in velocities, variation in impedance primarily is a factor of changes in wet bulk density.

Core velocities and densities were used to estimate in situ values of these parameters by estimating elastic rebound from the difference between core and borehole log data at Sites 1218 and 1219. The density rebound determined from this comparison is consistent with the rebound indicated by the comparison of the core data and published lithology dependent models for in situ density of pelagic sediments. The difference in log densities and core densities ranges from near zero at the top of the logged intervals (80 mbsf) up to 0.2 g/cm^3 at approximately 250 mbsf.

PP22A-0350 1330h POSTER

Paleogene and Neogene Paleoclimate Implications of High-Resolution Mineralogy and Mass Accumulation Rates for Equatorial Pacific Sites Drilled During ODP Leg 199

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ODP Leg 199 drilled a transect of sites in the equatorial Pacific for the purpose of studying Paleogene and Neogene paleoclimate and paleoceanography. To help achieve this goal, high-resolution mineralogy and mass accumulation rates were calculated at each site. Leg 199 was the first ODP cruise in which reflectance spectra were routinely measured from sediment cores at an extended bandwidth (350-2500 nm) using light absorption spectroscopy (LAS). Precruise calibration of spectral features to local ground-truth samples enabled shipboard calculation of concentrations of calcite and opal, the two biogenic sediment components, and smectite and illite, the two main terrigenous sediment components. These mineral calculation transforms were refined postcruise with additional ground-truth samples. Using multiple regression and LAS mineralogy, the multi-sensor track physical properties data were converted into high-resolution mineralogy logs. These logs, as well as age and dry-bulk density, were used to calculate high-resolution carbonate, opal, and terrigenous mass accumulation rates (MAR) for each Leg 199 site. Plots of opal MAR versus paleolatitude show that during the Paleogene, the opal equatorial accumulation bulge extended to about 12°N, whereas in the Neogene the bulge extended only to about 7°N. Carbonate accumulation rates during the middle to late Eocene were very low except for a few isolated intervals (e.g., around 41 Ma). Carbonate accumulation rates in the Oligocene and early Miocene were much higher than in the Eocene, with the carbonate equatorial bulge extending to 4°N. Terrigenous MAR are much more variable between adjacent sites, probably because of ocean bottom currents. A Pliocene increase in terrigenous accumulations in the north (20°-25°N) may correspond to an increase in the Asian dust flux that occurred ∼3.6 Ma.

PP22A-0351 1330h POSTER

Evidence for Carbonate Compensation Depth Shoaling at the Paleocene-Eocene Thermal Maximum on Shatsky Rise, ODP Leg 198

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The Paleocene-Eocene Thermal Maximum (PETM) was a transient interval of global warming approximately 55 million years ago. The event is associated with a prominent carbon isotope excursion that can best be explained by rapid dissociation of methane hydrate. This massive release of methane in conjunction with its subsequent oxidation to carbon dioxide likely resulted in a shoaling of the lysocline and carbonate compensation depth (CCD). Ocean Drilling Program Leg 198 on Shatsky Rise in the central Pacific recovered the PETM at five sites (Sites 1208 to 1212) spanning a modern depth range of almost 1000 meters from 2387 m at Site 1209 to 3346 m at Site 1208. These sites provide an ideal opportunity to test the response of the Pacific lysocline and CCD to events at the PETM.

In the shallowest four sites (Sites 1209-1212), the PETM corresponds to an 8 to 23 cm-thick layer of clayey nannofossil ooze with a sharp base and a gradational upper contact. The clay-rich layer is generally yellowish brown in color and is often bioturbated into the underlying sediment. An extremely thin (1 mm) dark brown clay seam lies at the base of the PETM in several locations. The deepest of the four shallowest sites (Site 1211) shows a greater sedimentological response to the PETM indicating that it was at a depth close to the lysocline that was more sensitive to changes in carbonate solubility. At the deepest site on Shatsky Rise (Site 1208), the PETM is highly condensed (<3 cm), lies in a dark claystone with few nannofossils and almost no foraminifers, and was clearly close to the CCD before and after the event.

Detailed counts of planktonic and benthic foraminifers as well as other grains (fish teeth, zeolites) have been conducted. This has been combined with measurements of percent CaCO3 and observations of test ultrastructure in the scanning electron microscope. The survey of pore infilling and secondary calcite overgrowth of foraminifera indicates that preservation deteriorates at the base of the PETM, likely due to lysocline shoaling. In some sections, poor preservation is also observed in the 1-2 cm below the event. Foraminiferal preservation is poorest and percent sand fraction highest immediately above the base of the event. All observations support the expected shoaling of the Pacific lysocline and CCD as a result of hydrate dissociation at the PETM.

PP22A-0352 1330h POSTER

Calcareous Nannofossils at the Paleocene/Eocene Transition in the Equatorial Pacific Ocean (ODP Leg 199)

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Calcareous nannofossil assemblages from the first Paleocene/Eocene sections ever to be sampled in the central tropical Pacific (ODP Sites 1215, 1220 and 1221) were preliminary studied with the purpose of obtaining informations on the evolutionary turnovers associated with the P/E boundary time and the peculiar global climatic conditions. We have documented the distribution ranges of some taxa, as *Ericsonia, Discoaster, Fasciculithus, Rhomboaster* and *Tribrachiatus*. Data were obtained through quantitative analyses on the assemblages. These detailed analyses were mainly focused on the evolution of *Rhomboaster- Tribrachiatus* lineage in the lower Eocene interval, and on the stratigraphic relationship of these taxa with the genus *Fasciculithus*. We have documented the consistent occurrence of *Thoracosphaera* cysts at the P/E boundary interval. Thoracosphaerids are considered representatives of opportunistic flora, and blooms of these forms are observed in sediments immediately above the extinction horizon of the Cretaceous/Paleogene boundary. Their abundance at the P/E transition could document a change of critical boundary conditions in surface waters. The analyses on calcareous nannofossils from the Early Paleogene sediments recovered during ODP Leg 199 provide also a new set of data for the nannofossil biostratigraphy and biochronology at the P/E transition interval.

PP22A-0353 1330h POSTER

Middle Eocene Equatorial Pacific Paleoceanography: Insights From Bulk Sediment Geochemistry, ODP Site 1218

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The deep equatorial Pacific was dominated by siliceous sedimentation from 45 Ma to the Eocene-Oligocene boundary. Inspection of Paleogene sediments recovered during Ocean Drilling Program (ODP) Leg 199 and Deep Sea Drilling Program Leg 16 indicate several episodes of carbonate deposition during the Middle Eocene. The well-preserved and expanded sedimentary sequence recovered at ODP Site 1218 presents an opportunity to document the Middle Eocene paleoceanographic history of the equatorial Pacific, and to determine whether the occurrence of Middle Eocene carbonates in Chron C18 is coincident with a sequence of rapid paleoceanographic and climatic changes.

Here we present high-resolution bulk sediment oxygen and carbon isotope records, carbonate, opal, and organic carbon accumulation data, and coarse sand fraction data for chalks and radiolarites spanning Chron C18 from ODP Site 1218. Stable isotope and % carbonate records exhibit large-amplitude oscillations corresponding to obliquity and eccentricity frequencies. In addition, a series of stepwise oxygen isotope excursions of 0.5 to 0.8 per mil at roughly 40.5, 40.4, and 40.3 Ma, occur in coincidence with large-scale drops in % carbonate. These data may record rapid CCD fluctuation associated with transient warming and cooling events and/or ephemeral polar ice sheets.

PP22A-0354 1330h POSTER

New palaeoceanographic contraints on the Eocene-Oligocene Transition in the Pacific

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The Eocene-Oligocene (E/O) transition represents perhaps the most pivotal phase in the shift from Cenozoic greenhouse to icehouse and is marked by the most pronounced shift in the calcite compensation depth (CCD) over the last 100 Myr. Yet detailed palaeoceanographic records for these important events are rare because of the lack of well-dated, expanded deep-sea sedimentary sections containing well-preserved calcareous microfossils. Recently, during Ocean Drilling Program Leg 199, we recovered a series of high-quality E/O sections across a latitudinal and depth transect in the central tropical Pacific Ocean. These sections provide an excellent opportunity to improve our understanding of the palaeoceanographic chain of events that took place across this important interval in the region of the world where the CCD perturbation is believed to be most extreme and in the largest ocean basin. Here, we report new high-resolution records of bulk sediment carbon and oxygen isotopes and percent carbonate from ODP Sites 1217 through 1220. Our results show the following: (i) Bulk records from the central tropical Pacific have the potential to provide a remarkably clean and detailed chemostratigraphy for the E/O transition. (ii) CCD deepening occurred remarkably rapidly (initial depression <50 ka) and, in the most expanded section, at the shallowest end of the transect (Site 1218), as a two-step shift. (iii) The form of this two-step shift is strikingly similar to the bulk oxygen isotope record on the build up to Oi-1. (iv) The intermediate plateau that occurs between the two steps in the oxygen isotope series fits very well with the main 100-120 ky eccentricity cycles observed in multi-sensor track data and their amplitude modulation (plateau = one cycle). (v) The interval of maximum CCD as defined by high carbonate sediment content (more than 60 percent carbonate) at the deeper end of the transect (Site 1220) correlates with the onset of Oi-1 and lasts for 250 ka. (vi) Hitherto unrecorded extreme perturbations to low oxygen and carbon isotope values occur in the uppermost Eocene at Site 1218. (vii) stable isotope records from this site show significantly more structure within Oi-1 than published records (characteristic features of obliquity control, with a small imprint of precession).

PP22A-0355 1330h POSTER

Morphological Provincialism Indicated by Cretaceous Radiolarian Populations at DSDP and ODP Sites.

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Assemblages of Cretaceous radiolarians recovered from DSDP and ODP core samples have been analyzed to determine the quantitative and qualitative relationships of morphological characteristics within a temporal and spatial framework. Radiolarians have been chosen for these investigations because of the potential variety within an assemblage of readily quantifiable test morphologies displayed by these faunas. The Cretaceous was selected as representative of a substantial time period for which much environmental data have been published.

Preliminary results of this pilot study strongly suggest that the morphology of the radiolarian test is important in determining the rate of the evolution of these organisms in terms of species diversity and also in the rates of cosmopolitan occurrence in Cretaceous oceans.

The success of a genus in terms of adaptation to environment, abundance, and geographical distribution patterns is recorded. The occurrence patterns are correlated with changing conditions in the physical environment and with evolutionary changes in other marine microfossil groups. Distinct patterns emerged from this study that show potential for further, more detailed analyses.

PP22B MCC: 123 Tuesday 1330h

Antarctic Climate Evolution II *(joint with C, A, OS, GC)*

Presiding: **R B Dunbar,** Stanford University**; M Siegert,** University of Bristol

PP22B-01 1330h INVITED

Antarctic Climate Evolution: The Next Step

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The Antarctic ice sheet plays a special role in the global atmosphere-ocean system due to its influence on Southern Hemisphere climate, on water masses and deep-ocean ventilation and on sea level world-wide. However, its behaviour is still poorly understood, and in particular the nature and timing of its likely response to global warming. In the last decade Antarctic margin drilling by the Ocean Drilling Programme and the Cape Roberts Project, along with land-based studies of glacial deposits and landscape history, have provided a widely accepted view of the formation of ice sheets on Antarctica through Cenozoic times. Although the Antarctic continent has been in a polar position since the early Cretaceous, the first records of a continental ice sheet there are not found until around 34 Ma. From that time on the continent supported temperate ice sheets that responded to Milankovitch forcing. The cool temperate vegetation around the coast declining to sub-polar tundra until around a permanent ice sheet became established around 14 Ma. This most likely continued to respond to orbital forcing, though it may have been more variable in size than the cold ice sheet of Quaternary times. While some regional issues remain unresolved there is now increasing interest in the causes of the major cooling events at around 34, 24 and 14 Ma, and the warming events of the mid Pliocene and MIS 31 and 11. Future work not only involves drilling at key locations to sample strata the record these transitions (eg. ANDRILL), but also the testing and extension of these results through the use of the new generation of climate models and their coupling with ocean, ice sheet and sediment models (ACE: www.geo.umass.edu/ace/). The goal is to simulate Antarctic climate for varying influences, such as atmospheric CO2 levels and changing topography in order to understand the behaviour of ice sheets and shelves, to simulate past behaviour and provide scenarios for possible futures.

PP22B-02 1345h INVITED

Coupled Climate-Ice Sheet Simulations of the Early Cenozoic History of the Antarctic Ice Sheet

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Numerical modeling studies of ancient Antarctic ice sheets have relied on empirical parameterizations based on modern climatologies for their surface mass balance forcing. An alternative approach, using a Global Climate Model (GCM) asynchronously coupled to a dynamical ice sheet model, has been developed, tested, and applied to the early glacial history of Antarctica. The coupled GCM-ice sheet model was used to test the sensitivity of the coupled atmosphere-ocean-cryosphere system to evolving Cenozoic boundary conditions, including paleogeography, atmospheric carbon dioxide, changing orbital parameters, and changes in ocean heat transport. The asynchronous coupling scheme enables long (10^6 year) integrations, simulating not only ice sheet inception, but subsequent ice sheet variability over orbital timescales.

Our results suggest that the combination of declining Cenozoic atmospheric carbon dioxide and an orbital configuration producing cold austral summers triggered snow/ice albedo and height-mass balance feedbacks that allowed a continental-scale East Antarctic Ice Sheet (EAIS) to form in a relatively sudden transition. In the model, the CO_2 threshold for glacial inception is between 3 and 2.5 present. The simulated early Oligocene ice sheets exhibit extreme variability in response to orbital forcing. Changes in ocean heat transport, like those assumed to have occurred in response to the opening of Southern Ocean gateways (Tasmanian and Drake Passages) are shown to have a smaller effect than that expected in the transition from a greenhouse to icehouse climate, having only a minor effect on the timing of major glaciation. In our model, the opening of the Drake Passage is a potential trigger for glacial inception, but only within a narrow range of atmospheric CO_2, reinforcing the importance of pCO_2 as a fundamental boundary condition for Cenozoic climate change.

PP22B-03 1400h

Antarctic Ice and Sediment Flux in the Oligocene Simulated by a Climate-Ice Sheet-Sediment Model

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Models of subglacial deformable sediment and ice-free sediment transport are added to a global climate (GCM)-dynamical ice sheet model. The coupled model is applied to the evolution of early Oligocene Antarctic ice sheets, sediment distributions, and coastal sediment discharge under a range of prescribed atmospheric CO2 and orbital variations. The GCM-ice sheet model uses a computationally efficient asynchronous coupling scheme, enabling long (10 million year) integrations. The sediment component is initialized with a uniform 50m layer of regolith, assumed to have accumulated prior to the onset of widespread glaciation. Subglacial sediment deformation in the upper tens of cm is driven by basal shear stress where the basal ice is melting. The spatial distribution of sediment evolves by bulk transport of sediment under the ice, quarrying of new till by glacial ice in contact with clean bedrock, and fluvial downslope transport of freshly exposed sediment to the continental margin.

With a prescribed gradual decline of atmospheric CO2 over the 10 Ma long simulations, a sudden transition occurs around 2.5 x present CO2, from relatively small land-based ice caps localized on high topography, to a single large East Antarctic ice sheet comparable to today. Much of the pre-existing sediment is transported to the coast by the action of repeated orbital cycles, funneled into continental scale drainage basins and thence to a small number of major discharge sites. The predicted spatial and temporal patterns of sediment discharge are compared with observed distributions and core records of offshore Cenozoic sedimentary deposits.

PP22B-04 1415h

Antarctic Ice Evolution Viewed from NJ and the Deep sea

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Backstripping of mid-Cretaceous to Miocene sections from the New Jersey Coastal Plain (ODP Legs 150X and 174AX) provides a eustatic estimate for 100-8 Ma. Backstripping extracts amplitudes of global sea level from passive margin records by accounting for paleo-water depth variations and progressively removing the effects of sediment loading (including the effects of compaction) and tectonic subsidence. Rapid (less than 1 m.y.) sea-level lowerings of 20-35 m are associated with Cretaceouslower Eocene sequences; eustatic rises approach 50 m in some instances. Middle Eocene lowerings were approx. 45 m. Glacioeustasy is the only known mechanism that can account for these large, rapid changes. 2-D backstripping of Oligocene sequences yields estimates of 20-60 m for eustatic lowerings. 1-D backstripping yields early Miocene amplitudes of up to 40 m, whereas estimates of middle-late Miocene eustatic change are generally lower (20-40 m). We interpret the sea-level estimates in terms of glacioeustasy and reconcile the sea-level and deep-sea oxygen isotopic records. Because large N. hemisphere ice sheets developed during the late Pliocene, we ascribe these eustatic changes to Antarctic ice-volume variations, and thus, provide a prediction for Antarctic cryospheric evolution. Ephemeral small (20 m sea-level equivalent; 30% of the modern East Antarctic Ice Sheet [EAIS]) to medium-sized (35 m equivalent; 50% EAIS) ice sheets existed in Antarctica even during the peak warmth of the Late Cretaceous-early Eocene, although most of the time Antarctica was ice-free. Larger ice sheets (approx. 45 m equivalent, 70% EAIS) developed in the late middle Eocene (46 and 42 Ma). A large (54∓15 mm) earliest Oligocene drop in sea level was associated with development of a large ice sheet (87% EAIS), though sea level again rose by nearly 46∓15 m about 1 m.y. later, suggesting near collapse of the ice sheet. The ice sheet subsequently grew and decayed numerous times in the Oligocene-middle Miocene, testifying to a very dynamic ice sheet between ca. 33 and 14 Ma. By the middle Miocene, the East Antarctic ice sheet had become a permanent feature and sea level changes were primarily controlled by small ice-volume changes in Antarctica and the nascent growth of Northern Hemisphere ice sheets.

PP22B-05 1430h

Subglacial Bed Roughness in East Antarctica and Implications for Ice Sheet Dynamics

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A large airborne radio-echo sounding database was collected from East Antarctica in the 1970s. Flight lines, which make up the survey, were arranged in a grid, with a flight spacing of around 50 km. Navigational records and subglacial bedrock elevations were recorded every 20 seconds (or about 1.67 km). Hence, the RES database is made up of numerous bedrock profiles, each several hundred kilometres in length, in two orthogonal directions. These profiles were used to calculate the bedrock roughness along the flightiness. Spectral analyses were performed on 200 km sections of each flight, with a spacing of 10 km. Roughness coefficients were then calculated at a variety of scales from the spectral results, from which maps of roughness were established. The maps were then compared with ice-sheet modelling results to assess how current ice flow and subglacial temperatures correspond with bed roughness. Roughness maxima, at Ridge B and Dome A, correspond with the centre of the ice sheet where the ice base is very cold. Hence, these regions, either at present or in the past, may not be subject to glacial erosion that would act to smooth the topography. At Dome C the bed is smoother yet is also beneath the ice sheet centre. We suggest that Dome A and Ridge B have been covered by cold ice for several million years. At Dome C, however, we argue that the smoother topography is more consistent with a more dynamic eroding glacial regime than the current ice sheet configuration allows. Hence, the roughness at Dome C may be an artefact of a former ice cover more dynamic over the Dome C region than at present.

URL: http://www.ggy.bris.ac.uk/research/glaciology/personalpp/siegert/mashome.html

PP22B-06 1445h

Neogene History of Antarctic Sea-ice and Development of the Sea-ice Diatom Community

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Sea-ice plays an important role in the modern Antarctic climate system and in this regions linkage