Antarctica and major fluctuations in the East Antarctic Ice Sheet, while the intervals around the hiatuses represent times of relative warmth, but with continued current activity. The period between 11 to 9 Ma is characterized by conditions surrounding the formation and stabilization of the West Antarctic Ice Sheet causing a high velocity DWBC, yet the increased terrigenous input may result from either changing Antarctic conditions or more direct sediment transport from New Zealand.

The Pacific DWBC did not exert a major influence the sediment at Site 1124 from 9 Ma to the present; the late Miocene to Pleistocene sequence is more influenced by the climatic and tectonic history of New Zealand. Despite the apparent potential for increased sediment supply to this site resulting from changes in sediment channeling, increasing rates of mountain uplift, and volcanic activity, terrigenous fluxes remain low and fairly constant throughout this younger period.

PP11C-12 1135h INVITED

The Late Pleistocene Ross Ice Sheet and Eustatic Sea Level Rise

Kathy J. Licht[1] (klicht@iupui.edu)

John T. Andrews[2] (andrewsj@spot.colorado.edu)

[1]Indiana University Purdue University at Indianapolis , 723 W. Michigan St., Indianapolis, IN 46202

[2]Institute of Arctic and Alpine Research and Department of Geological Sciences, Box 450, Boulder, CO 80309

Radiocarbon dates obtained from central Ross Sea foraminifera indicate that glacial ice reached its maximum position in the Ross Embayment after 13.8 ^{14}C ka, suggesting that deglaciation of this major sector of the Antarctic ice sheet lagged the onset of Late Pleistocene eustatic sea level rise by 4-5 ky. The 13.8 ^{14}C date is the youngest of 18 ^{14}C dates from Ross Sea glacial till and provides a maximum constraint on the age of ice advance. Assuming that grounding line retreat was broadly synchronous across the western and central Ross Sea, ice sheet retreat was very likely in progress during the time of melt-water pulse (mwp)-IA (ca. 12 ^{14}C ka). However, the total contribution to mwp-IA from the various ice sheets remains poorly constrained.

A numerical model simulation shows that the maximum volume of grounded ice in the Ross Embayment during the last glacial maximum was 2.4 x 10^6 km^3 greater than the present-day ice sheet, which translates to ~6.75 m eustatic sea level rise. If stepwise retreat occurred from the maximum ice position back to Ross Island during mwp-IA, the ice sheet volume in the Ross Sea sector would have been reduced by ~20%, yielding a eustatic rise of <1.4 m. Given this conservative estimate of the contribution of expanded ice in the Ross Sea sector, it is highly unlikely that Antarctica was the sole, or even dominant source of mwp-IA (with a minimum eustatic rise of 13.5 m as described by Blanchon and Shaw, 1995, Geology v.23, p.4-8). Grounded ice in the Ross Embayment was still retreating at the time of mwp-IB (ca. 9.5 ^{14}C ka) and was likely a contributor to sea level rise at that time, but by similar logic, was most likely not the dominant source.

.

PP11C-13 1150h

The Oxygen Isotopic Composition and Temperature of Southern Ocean Bottom Waters During the Last Glacial Maximum

Mitchell J Malone[1] (1-979-845-0876; malone@odpemail.tamu.edu)

Jonathan B Martin[2] (jmartin@geology.ufl.edu)

Ulysses S Ninnemann[3] (ulysses.ninnemann@geol.uib.no)

Dirk Nürnburg[4] (dnuernberg@geomar.de)

Timothy S White[5] (tswhite@geosc.psu.edu)

[1]Texas A&M University, Ocean Drilling Program, College Station, TX 77845, United States

[2]University of Florida, Department of Geological Sciences, Gainesville, FL 32611, United States

[3]University of Bergen, Department of Geology, Bergen 5007, Norway

[4]Christian-Albrechts-Universität zu Kiel, GEOMAR, Kiel 24148, Germany

[5]The Pennsylvania State University, EMS Environment Institute, University Park, PA 16802, United States

We use oxygen isotopic measurements of pore waters recovered from ODP Sites 1168 and 1170 in the Indian Ocean sector of the Southern Ocean and a numerical model to obtain the oxygen isotopic composition of bottom waters during the last glacial maximum (LGM). At these sites, the pore water oxygen isotopic values increase by ~0.30 $^o/_{oo}$ in the upper 30-40 m below seafloor. Previous work has shown this maximum to be the diffusionally attenuated record of the glacial-interglacial (G-I) shift in oxygen isotopic composition of the ocean. Site 1168 is located in middle bathyal water depths (2463 m) on the slope of the western margin of Tasmania (42° 36.58' S, 144° 24.76'E) north of the present-day Subtropical Front (STF). Site 1170 is located 400 km south of Tasmania on the western South Tasman Rise (47° 9.04'S, 144° 2.98'E, 2705 m water depth) ~150 km south of the STF and well north of the Subantarctic Front. Currently, both sites are bathed by Circumpolar Deep Water (CDW). We applied a diffusion-advection model using a finite difference, central differencing scheme to solve for magnitude of the oxygen isotopic change in overlying seawater since the LGM. The model results produce similar values for the two sites: 1.0 $\pm 0.15^o/_{oo}$ at 1168 and 1.05 $\pm 0.15^o/_{oo}$ at 1170. Previously published values for this technique come from Atlantic sites, and resulted in a consistent G-I change of $0.8^o/_{oo}$. One exception is Site 1093, which is located in the Southern Ocean (Atlantic sector) and produced a calculated change ($1.1^o/_{oo}$) close to that of Sites 1168 and 1170. Likewise, the bottom waters at Site 1093 are probably CDW. We will also use the pore water results above with the G-I difference in the isotopic values of benthic foraminifers to calculate the temperature of bottom water during the LGM at Sites 1168 and 1170.

PP12A MCC: Hall D Monday 1330h

Southern Ocean Climatic Evolution: The Marine Geologic Record II
Posters *(joint with A, GP, OS, GC)*

Presiding: **D A Warnke,** California State University, Hayward**; P E OBrien,** Geoscience Australia

PP12A-0319 1330h POSTER

A 450 000 kyr Surface Hydrography History From the Subantarctic Atlantic Ocean (ODP Site 1089)

Giuseppe Cortese[1] (++49-0471-48311207; gcortese@awi-bremerhaven.de)

Andrea Abelmann[1] (aabelmann@awi-bremerhaven.de)

Rainer Gersonde[1] (rgersonde@awi-bremerhaven.de)

[1]Alfred Wegener Institute for Polar and Marine Research (AWI), Columbusstrasse - P.O. Box 120161, Bremerhaven 27515, Germany

We established a palaeo sea surface temperature (SST) record, by using a radiolarian-based transfer function, for the northern subantarctic Atlantic Ocean (ODP Site 1089, 40^0 56 S; 9^0 54 E), in order to reconstruct its surface hydrography and interocean heat exchange history during the last five climate cycles (ca. 450 ka). The produced record has a centennial scale time resolution, which makes it unique (in length and resolution) for the subantarctic zone. At this location, close to the subtropical front, ocean/atmosphere interactions, interoceanic exchange processes, and mesoscale eddy mixing play an important role in shaping the characteristics of sea water eventually advected to the North Atlantic. The centennial resolution allows to recognize millennial scale climatic events, similar to the Dansgaard-Oeschger cycles (originally described from Greenland ice cores), both during Marine Isotopic Stage (MIS) 3 and 6. Similar to observations from Termination I (Antarctic Cold Reversal), rapid cooling rebounds were encountered at Terminations II to V, and are not therefore limited either to the circum-Atlantic area or to last Termination. A comparison of SST and ice volume proxies suggests a lead of a few kyrs between SST and the minimum extent of global ice volume, indicating that temperatures rose substantially at subantarctic latitudes before any considerable northern hemisphere continental ice volume change was recorded. The climatic history of ODP Site 1089 displays good correlation to other records (e.g. Vostok) with the exception of MIS 10, where a warm SST anomaly was recognized. This anomaly is also present in oceanic records along the thermohaline circulation belt path, but absent in both Polar Zone and Vostok climatic records. The implications of our record for interhemispheric climate connecting mechanisms and the role played by the Southern Ocean in steering global climatic change will be discussed.

PP12A-0320 1330h POSTER

Plio-Pleistocene Biogenic Opal Deposition in the Southern Ocean

Gerhard Kuhn[1] (0049-471-4831-1204; gkuhn@awi-bremerhaven.de)

Rainer Gersonde[1] (0049-471-4831-1203; rgersonde@awi-bremerhaven.de)

[1]Alfred Wegener Institute, Columbusstrasse, Bremerhaven 27568, Germany

About 2/3 of the annual supply of silicic acid to the World Ocean is buried in the Southern Ocean as biogenic silica (BSi), formed by diatoms and radiolaria in surface waters and exported to the seafloor. Main BSi accumulation occurs in an area between the sea ice edge and the Polar Front Zone and seems to be steered by a complex interaction of biological and physical parameters governing the modern Southern Ocean ecosystem. Sediment cores recovered during Ocean Drilling Program Leg 177 and expeditions with RV POLARSTERN reveal the history of the opal deposition in the Atlantic and Pacific sector of the Southern Ocean during the Pliocene and the Pleistocene. This period is characterized by distinct changes and variability in global climate and ocean circulation that can be related to the spatial-temporal distribution of BSi deposition on long and short time scales. Changes in ocean circulation, water mass structure, sea ice and climatic variability that impact the distribution of silicic acid and the development of coarsly silicified diatoms (e.g. Actinocyclus ingens, Thalassiosira antarctica, Fragilariopsis kerguelensis), presenting the major carriers of biogenic opal, control past BSi deposition in the Southern Ocean. Major deposition in the area of the modern Southern Ocean opal belt starts at the Plio/Pleistocene transition. Such strong export of BSi and related organic carbon might have reinforced the trend of global cooling observed since the Mid-Pliocene climate optimum.

PP12A-0321 1330h INVITED POSTER

Late Neogene sedimentation at ODP Site 1171 (Leg 189), South Tasman Rise: history of paleoproductivity and ice rafting.

Liselotte Diester-Haass[1] (+49-681-302-64145; a.l.haass@t-online.de)

Stefan Nees (snees@web.de)

[1]Universitaet des Saarlandes, Zentrum fuer Umweltforschung, Saarbruecken 66041, Germany

The late Neogene (11.3-1 Ma) sediments at Site 1171 reflect changing paleoproductivity, radiolarian opal preservation as well as coarse glauconite and clastic material input as shown by an analysis of the coarse fraction and stable isotopes. A hiatus spans the 8.7-5.23 Ma interval. Accumulation rates fluctuate between 0.5 and 4.5 cm/ky. The following results have been obtained:

1. A coarsening of the sand (increase in >250 μm sized fraction and related reduction in fine sand) since 5.23 Ma is not due to winnowing after the time of non-deposition, but to improved carbonate preservation.

2. Up to 1000 μm sized glauconite, quartz grains and rock debris present in nearly all samples are attributed to delivery from melting icebergs (IRD). Major periods of IRD delivery are at 10.5-10.7, 9.2-10.2 and 3.2 Ma.

3. Two measures of paleoproductivity, which were thought to be interdependent so far, proved to be independent. Whereas the paleoproductivity data in gC/cm^2*ky derived from benthic foraminiferal numbers as well as Uvigerina numbers, fish debris concentration and carbonate dissolution show a coherent picture with higher productivity prior to 9 Ma (paleo-export- productivity values of 25-75 gC/cm^2*ky) than after the hiatus (values of 8-45 gC/cm^2*ky), the data derived from radiolarian and sponge skeletons show minima during times of highest paleoproductivity as derived from benthic foraminifers. Abundance of radiolarian skeletons is interpreted in terms of preservation conditions related mainly to production, location of the site relative to the polar front and water temperature. The observed anticorrelation of radiolaria and IRD leads to the assumption that radiolaria are better preserved during cool periods, whereas during warmer intervals radiolarian opal is more or less completely dissolved and IRD supply is enhanced perhaps because of more rapidly moving glaciers or preferential melting over Site 1171 or less sea-ice that impedes iceberg dispersal or increased strength of the warm East Australian Current.

4. We tentatively correlate the depressions in $CaCO_3$ content at 9.6-10 Ma and 10.6-11.2 Ma and related high productivity and dissolution spikes to the "carbonate crash events" and the strong dissolution, higher Uvigerina numbers and slightly increased paleoproductivity at 4.5-5.23 Ma to the declining late Miocene "biogenic bloom" event. These two major paleoceanographic events during the late Neogene have so far been known only from equatorial and subtropical upwelling areas.

PP12A-0322 1330h POSTER

History of Ice Rafting at Sites TN057-6-PC4/ODP 177-1090 (Agulhas Ridge, South Atlantic) Marine Isotope Stages 1-14

Lora F Teitler[1] (510-885-3486)

Detlef A Warnke[1] (510-885-4716; dwarnke@csuhayward.edu)

Kathryn Venz[2] (352-392-6137; venz@ufl.edu)

David A Hodell[2] (352-392-6137; dhodell@geology.ufl.edu)

[1]California State University, Hayward, 25800 Carlos Bee Blvd., Hayward, CA 94542, United States

[2]University of Florida, 241 Williamson Hall, Gainesville, FL 32611, United States

The presence of ice-rafted debris (IRD) in marine cores is a clear indication of both the existence of a large and dynamic ice sheet in the source area, and of sea surface temperatures (SST) low enough to permit the survival of the rafting icebergs to a particular site. The newly-completed analysis of IRD from the spliced records of two South Atlantic (Agulhas Ridge) sites (TN057-6-PC4/ODP 177-1090) covering Marine Isotope Stages (MIS) 1 through 14, extends our previous findings concerning the pattern of IRD delivery in the South Atlantic (Teitler et al, 2001). In general, IRD increases significantly after glaciations begin, but drops off before or at glacial peaks in either benthic or planktic δ^{18}O, with little or no IRD at glacial terminations. Minor pulses of IRD arrive during strong stadials within interglacials; isolated grains arrive even during lesser stadials. Thus this record shows the continuity of at least the East Antarctic Ice Sheet (based on the presence of garnets indistinguishable from those found in East Antarctica throughout both cores) during this entire time span. Further, the arrival of IRD is apparently governed by SST, with icebergs surviving to this distance whenever temperatures are low enough. Decreases in planktic δ^{18}O lead decreases in benthic δ^{18}O at the end of glacials at these sites by about 3 to 4.5 kyrs for MIS 2 through 12. For MIS 14, the lead of planktic d18O change appears to be about 12 kyrs. This relationship suggests that SST begins to warm before ice volume decreases, confirmed by the drop off in IRD at or before the peaks in δ^{18}O. The occurrence of early warm SST is further supported by the presence of the radiolarian *Dictyocoryne profunda*, a warm water indicator [Casey, 1971]). This indicator (in the size fraction 250 μm to 2 mm) occurs only during the warmest intervals, including mid-MIS 11 and the transitions from MIS 6 to 5e and from MIS 2 to 1; samples between late MIS 10 and early MIS 6 remain to be checked. Results from these sites will add to the debate on the degree of warmth reached by the ocean in different interglacials.

PP12A-0323 1330h POSTER

On the Magnetostratigraphy of Leg 189 and the Opening of the Tasmanian Gateway.

Yannick Touchard[1] (touchard@cerege.fr)

Mike Fuller[2] (1-808-856-4038; fuller@soest.hawaii.edu)

[1]Cerege, 13545, Aix-enProvence Cedex 4, France

[2]HIGP-SOEST, U.Hawaii,, 2525 Correa Rd, Honolulu, HI 96822, United States

ODP Leg 189 drilling has allowed documentation of the opening of the Tasmanian Gateway during the drifting of Australia from Antarctica in the late Paleogene and of subsequent paleoceanographic events in this region throughout the Neogene and Quaternary. An excellent recovery of Maastrichtian to Quaternary sediments has allowed detailed analysis of critical intervals for numerous studies emerging form this Leg. Magnetostratigraphy, coupled with biostratigraphy and cyclostratigraphy, constrain the timing of these various events and if the magnetostratigraphy is clearly enough established it provides improved calibration for biostratigraphic events. The advent of the new magnetometer on the Resolution brought much of the carbonate Neogene and Quaternary section into a measurable range, and the rapid deposition of Eocene siltstones provided reliable magnetostratigraphy for this time interval. In particular, site 1172 provided a remarkably good paleomagnetic record.

PP12A-0324 1330h POSTER

Early Miocene Variability of Precipitation at Southern High Latitudes (ODP Site 1168, Western Tasmanian Region).

Christian Robert[1] (robert@com.univ-mrs.fr)

Guillaume Larnicol[2] (g.larnicol@libertysurf.fr)

Stephen A Schellenberg[3] (schellenberg@geology.sdsu.edu)

Helen Pfuhl[4] (hpfuhl@bgc-jena.mpg.de)

[1]PBDS, Centre d'Oceanologie, Universite de la Mediterranee, Luminy, Marseille 13009, France

[2]PBDS, Universite de Lille 1, Villeneuve d'Ascq 59655, France

[3]Geological Sciences, San Diego State University, San Diego CA 92182, United States

[4]Max Planck Institute for Biogeochemistry, Carl-Zeiss Promenade 10, Jena 07745, Germany

Clay mineral assemblages and foraminiferal stable-isotope variations have been investigated in a late Oligocene/early Miocene sequence drilled at bathyal depths of the Western Tasmanian margin (ODP Site 1168). The sediment ranges from clay-bearing nannofossil chalk to nannofossil claystone, and its terrigenous fraction is mostly eroded from adjacent emerged areas of Tasmania. Dominant smectite and kaolinite associated with minor amounts of illite indicate the preponderance of chemical over physical weathering in the drainage basins of the passive Tasmanian margin. Smectite and kaolinite are typical of relatively warm climates: smectite develops in semi-arid areas with seasonal precipitation, whereas kaolinite rather expands in areas of high precipitation and run-off.

High values of the benthic oxygen-isotopes in the earliest Miocene (indicative of cooler intermediate waters during the Mi-1 and Mi-1a events) are associated with an increasing trend of smectite. Cooler waters and decreased ocean-to-continent heat transfer may have increased continental aridity and thereby smectite production. However the cooling was insufficient to increase significantly physical weathering and illite production in the adjacent drainage basins. The oxygen isotopes returned to lower values around 23Ma, suggesting that intermediate waters warmed and/or that Antarctic ice-volume decreased. However aridity persisted, with important fluctuations in the relative abundance of smectite and kaolinite indicative of climate instability. About 400kyr after the oxygen-isotope decrease, an increasing trend in kaolinite suggests that precipitation and ocean-to-continent heat transfer intensified.

What caused the increase of precipitation, and why did it occur 400kyr after intermediate waters began to warm? Parameters like sea-surface temperature, saturated and efficient vapor pressures of the atmosphere, concentration of greenhouse gases, and convection, play a key role in the control of precipitation. Intervals of increased kaolinite in the earliest Miocene of Site 1168 generally correlate with fluid escape structures in the sediment and/or negative anomalies of carbon isotopes. Sediment deformation is very similar to those ascribed to methane hydrate dissociation. Negative carbon-isotope anomalies may result from the release and oxidation of methane hydrates to carbon dioxide. We hypothesize that gas hydrates formed as cold waters expanded during Mi-1, and were subsequently destroyed following Mi-1when intermediate water warming crossed a stability threshold. Methane release may have altered ocean/atmosphere interactions and increased the temperature and moisture of the lower troposphere, resulting in intensified convection and precipitation.

PP12A-0325 1330h POSTER

Cyclicity in Eocene Southern Ocean Sediments; Patterns From the Tasmanian Gateway, ODP 189, Site 1172.

Ursula Roehl[1] (+49-421-2182482; uroehl@uni-bremen.de); Henk Brinkhuis[2] (+31.30.2537691; H.Brinkhuis@bio.uu.nl); Mike Fuller[3] (fuller@soest.hawaii.edu); Catherine E Stickley[4] (845-365-8597; ces@ldeo.columbia.edu); Jeroen Warnaar[2] (J.Warnaar@bio.uu.nl); Graham L Williams[5] (gwilliam@agc.bio.ns.ca)

[1]Department of Geosciences, Research Center for Ocean Margins, Bremen University, PO Box 330440, Bremen 28334, Germany

[2]Laboratory of Palaeobotany and Palynology, Utrecht University, Budapestlaan 4, Utrecht 3584 CD, Netherlands

[3]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, 2525 Correa Road, Honolulu, HI 96822, United States

[4]Lamont-Doherty Earth Observatory, Paleomagnetics building, 61 Route 9W, Palisades, NY 10964, United States

[5]Atlantic Geoscience Centre, PO Box 1006, Dartmouth, NS B2Y 4A2, Canada

Here we present major element, diatoms and dinocysts data from sediments of Middle to early Late Eocene age, recovered during ODP Leg 189. Sites were selected to obtain an early Paleogene record of rifting between Antarctica and the Southern Tasman Rise. This was a time of minimal or no connection between the Indian and Pacific Oceans. Analysis of these cores is allowing a better understanding of paleoceanographic and paleoclimatic conditions prior to the opening of the Tasmanian Gateway and subsequent Antarctic Circumpolar Current development. In the early Paleogene marine siliciclastic sediments, largely silty claystones were deposited off Tasmania (at 65° S paleolatitude) under a sluggish ocean circulation within a restricted environment in relatively shallow water. Most of the Tasmanian Promontory had not yet subsided and the Antarctic hinterland provided most of the sediments to the Tasman Basin, resulting in relatively high accumulation rates. In Holes 1172A and 1172D the Eocene magnetic polarity zones are well defined; calcareous microfossils are sporadic, whereas siliceous microfossils (notably diatoms) and organic walled microfossils (dinocysts, spores, and pollen) are consistently abundant.

High-resolution X-ray fluorescence (XRF) Core Scanner data of the Middle Eocene at Site 1172, East Tasman Plateau, reveals clear cycles of varying length that are present throughout most of the sequence. Ca and Fe were selected as proxies for climate-paleoceanographic cycles, since these elements mirror changes in calcium carbonate/clay ratios. Our data match well with other proxy data (e.g., magnetic susceptibility, color reflectance) but show a significantly higher signal-to-noise ratio. The major element data better define the origin and nature of cycles (Milankovitch, runoff and SST variations), the derived cyclostratigraphy helps to understand and explain regional similarities and differences in sedimentation and climate, and probable influences of sea-level changes.

Quantitative palynological and diatom analysis of selected intervals straddling the distinct cyclic patterns provides paleoecological information on changing conditions not only at the sea surface but also on the sea floor (benthic diatoms). Generally the dominant taxa are endemic. Cycles are characterized by massive compositional changes in the assemblages, indicative of changes in eutrophic state, sea surface temperature, runoff/sea level and associated hydrodynamic energy levels.

PP12A-0326 1330h POSTER

Magnetobiostratigraphic Chronology and Palaeoenvironmental History of Cenozoic Sequences From ODP Sites 1165 and 1166, Prydz Bay, Antarctica

Fabio Florindo[1,2] (+39-0651860383; florindo@ingv.it); Steven M Bohaty[3] (sbohaty@es.ucsc.edu); Patrick S Erwin[4]; Carl Richter[5] (richter@tamu.edu, crichter@louisiana.edu); Andrew P Roberts[2] (arob@soc.soton.ac.uk); Patricia A Whalen[6] (micropaw@ipa.net); Jason M Whitehead[7] (jm$_w$*hitehead@hotmail.com*)

[1]Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, Roma 00143, Italy

[2]School of Ocean and Earth Science, University of Southampton, European Way, Southampton SO14 3ZH, United Kingdom

[3]Department of Earth Sciences, University of California, Santa Cruz, Santa Cruz, CA 95064, United States

[4]Department of Earth Sciences, University of Oxford, Parks Road, Oxford OX1 3PR, United Kingdom

[5]Ocean Drilling Program, 1000 Discovery Drive, Texas A M Research Park, College Station, TX 77845-9547, United States

[6]Department of Geosciences, University of Arkansas, 118 Ozark Hall, Fayetteville, ARK 72701, United States

[7]Department of Geology, University of Nebraska, 214 Bessey Hall, Lincoln, NE 68588-0340, United States

A transect of three sites was drilled during Leg 188 of the Ocean Drilling Program, proximal to the East Antarctic Ice Sheet (EAIS) across the Prydz Bay continental shelf (Site 1166), slope (Site 1167), and rise (Site 1165). We present results of a palaeomagnetic and rock magnetic study of sediments recovered at sites 1165 and 1166. Magnetostratigraphic interpretations are presented for both holes, and are mainly constrained by diatom and radiolarian biostratigraphy that are interpreted in the light of recent refinements to Southern Ocean zonal schemes and datum calibrations for these microfossil groups. Site 1165 records a history of sedimentation on the continental rise extending back to earliest Miocene time. Several long-term

changes characterize this record, including an overall trend of decreasing sedimentation rates from the bottom to the top of the hole. There is a progressive decrease in sedimentation rate above about 308 mbsf, which is marked by a transition from dark-grey fissile claystones to greenish-grey diatom-bearing clays. At this transition, ice-rafted debris, sand grains, and total clay content also increase. The chronology presented here indicates a middle Miocene age (14.3 Ma) for the lithological transition. Correlation to ODP Hole 747A from the Kerguelen Plateau suggests that this transition coincides with the base of the Mi-3/3a event, which suggests palaeoclimatic control on middle Miocene sedimentation changes at Site 1165. Core recovery was poor at Site 1166. Consequently, the magnetostratigraphic data are of limited value. The deepest cores recovered at Site 1166 record brief intervals in the history of the EAIS for the Prydz Bay region, extending back through the early stage of glaciation to pre-glacial times. An Early Cretaceous fluvio-lacustrine unit, lagoonal deposits and sandy fluvio-deltaic units of mid-late Eocene age contain a sporadic record of the transition from humid and mild conditions to cool temperate conditions.

PP12A-0327 1330h POSTER

850,000-Year Record of Sea-Level Fluctuations and Margin Evolution from Great Australian Bight, Site 1127, ODP Leg 182

Stefano M Bernasconi[1] (+41 1 632 3693; stefano@erdw.ethz.ch)

Miriam S Andres[1] (+41 1 632 3691; miriam@erdw.ethz.ch)

Judith A McKenzie[1] (+41 1 632 3828; sediment@erdw.ethz.ch)

[1]Geological Institute, ETH-Zentrum, Zurich 8092, Switzerland

The importance of the Southern Ocean within the global climate system has been shown in numerous Late Pleistocene studies. Yet, long and continuous marine records from the southern mid-to-high latitudes are sparse. Here, we present the 400-m long marine sediment record spanning the last 850,000 years, recovered at Site 1127, ODP Leg 182, during drilling on the Great Australian Bight (GAB). The GAB, a wide ramp-type shelf, directly facing the Southern Ocean, is the largest cool-water carbonate depositional environment on Earth today. At present, oceanography is influenced by the warm, oligotrophic water of the Leeuwin Current, which flows around the tip of southwest Australia, and by the cooler, nutrient-rich waters of the Southern Ocean entering the Bight from the east as the Flinders Current. One of the objectives of our study was to identify Pleistocene paleoceanographic changes on glacial-interglacial time scales at the northern boundary of the Southern Ocean and to study the response of a ramp-type margin to sea-level fluctuations. High sedimentation rates (average 45cm/kyr) and well-preserved foraminifera allow a high-resolution oxygen and carbon isotope stratigraphy and the development of a reliable age model. Variations in carbonate mineralogy, sand-fraction percentages and Natural Gamma Ray measurements reflect the response of the neritic shelf community to sea-level rise and fall. During the last 250 ka (MIS 1-6), bryzoan mound growth is prolific during nutrient-rich glacial conditions, but absent during warm Leeuwin Current-influenced interglacials. The less pronounced mid-Pleistocene glacial-interglacial fluctuations (MIS 7 to 21) are explained by a generally northerly position of the Subtropical Convergence Zone, which also prevents Leeuwin Current flow into the GAB region during interglacials. The Site 1127 record not only represents the longest continuous record of paleoceanographic change in the sparsely documented southern mid-latitude region but also it links open-ocean changes to cool-water carbonate sedimentation on a continental margin, demostration the viability of such environments for paleoceanographic studies.

PP12A-0328 1330h POSTER

Late Quaternary Palaeoceanography of the Falkland Trough, SW Atlantic: Evidence of Rapid Changes in Ocean Conditions

Claire S. Allen[1,2] (44-(0)1223-221422; c.allen@bas.ac.uk)

Jennifer Pike[2] (44-(0)29-2087-4830; PikeJ@cardiff.ac.uk)

Carol J. Pudsey[1] (44-(0)1223-221571; cjp@bas.ac.uk)

[1]British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom

[2]Dept. of Earth Sciences, Cardiff University, PO Box 914, Park Place, Cardiff CF10 3YE, United Kingdom

The Scotia Sea in the SW Atlantic exerts a disproportionately large effect on the water masses of the Southern Ocean. Water masses entrained in the Antarctic Circumpolar Current (ACC) follow a complex path across the Scotia Sea region and emerge, via the Falkland Trough, into the South Atlantic basin strongly modified by the mixing induced by local bathymetry. Core KC073 is from a sediment drift at the mouth of the Falkland Trough, under the path of the ACC, close to the southerly path of the Polar Front (PF) and immediately down stream of where North Atlantic Deep Water (NADW) is entrained into the ACC. The core site is ideally placed to record signals of variations in the flow regimes of the ACC and NADW within the SW Atlantic.

Core KC073 contains sediments from the last glacial maximum (LGM) to present dated using radiocarbon dating and radiolarian stratigraphy. Significant variations in the ocean environment are reflected in the high amplitude changes in the diatom concentrations and assemblage composition. Diatom assemblage data indicates that at the LGM, the site was covered by winter sea ice, subsequent retreat of sea ice extent during the deglaciation led to the establishment of permanently open ocean conditions by the beginning of the Holocene. An episode of lower productivity and higher meltwater flux at the end of the deglacial is broadly synchronous with the Antarctic Cold Reversal.

Variations in the numbers of *Chaetoceros* resting spores (CRS) dominate the changes in diatom concentration down core and reflect dramatic changes in productivity. The productivity signal is probably derived from the Falkland Plateau where Antarctic waters upwelling to the surface would provide a suitable environment for *Chaetoceros* blooms. Deeper water masses on the Falkland Plateau flow southwards into the Falkland Trough and transport sinking diatoms to the core site. It is proposed here that high frequency variations in the concentrations of CRS during the Holocene reflect either change in the productivity supported by the ACC or variability in the strength and position of NADW flow into the Falkland Trough.

PP12A-0329 1330h POSTER

A Significant Warming Event in the Southern Ocean During the Late Middle Eocene

Steven M. Bohaty[1] (831-459-5088; sbohaty@es.ucsc.edu)

James C. Zachos[1] (jzachos@es.ucsc.edu)

[1]University of California, Santa Cruz, Earth Sciences Department, Santa Cruz, CA 95064, United States

The late middle-to-late Eocene (∼45 to 34 Ma) is a critical period of Cenozoic climatic evolution, characterized by long-term cooling of deep waters and small-scale growth of ice sheets on Antarctica. This time interval, however, is poorly represented in deep-sea sediment archives, and high-resolution paleoceanographic records have not been developed for many of the sections that are available. Several Southern Ocean sites have adequate stratigraphic coverage through the middle-to-late Eocene and provide an opportunity to investigate regional paleoceanographic change through this time interval. In order to supplement the existing database, we have generated high-resolution stable isotope records from fine-fraction carbonates and foraminifera at Site 748, located on the southern Kerguelen Plateau.

Integration of middle-to-late Eocene oxygen isotope records from Sites 748 and 738 (Kerguelen Plateau) and Site 689 (Maud Rise) reveals a prominent, short-term warming event at ∼41.5 Ma, designated as the Middle Eocene Climatic Optimum (MECO). At Site 748, both surface-dwelling (*Acarinina* spp.) and benthic (*Cibicidoides* spp.) exhibit two $\delta^{18}O$ minima, indicating that this event is characterized by two brief intervals of peak warming in both surface and deep waters. Benthic foraminiferal $\delta^{18}O$ data further indicate that middle-bathyal waters warmed $\sim 4^{o}C$ on both the Kerguelen Plateau and Maud Rise during the MECO. Accordingly, this transient event (<500 k.y. in duration) is interpreted to represent a significant climatic reversal in the long-term middle-to-late Eocene cooling trend in the Southern Ocean.

If global in nature, the MECO would represent one of the more rapid global warming events of the Cenozoic. The lack of a significant negative carbon isotope excursion, as observed during the Paleocene-Eocene Thermal Maximum, suggests that this event was not triggered by methane dissociation. Instead, the MECO may possibly be linked to increased pCO_2 associated with the Chron C20-19 plate reorganization. Possible sources of CO_2 during this period of global tectonic change are metamorphic decarbonation in the Himalayan orogen and inter-plate volcanism.

PP12A-0330 1330h POSTER

Foraminiferal Zn/Ca: New Insights as to Glacial-Interglacial Changes in North Atlantic Deep Water Fluxes to the Southern Ocean

Rachael H James[1] (+44 1908 654296; R.H.James@open.ac.uk)

William Austin[2] (bill.austin@st-andrews.ac.uk)

Nick W Rogers[1] (N.W.Rogers@open.ac.uk)

[1]Dept. of Earth Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, United Kingdom

[2]School of Geography and Geosciences, University of St Andrews, Fife KY16 9AL, United Kingdom

The subantarctic section of the Southern Ocean is particularly suited to monitoring fluctuations in the global influence of North Atlantic Deep Water (NADW), but proxy data for past NADW fluxes into this region taken from sediment cores have yielded conflicting information. Variations in benthic foraminiferal $\delta^{13}C$ and Nd isotope ratios in the Fe-Mn oxide component of sediments support the idea of a weakening or shutdown of NADW production during glacial times, whereas other proxies, such as Cd/Ca, Ba/Ca and $^{231}Pa/^{230}Th$ ratios, show little change from the Last Glacial Maximum (LGM) to the Holocene epoch.

Because of the potential importance of deep water circulation for global climate change, it is imperative to find new tracers for reconstructing changes in water mass composition. One such tracer is Zn. Firstly, there is a particularly large (∼sevenfold) increase in Zn between the deep North Atlantic and the deep South Atlantic, so Zn will be a sensitive tracer of the glacial-interglacial interactions between NADW and southern source deep waters such as Circumpolar Deep Water (CPDW). Secondly, Zn is associated with the refractory parts of planktonic material produced in surface waters, so the Zn concentration of deep waters will be less sensitive to changes in surface productivity than other proxy data (Cd and $\delta^{13}C$). Finally, because Zn has a long residence time in the oceans (a few thousand to tens of thousand years) relative to the estimated residence time of CPDW (∼120 years), then bottom water Zn concentrations respond to changes in NADW fluxes on a sub-millenial timescale.

In order to test this idea, we have measured the glacial-interglacial variation of Zn/Ca (and also Mg/Ca, Sr/Ca and Cd/Ca) in benthic foraminifera recovered from the subantarctic Southern Ocean (ODP Site 1089). Preliminary results obtained to date suggest that Zn/Ca is lower during interglacials and this is thought to reflect stronger influence of NADW (with low Zn) at this site. In contrast, the corresponding Cd/Ca data show little change.

PP12A-0331 1330h POSTER

Middle Miocene Paleoceanography in the Southern High-Latitudes Off Tasmania: Stable Isotope Records from ODP Sites 1170 and 1172

Atsuhito Ennyu[1] (814-865-7819; aennyu@geosc.psu.edu)

Michael A Arthur[1] (814-863-6054; arthur@geosc.psu.edu)

[1]Department of Geosciences, The Pennsylvania State University, 437 Deike Building, University Park, PA 16802

The middle Miocene encompasses one of the major steps in a global cooling trend towards the permanent establishment of east Antarctica ice sheet (EAIS), as inferred from the worldwide ca. $1^{o}/_{oo}$increase in benthic foraminiferal $\delta^{18}O$. It has been suggested that an intensified Antarctic Circumpolar Current (ACC) prompted the mid-Miocene cooling, thereby increasing the meridional thermal gradient in the southern high-latitudes, and, ultimately, accumulation of the EAIS. At the same time, the southwest Pacific sector is thought to have ameliorated regionally through the incursion of a warm western boundary current, i.e., the proto-East Australian Current (EAC). In order to test the potentially contrasting effects of the EAC and ACC on evolution of the meridional thermal gradient in the southern high-latitudes across the middle Miocene climate transition, we have reconstructed near-surface paleohydrography by measuring $\delta^{18}O$ and $\delta^{13}C$ of planktic foraminifer *Globigerina bulloides* and *Orbulina universa* and bulk fine-fraction carbonates from ODP Sites 1170 (South Tasman Rise; Indian Ocean sector) and 1172 (East Tasman Plateau; Pacific sector) off Tasmania for the interval 8-20 Ma.

Our results show no significant differences in the $\delta^{18}O$ values between Sites 1170 and 1172. This suggests that the both sites were influenced by the same water mass in the middle Miocene. Long-term trends in the fine-fraction $\delta^{18}O$ from the both sites indicate a

signal of the early middle Miocene "climatic optimum" (MMCO) and the subsequent EAIS positive δ^{18}O shift, and are similar to those reported from other lower latitude sites. In contrast, the planktic foraminiferal δ^{18}O records from Sites 1170 and 1172 do not exhibit significant long-term trends, with values ranging from ca. 0.6 to 1.6$^{o}/_{oo}$. This implies that near-surface seawater temperatures at Sites 1170 and 1172 increased across the middle Miocene EAIS event (after ca. 14.5 Ma), as assuming that the mid-Miocene increase in the benthic foraminiferal δ^{18}O reflects the global ^{18}O budget due to accumulation of continental ice. We suggest that Sites 1170 and 1172 were in the north of ACC, and these sites were warmed by intensified EAC during the mid-Miocene EAIS event.

PP12A-0332 1330h POSTER

Timing and Nature of the Opening of the Tasmanian Gateway at the Eocene-Oligocene transition: ODP Site 1172

A. Sluijs[1]; H. Brinkhuis[1]; S. A. Schellenberg[2]; C. E. Stickley[3] (ces@ldeo.columbia.edu); M. Fuller[4]; M. Grauert[5]; U. Röhl[6]; J. Warnaar[1]; G. L. Williams[7]

[1]Laboratory of Palaeobotany and Palynology, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, Netherlands

[2]Department of Geological Sciences, San Diego State University, 5500 Campanile Drive, San Diego, CA 92182, United States

[3]Lamont-Doherty Earth Observatory, Paleomagnetics Building, 61 Route 9W, Palisades, NY 10964, United States

[4]HIGP-SOEST, University of Hawaii, Honolulu, HI 96822, United States

[5]Geografisk Institut, Kbenhavns Universitet, ster Voldgade 10, 1350 Kbenhavn, Denmark

[6]Department of Geosciences, Bremen University, P.O. Box 33 04 40, 28334 Bremen, Germany

[7]Atlantic Geoscience Centre, PO Box 1006, Dartmouth, NS B2Y 4A2, Canada

In the late Paleogene, Australia finally separated from Antarctica and continued to drift northwards allowing the eventual development of the Antarctic Circumpolar Current. The exact timing and nature of the opening of this gateway during its final acceleration across the Eocene-Oligocene boundary (33.5 Ma), remains a high point of interest particularly in relation to its apparent synchroneity with climate deterioration on continental Antarctica.

The recovery of a quasi-continuous marine sedimentary record across the E/O transition at four sites within the Tasmanian Seaway during ODP Leg 189, allows detailed palaeoenvironmental changes to be documented at high-resolution for the first time in this region. The critical sedimentary units are barren of calcareous microfossils; yet siliceous- and organic-walled microfossils (notably diatoms and dinoflagellate cysts) are extremely abundant and excellently preserved, affording an opportunity for an integrated and detailed palaeoenvironmental analysis of the E/O transition. We present results on the timing and nature of several step-wise deepening events and palaeoceanographic changes leading up to, during and just after the E/O transition at Site 1172 (East Tasman Plateau) assimilating diatom and dinocyst analyses with geochemical, lithological, and physical property data. A robust chronology is determined from a combined diatom-dinocyst biostratigraphy and magnetostratigraphy.

This combined approach is proving a key to understanding the separation of Australia and Antarctica and how this dramatic tectonic event may have played a role in global climate change.

PP12A-0333 1330h POSTER

Carbon isotopes of live benthic foraminifera from the South Atlantic Ocean: sensitivity to organic matter rain rates and bottom water carbonate saturation state

Andreas Mackensen[1] (amackensen@awi-bremerhaven.de)

Laetitia Licari[1] (llicari@awi-bremerhaven.de)

[1]Alfred Wegener Institute, Columbusst., Bremerhaven 27515, Germany

Live benthic foraminifera of surface and sub-surface sediments from 25 stations in the eastern South Atlantic Ocean and the Atlantic sector of the Southern Ocean are analyzed to decipher a potential influence of seasonally and spatially varying high primary productivity on the stable carbon isotopic composition of foraminiferal tests. Stations were chosen such that productivity strongly varies whereas conservative water mass properties change only little. Intraspecific δ^{13}C variability of all species at a single site is constantly low throughout their distribution within the sediments, i.e. species specific and site dependent mean values calculated from all subbottom depths on average only vary by 0.09 ‰. Vital and/or microhabitat effects were further quantified: (1) δ^{13}C values of endobenthic species consistently are by between -1.5 and -1.0 ‰ VPDB more depleted than δ^{13}C values of preferentially epibenthic species. (2) on the African continental slope *Fontbotia wuellerstorfi* at all stations except one, records bottom water $\delta^{13}C_{DIC}$ values without significant offset, whereas closely related species deviate from bottom water values by between -0.4 and -0.6‰. The large offset of -1.5 ‰ between bottom water $\delta^{13}C_{DIC}$ and δ^{13}C values of infaunal living *B. aculeata* at one station in contrast to eight stations with -0.6±0.1 ‰ directly reflects locally increased organic matter fluxes. Offsets between deep infaunal *G. affinis* and *F. wuellerstorfi* as well as between shallow infaunal *U. peregrina* and *F. wuellerstorfi* δ^{13}C values tend to increase with generally increasing organic matter decomposition rates. Furthermore, the data suggests that in high productivity areas where sedimentary carbonate contents are lower than 15 weight %, epi- and endobenthic foraminiferal δ^{13}C values are strongly enriched probably due to carbonate ion undersaturation, whereas above this sedimentary carbonate threshold endobenthic δ^{13}C values reflect the depleted pore water $\delta^{13}C_{DIC}$.

PP12A-0334 1330h POSTER

Does the Larson Ice Shelf Play a Role in Directing Iceberg Traffic Into the Southern Ocean?

LLoyd H. Burckle[1] ((845) 365-8406; burckle@LDEO.columbia.edu)

James D. Hays[1] ((845) 365-8403; jimhays@LDEO.columbia.edu)

Aldo Shemesh[2] (Aldo.Shemesh@weizmann.ac.il)

[1]Lamont-Doherty Earth Observatory of Columbia University, Route 9W, Palisades, NY 10964, United States

[2]Department of Environmental Sciences and Energy Research , Weizmann Institute of Science, Rehovot 76100, Israel

We speculate that fluctuations in the areal extent of the Larson Ice Shelf (LIS) played a role in steering icebergs into the Atlantic and Indian sectors of the Southern Ocean. At present, most icebergs forming in the Weddell Sea float westward along the coast to the Antarctic Peninsula and the LIS where they are directed northward into the Southern Ocean. During interglacials the LIS retreated westward and northward and icebergs were steered into the western Atlantic sector. During glacials, the LIS expanded southward and eastward, steering icebergs farther to the east. This scenario is suggested by two lines of evidence; oxygen isotope composition of marine diatoms and ice-rafted detritus (IRD) in cores containing a Last Glacial Maximum (LGM) record. Diatoms from cores in the western Weddell are enriched in 18O during the LGM while diatoms in sediment cores to the east show 16O enrichment during this period suggesting that the ice shelf had extended eastward and icebergs were steered in that direction. This is clearly a meltwater signal suggestive of a low salinity lid. Although melting sea ice changes the salinity of the water very little, icebergs play a larger role and are focussed in space. Further, enrichment in 16O in late Holocene sediments indicates continuing retreat of the ice shelves along the east side of the Antarctic Peninsula. During glacials, the expanded ice shelves and sea ice cover in the Southwestern part of the Weddell Sea means that this region would not be contributing IRD to the Southern Ocean sediments (i.e. icebergs would not be formed in this region because it would be ice locked).

PP12A-0335 1330h POSTER

A High-Resolution Record of Early Miocene Antarctic Glacial History From Downhole Logs, Site 1165, ODP Leg 188

Trevor Williams[1] (845 365 8626; trevor@ldeo.columbia.edu)

Sam Barr[2] (+44 116 252 3608; srb7@leicester.ac.uk)

David Handwerger[3] (801 585 5328; dahandwe@mines.utah)

[1]Lamont-Doherty Earth Observatory, 61 Route 9W, Palisades, NY 10964, United States

[2]University of Leicester, University Road, Leicester LE1 7RH, United Kingdom

[3]University of Utah, 1460 East 135 South, Salt Lake City, UT 84105, United States

ODP Site 1165, located 400 km NW of Prydz Bay, contains the most detailed record yet obtained of Early Miocene Antarctic glacial history. The 520-m-thick Early Miocene consists of dark grey claystone with silt laminae (contourites) alternating with decimeter-scale layers of greenish-grey bioturbated claystone that contain common ice rafted debris (IRD). These sediments are interpreted to record pulses of IRD from the continent, and alternations in the position or strength of the currents at the site. Downhole logs of electrical resistivity, natural gamma radiation, and density also record the alternations between the two facies.

Here we assess the lithological significance of the logs by examining the opal, IRD, and susceptibility of two short intervals at high resolution, with samples taken every 10 cm, or about 1250 yr. The IRD-bearing greenish-grey claystone corresponds to higher resistivity and density because of increased cementation by silica, and corresponds to lower natural gamma radiation because of decreased clay content. Thus, using the logs, lithology can be inferred for intervals where no core was recovered.

Based mainly on magnetostratigraphy, the age of the base of the hole is 22 Ma, and the sedimentation rate for the Early Miocene about 9 cm/kyr. The regular spacing of the facies alternations in the logs suggests they are astronomically paced. Between 18-20 Ma, the main periodicity is in the precessional range, and between 20-22 Ma, the logs have a saw-toothed form, with a major peak in IRD at the beginning of each, repeating about every 100 kyr. We think that the IRD pulses represent deglaciations. Hence our data suggest that the Antarctic continent, at least around the Prydz Bay region, was glaciated in the Early Miocene, and that the size of the ice sheet oscillated on Milankovitch time scales.

PP12A-0336 1330h POSTER

Southeast Atlantic Sea-Surface Temperatures During the Last Full Glacial Cycle

Maria C Schriver[1] (schriver@mit.edu)

Julian P Sachs[1] (jsachs@mit.edu)

[1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room E34-254, Cambridge, MA 02139, United States

Sea-surface temperatures (SSTs) were determined in Cape Basin core TN057-6-PC4 (42°55'S, 8°54'E, 3751 m) over the last glacial cycle using the alkenone paleotemperature technique. Sedimentation rates at the site averaged approximately 3 cm/kyr. SSTs at the top of the core, which is dated at about 9 ka, are 11.2 deg C, similar to mean annual atlas temperatures above the site at 0 m water depth. Maximum SSTs of 16.5 deg C were reached in MIS 5e, while minimum temperatures of 6 deg C occurred during MIS 3.

Two of the most prominent and surprising features of the record are (1) a 6 degree warming trend between approximately 55 and 28 ka, and (2) last interglacial SSTs that were 5 degrees higher than early Holocene temperatures. Neither of these two features is evident in global oxygen isotope records. However, they are observed in alkenone paleotemperature records from nearby drift sites in the Cape Basin. Indeed, the alkenone paleotemperature records from the drift (TN057-21 and ODP 1089) and non-drift (TN057-6) sites are remarkably similar during the last 130 kyr, providing support for the fidelity of alkenone paleotemperature reconstructions in the Cape Basin.

Close co-variation is observed betweeen the Cape Basin SST records and the record of deuterium excess in the Vostok (Antarctica) ice core. The latter is believed to represent the temperature history of the moisture source for Vostok snow, the middle latitudes of the Indian and Pacific Oceans. The climate forcing for changes in deuterium excess has been attributed to obliquity (Vimeux et al., Nature, 398:410, 1999). Covariation between Cape Basin SSTs and Vostok deuterium excess may imply that southern mid-latitude SSTs changed in concert, perhaps forced by obliquity, or that a common forcing influenced the proxy records through different mechanisms.

PP12A-0337 1330h POSTER

Late Quaternary Paleoceanographic And Paleoclimatic Changes in the Tasmanian Seaway (ODP Leg 189)

Dirk Nuernberg[1] (++49-431-600-2313; dnuernberg@geomar.de)

Natasja Brughmans[1] (++49-431-600-2314; nbrughmans@geomar.de)

Joachim Schoenfeld[2] (++49-431-600-2315; jschoenfeld@geomar.de)

Ulysses Ninnemann[3] (++47-55583577)

[1]Geomar, Wischhofstrasse 1-3, Kiel D-24148, Germany

P
P

[2]Tethys-Geoconsulting GmbH, Wischhofstrasse 1-3, Kiel D-24148, Germany

[3]Department of Geology, University of Bergen, Allegatan 41, Bergen N-5007, Norway

The Tasmanian Gateway, focussed on during ODP-Leg 189, is an oceanographic key area within the Southern Ocean (Power-House-Ocean). Our investigations focus on the last approximately 500.000 years of sedimentation at sites 1168 (western Tasmania margin), 1170 and 1171 (Tasman Rise), and 1172 (East Tasman Plateau). We established age models for sites 1168, 1170, and 1172 by applying benthic oxygen isotope stratigraphy. The stratigraphy of site 1171 was established by correlating the high resolution reflectivity record to the other cores. Inferred sedimentation rates are around 1-4 cm/kyr during most of the time.

Nannofossil oozes with an important foraminiferal component dominate the sedimentation. Carbonate concentrations range from 70-98%, with lowest concentrations at sites close to Tasmania. The temporal variability of the carbonate sand fraction indicative of changes in carbonate preservation/dissolution shows clear differences east and west of Tasmania, pointing to temporal and spatial changes in lysocline depths at the interface between Pacific and Indian oceans.

The flux of terrigenous matter (indicated by magnetic susceptibility, concentrations of siliciclastics, aluminum, iron and titanium concentrations) is very low, but regionally different. Close to Tasmania, the supply of terrigenous material is highest. Eolian transport apparently serves as the prime source for terrigenous matter, since i) Fe/Al ratios of 0.3 are close to dust values, ii) iron, titanium and aluminum accumulation rates match the Vostok dust record, and iii) the glacial/interglacial magnitudes of iron accumulation rates in the sediment records correspond to eolian iron fluxes.

Marine productivity (assessed from calcium carbonate, biogenic barium, and chlorins) is reflecting the glacial/interglacial change in the strength of the subtropical East Australian Current. During glacials, the waning influence of the oligotrophic East Australian Current allows the intrusion of nutrient-rich subantarctic waters, and thus the northward propagation of the Subtropical Convergence.

PP12A-0338 1330h POSTER

A Million Year Record of Sub-decadal Climate Variability: Southern Ocean Cores and Sediment Traps

Ivo Grigorov[1] (+44 2380 596478; ivo_grigorov@hotmail.com)

Richard Pearce[1]

Alan Kemp[1]

Susumu Honjo[2]

Jean Dean

[1]Southampton Oceanography Center, Empress Dock, Southampton SO14 3ZH, United Kingdom

[2]Woods Hole Oceanographic Institution, Woods Hole, Woods Hole, MA 02543, United States

The Southern Ocean is a centerpiece in global biogeochemical cycles and ocean circulation. Recent drilling in the Atlantic Sector (ODP Leg 177, Shipboard Scientific Party, 1999) has recovered laminated diatom ooze sediments, spanning intermittently throughout the last 2.8 Mya which potentially record a seasonal surface water productivity signal. Although the mechanisms of formation of laminated sediments in the open ocean is not fully understood, they are thought to be associated with the seasonal productivity of the Polar Front. On time scales of 105 yrs, the stratigraphy of these deposits can track frontal migrations through time.

The proposed annual layering of Southern Ocean sediments in the vicinity of the Polar Front was tested using an array of sediment traps (JGOFS/AESOPS - Antarctic Environment and Southern Ocean Process Study), deployed in the Indian Sector along 170oW. These are complimented by fluff layer and top 0.5 mm sediment surface samples.

Results show that the expression of seasonality is similar in both sediment and water column thus supporting annual laminations of Southern Ocean sediments. The resulting sedimentation rates are between 55 cm kyr-1 for MIS 11/12, and 80 cm kyr-1 for MIS 29. In addition, time-series analysis of 900 kyr old laminates shows cyclicities identical to the Quasi-Bienniel Oscillation (QBO), El Nino-Southern Oscillation (ENSO) and the Antarctic Circumpolar Wave (ACW), all known to affect surface hydrography and primary production in the vicinity of the Polar Front.

PP12A-0339 1330h POSTER

A Revised Chronology for the Late Miocene Carbon Isotope Shift (ODP Site 1172B): A Stable Isotopic and Sedimentologic Investigation

Rebecca A Tedford[1] (608-262-1698; rtedford@geology.wisc.edu)

Daniel Clay Kelly[1] (608-262-1698; ckelly@geology.wisc.edu)

[1]Department of Geology and Geophysics, 1215 West Dayton Street University of Wisconsin- Madison, Madison, WI 53706, United States

The late Miocene is punctuated by a gradual, yet permanent shift in the $\delta^{13}C$ compositions of terrestrial and marine materials, signifying a fundamental change in the global cycling of carbon. A relatively complete Late Neogene section (Site 1172B; 44° 57.57 S, 149° 55.70 E) was recovered by ODP Leg 189 from atop the East Tasman Plateau (water depth ~2630 m). The excellent magnetobiochronology for this site provides an exceptional opportunity to investigate the timing of this isotopic shift, and related sedimentological and microbiotic responses. Stable isotope records generated from size-specific specimens of planktonic (*Globigerina bulloides*, surface water; *Globoconella* clade, thermocline) and benthic (*Planulina wuellerstorfi* and *Cibicidoides* sp.) foraminiferal species show a gradual $\delta^{13}C$ decrease of $\sim 0.7\ ^{o}/_{oo}$. The onset of the $\delta^{13}C$ decrease coincides with the onset of Chron 3Br.1n indicating an age of 7.17 Ma, roughly 970 k.y. older than previous estimates. Prior to the long-term $\delta^{13}C$ shift, foraminiferal isotope records display a transient $\delta^{13}C$ increase accompanied by intensified carbonate dissolution. Parallel changes are also seen in planktonic foraminiferal assemblages, most notably a decline in the relative abundances of *G. bulloides* and *Orbulina universa*, which we attribute to species-specific dissolution. Thus, the lower portion of the carbon isotope shift is condensed, though the overall stratigraphic section is relatively complete. A curious aftereffect of the late Miocene $\delta^{13}C$ shift is that surface-to-bottom $\delta^{13}C$ gradients collapse, while thermocline-to-bottom $\delta^{13}C$ gradients increase. Convergence of surface-water $\delta^{13}C$ values onto benthic values may reflect a vital effect in *G. bulloides* driven by increased ocean alkalinity (i.e. carbonate ion effect). These patterns of $\delta^{13}C$ convergence may reflect a drawdown of atmospheric CO_2. A number of mechanisms have been proposed for the cause of the marine carbon isotope shift (e.g., changes in ocean circulation, eustatic sea level fall). However, little to no variation is displayed in the oxygen isotopic records to indicate a substantial growth of the Antarctic ice sheet. The revised age (~7.1 Ma) for the carbon isotope shift at Site 1172B is more permissive for our hypothesis that the $\delta^{13}C$ decrease in the marine record may be a reciprocal change to a $\delta^{13}C$ increase in the isotopic composition of the terrestrial reservoir of the carbon cycle (i.e. expansion of C4 grasses).

PP12A-0340 1330h POSTER

Plio-Pleistocene sediment geochemistry on the South Tasman Rise: Changes in export production or a dirty story from the deep?

Jennifer C Latimer[1,2] ((317) 274-7484; jclatime@iupui.edu)

Gabriel M Filippelli[2] ((317) 274-7484; gfillippe@iupui.edu)

[1]Indiana University, Department of Geological Sciences, Bloomington, IN 47405, United States

[2]Indiana/Purdue University at Indianapolis, Geology Department, Indianapolis, IN 46202, United States

ODP Site 1171 is located in subantarctic waters on the south Tasman Rise at a water depth of 2150 m. Based on preliminary shipboard data, the site has experienced nearly continuous and constant sedimentation from the early Pliocene to present, with sedimentation rates averaging 1.3 cm/kyr (Exon et al., 2001). Furthermore, carbonate-content averages >90 wt % and sediments are characterized as either nannofossil ooze or chalk. Despite nearly constant carbonate content, significant variability exists in the bulk geochemistry from this site.

We sampled at 5 cm resolution (4 kyr) through the Pliocene in order to investigate changes in cyclicity observed in bulk sediment geochemical records in three time windows: 1.9-2.2 Ma (41k world), 0.9-1.2 Ma (transition time), and 0.4-0.7 Ma (100k world). Elements analyzed include terrigenous metals, such as Fe, Al, and Ti and elements associated with nutrients and/or productivity, such as P and Ba. The proxies P/Ti and Ba/Ti can be indicators of export production, with maxima in these proxies suggesting increases in export production (Ti normalization provides an indication of the excess biogenic fraction). Distinct peaks are observed in the export production proxies despite a nearly constant flux of biogenic material to the seafloor. Maxima in P/Ti and Ba/Ti correspond to minima in terrigenous accumulation, perhaps indicating that in this setting the ratios are dominated by periodic input of terrigenous material (the dirty little story of the deep). Thus, the biogenic records likely record changes in the input of hemipelagic material at this site and may provide insight into the strength of hemipelagic loading of the Antarctic Circumpolar Current.

PP12A-0341 1330h POSTER

Nutrient Cycling and Carbon Burial in the Southern Ocean During the Oligocene and Early Miocene

Gabriel Filippelli[1] (gfilippe@iupui.edu); Jennifer Latimer[1]; Sharon Kanfoush[2]; David Hodell[2]; Katharina Billups[3]; Jose Abel Flores[4]; Francisco Javier Sierro[4]

[1]Indiana Univ.-Purdue Univ. Indianapolis, Dept. of Geology 723 W. Michigan St., Indianapolis, IN 46202-5132, United States

[2]Univ. Florida, Dept. of Geology, Gainesville, FL 32611

[3]Univ. Delaware, College of Marine Studies, Lewes, DE 19958

[4]Univ. Salamanca, Dept. of Geology, Salamanca 37008, Spain

Several aspects of mid-Cenozoic paleoceanography are poorly constrained, particularly in the southern hemisphere. This is a key component of Cenozoic climate history, given the onset of Antarctic glaciation and the initiation and development of the Antarctic Circumpolar Current. One important aspect is constraining the interplay between nutrient cycling, surface water productivity, and biogenic sedimentation in the Southern Ocean.

Here we present sedimentologic and nutrient histories from ODP Site 1090 (43*S in the south Atlantic) from the early Oligocene through the middle Miocene (31-17.5 Ma). These records indicate a positive correlation between carbon isotopic composition of deep water (a proxy of organic versus inorganic carbon burial and carbon inputs) and P/Ti ratio of the sediment (a proxy of export production). For example, the Oligocene is marked by a steady increase in carbon isotope values from 0.5 per mil to 1.6 per mil that persists to the earliest Miocene (24 Ma), with one interval of lighter values from 26-24 Ma. The early Miocene displays heavy values from 24-23 Ma, followed by a return to lighter values (0.7 per mil) to 17.5 Ma. One interpretation of this trend is an increase in organic carbon burial up to 23 Ma, followed by a decrease. The increase in P/Ti observed at Site 1090 up to 23 Ma supports the hypothesis of increased carbon burial, perhaps driven by an increased supply of nutrients to the surface ocean. To drive the whole-ocean response observed in the carbon isotopic trends requires a whole-ocean increase in the flux of nutrients provided from land, however, and whether Site 1090 reflects that is an open question. The trend toward lighter carbon isotope values and lower P/Ti from 23-17.5 Ma may be explained by lower nutrient supplies and lower organic carbon burial. Intriguingly, however, the opal content, an indicator of silica production and somewhat related to nutrient flux to surface waters, exhibits a negative correlation with carbon isotopes and P/Ti. This may be related to decoupling between silica and phosphorus cycles or ecological shifts, and will be pursued further.

PP12A-0342 1330h POSTER

Yo-yo-ing of the Subtropical Convergence in Sympathy with the Vostok Climatic Record, 0-0.38 Ma: ODP Site 1119, Southwest Pacific Ocean

Robert M. Carter[1] (+61-747-814-397; bob.carter@jcu.edu.au)

Paul Gammon[2] (+61-8-8303-4042; paul.gammon@adelaide.edu.au)

Lynn Millwood[3] (lynn8510@omega.uta.edu)

[1]Marine Geophysical Laboratory, James Cook University, Townsville, Qld 4811, Australia

[2]Department of Geology, University of Adelaide, Adelaide, SA 5005, Australia

[3]Department of Geology, University of Texas, Arlington, TX 82114, United States

ODP site 1119 is located at water depth 395 m near the subtropical convergence, and just downslope from the shelf edge of eastern South Island, New Zealand. The site contains an expanded stratigraphic record of Southern Ocean Quaternary oceanographic change, the younger part of which correlates closely with the climatic history contained within the Vostok ice core.

Four palaeoceanographic proxy measures vary in consonance with the main lithological glacial-interglacial cyclicity at the site. Interglacial intervals are characterised by high d13C and colour reflectance (a proxy for carbonate content), and low gamma-ray (a proxy for clay content) and d18O; conversely, glacial intervals exhibit low d13C and reflectance, and high gamma ray and d18O. Early interglacial intervals are represented by silty clays which enclose intervals of 10-65 cm thick, sharp-based, Chondrites-burrowed, shelly, graded, very fine sands. The sands are rich in foraminifers, including species of warm water affinities, and were deposited distant from the shoreline under the influence of longitudinal flow in relatively deep water, as the palaeo-STC passed shorewards across the upper slope. The enclosing glacial units, which comprise mostly micaceous silty clay, though with some thin (3-25 cm thick) sands present also at peak cold periods, contain the cold-water scallop Zygochlamys delicatula.

The 1119 core records the seaward movement of the STC during glacial periods, accompanied by the incursion then of warmer subtropical water (STW) above the site, and landward movement during interglacials, resulting in a dominant influence then of colder subantarctic surface water (SAW). Intervals of thin, sharp-based, graded sands-muds occur within cold periods MIS 2-3, 6.2 and 7.4, and indicate the onset at times of peak cold of intermittent bottom currents which correspond to strengthened and expanded frontal flows along the STC, which at this time lay east of site 1119 in relatively close proximity to seaward-encroaching subantarctic waters within the Bounty gyre.

PP12B MCC: 270 Monday 1330h

Understanding Pre-Quaternary Climate Using Models and Data *(joint with A, OS, GC)*

Presiding: **R T Pierrehumbert,** University of Chicago

PP12B-01 1330h

Feedback of atmospheric chemistry, via CH4, on the Eocene climate

David Beerling[1] (+44-114-222-4359; d.j.beerling@sheffield.ac.uk)

Paul Valdes[2] (p.j.valdes@reading.ac.uk)

[1]Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, United Kingdom

[2]Department of Meteorology, University of Reading, Reading RG6 6BB, United Kingdom

Atmospheric CH4 is a potent greenhouse gas, but it lacks a geochemical or paleobiological proxy for the pre-Quaternary. So the concentrations of CH4 prescribed in Mesozoic and early Tertiary paleoclimate modelling studies have tended to depend on simple approximations and assumptions. To move towards more realistic attempts at setting the global CH4 levels in paleoclimate models, we developed a new process-orientated approach to defining them. Our approach is based on modelling terrestrial ecosystem distributions and productivity, and the emissions of trace gases, particularly the volatile organic carbon (VOCs) compounds isoprene and monoterpene, for a given paleoclimate. The effects of the trace gas emissions on the chemistry of the atmosphere are assessed using a three-dimensional atmospheric chemical transport model coupled to the UK Meterological office (UKMO) ocean-atmosphere general circulation model of global climate. Results for simulations in the early Eocene indicate atmospheric CH4 concentrations in excess of 3000ppb, with VOC and climate reaction feedbacks being especially important. The feedback of this level of CH4 on climate in the early Eocene was assessed in separate sensitivity experiments with the UKMO GCM. The results indicate strong seasonal warming (up to 5oC), particularly of continental interiors in the Northern hemisphere during the winter months.

PP12B-02 1345h

Paleoceanography in Northwest Pacific during Early Albian: Global Carbon Cycle and the Related Ocean Environments

Mitsuru Yamamura[1] (+81-298-61-3765; m.yamamura@aist.go.jp)

Hodaka Kawahata[1,2] (+81-298-61-3765; h.kawahata@aist.go.jp)

Reishi Takashima[3] (+81-92-726-4764; takagse@mbox.nc.kyushu-u.ac.jp)

Hiroshi Nishi[3] (+81-92-726-4643; hnishi@rc.kyushu-u.ac.jp)

[1]Graduate School of Science, Tohoku University, Aoba, Sendai 980-8578, Japan

[2]National Institute of Advanced Industrial Science and Technology, 1-1-1 Higashi, Tsukuba 305-8567, Japan

[3]Department of Earth Science, Kyushu University, 4-2-1 Ropponmatsu, Fukuoka 810-8560, Japan

The major components (organic carbon and carbonate) and inorganic elements are analyzed in the sediments from the Okusakainosawa and Chirashinaigawa sections in the middle to north Hokkaido, Japan. It is estimated that the Yezo basin was located on a continental slope at the middle latitude of the northwest Pacific from late Aptian to early Albian. Total organic carbon contents vary from 0.30 to 1.12 wt. %, averaging 0.79 wt. % in the Okusakainosawa section, and from 0.32 to 0.95 wt. % in the samples of the Chirashinaigawa section. The black shale is not recognized at the studied area. The mean $C_{organic}/N$ atomic ratios of samples reveal about 20, which shows that most of the organic matter was terrigenous in origin at the Okusakainosawa section, while the organic matter is a mixture of marine and terrestrial organic carbon in the Chirashinaigawa section. Namely, terrestrial organic matter had been a main contributor in both sections and labile organic matter, which could reduce dissolved oxygen content very little in the bottom water, hardly deposited during early Albian. On the other hand, both sections are characterized by very low occurrence of carbonate due to dissolution through the water column and/or on the seafloor. As the cause of low content of marine organic carbon in both sections, the primary records of carbonate preservation were affected by seawater chemistry rather than by local rain of organic matter. Based upon the organic carbon content at the Tethys, the severe dissolution of carbonate is attributed to the degraded intermediate and deep seawater rather than the released carbon dioxide by the local rain. Hence, there is some possibility that the intermediate-deep water at the northwest Pacific Ocean was one of the oldest during mid Cretaceous. Nevertheless the dissolved oxygen in the bottom water had not been completely consumed during early Albian from the behavior of Mn in the sediment. In contrast, dissolved oxygen is completely consumed in the northwest Atlantic although all carbonate is well preserved. If any possibility is adopted, big differences exist between the north Pacific and Atlantic during early Albian. Actually, the organic rich strata were only deposited at the limited area in the Pacific as compared with the Atlantic. It is suggested that the Pacific seldom experienced the reduced conditions spatially and/or temporally in contrast to the Tethys Sea. These observations point out one possibility that the Pacific and Atlantic had each original chemical composition of intermediate and deep water and different conveyor belt thermohaline circulation may exist at least during early Albian.

PP12B-03 1400h

Ice Sheet Stability during the Late Ordovician: Obliquity Forcing with 8-12x Pre-industrial Levels of Atmospheric pCO_2

Achim D. Herrmann[1] (8148656716; achim@geosc.psu.edu)

Mark E. Patzkowsky[1] (brachio@geosc.psu.edu)

David Pollard[2] (pollard@essc.psu.edu)

[1]Department of Geosciences and NASA Astrobiology Institute, The Pennsylvania State University, University Park, PA 16802, United States

[2]EMS Environment Institute, The Pennsylvania State University, University Park, PA 16802, United States

Coupled ice sheet and atmospheric general circulation model results show that the formation and persistence of ice sheets during the Late Ordovician were sensitive to atmospheric pCO_2 levels and orbital forcing at the obliquity timescale (30 to 40 k.y.). Without orbital forcing, ice sheets develop with pCO_2 levels as high as 10x PAL. However, with orbital forcing permanent ice sheets that survive warm summer orbits develop only with atmospheric pCO_2 levels of 8x PAL. The ice sheet model results further indicate that during exceptionally long periods of low summer insolation and low atmospheric pCO_2 (8-10x PAL), large ice sheets could have formed that were able to persist under subsequently higher pCO_2 values. If atmospheric pCO_2 is a main driver for the timing of the Late Ordovician glaciation, our results have implications for the pCO_2 levels necessary to begin and end the Late Ordovician glaciation. In order to initiate growth of a permanent ice sheet in the Late Ordovician, atmospheric pCO_2 must have fallen to at least 8x PAL. Thus, the pCO_2 threshold for the initiation of glaciation in the Late Ordovician was on the lower end of previously published estimates of 8-20x PAL. Moreover, in order to end glaciation pCO_2 levels must have risen beyond the 8x PAL threshold for ice sheet formation. The model predicts multiple equilibria with respect to changes in atmospheric pCO_2 levels and amplitudes of the orbital perturbations. These sharp bifurcations can be attributed to small ice sheet instability.

PP12B-04 1415h

Glacial Flow of Floating Marine ice in 'Snowball Earth'

Jason C Goodman[1] (773-517-0725; goodmanj@uchicago.edu)

Raymond T Pierrehumbert[1] (rtp1@uchicago.edu)

[1]University of Chicago Department of Geophysical Sciences, 5734 S. Ellis Ave, Chicago, IL 60637, United States

An intense debate is underway over whether the Earth's oceans were globally ice-covered during parts of the Neoproterozoic. Ice-free regions generally persist in GCM simulations of glaciated Neoproterozoic climates; however, these models have not considered the tendency of thick layers of floating marine ice to deform and spread laterally.

We have constructed a simple model of the production and flow of marine ice on a planetary scale, and determined ice thickness and flow in two situations: when surface air temperature is everywhere below freezing, and when tropical temperatures rise above freezing. In both cases, ice flow strongly affects the distribution of marine ice. Flowing ice probably carries enough latent heat and freshwater to significantly affect the transition into a Snowball Earth climate. We speculate that flowing marine ice, rather than continental ice sheets, may be the erosive agent which created some Neoproterozoic glacial deposits.

URL: http://geosci.uchicago.edu/~goodmanj/snowball_ice_sheets.pdf

PP12B-05 1430h

Towards a Composite $\delta^{13}C$ reference section for the Neoproterozoic

Galen P Halverson[1] (617-496-4356; halvers@fas.harvard.edu)

Paul F Hoffman (617-495-3636; hoffman@eps.harvard.edu)

[1]Dept. of Earth and Planetary Sciences Harvard University, 20 Oxford St., Cambridge, MA 02138, United States

We present a high-resolution $\delta^{13}C$ record of marine carbonates, which spans much of the Neoproterozoic Era (~850 to 543 Ma). Constructing a $\delta^{13}C$ reference curve for this time period has proved difficult because of poor radiometric age control, discontinuities in shelf carbonate sedimentation, and ambiguous global correlations. Furthermore, much scatter and uncertainty in composite Proterozoic isotopic records are imposed by inclusion of multiple, poorly-correlated, stratigraphic successions. We avoid these pitfalls by utilizing only two well-studied carbonate-dominated sections for the bulk of the new curve : the Otavi Group of northern Namibia and the upper Hecla Hoek Succession of northeastern Svalbard. The key to the composite record is the correlation between the two successions, which is based on common isotopic and stratigraphic features, most notably a prominent pre-glacial $\delta^{13}C$ anomaly and the character of distinctive cap carbonates. The fortuitous overlap between the two successions yields a nearly continuous $\delta^{13}C$ record (excluding glaciations) from the base (~850 Ma) of older, Akademikerbreen Group carbonates in Svalbard through the top (~600 Ma) of the younger Abenab and Tsumeb group carbonates in Namibia. Because the latest Neoproterozoic is not preserved in northern Namibia, continuity of the record to the Precambrian/Cambrian boundary requires a connection with the Witvei and Nama Groups in central and southern Namibia. Though we stress that this composite reference section is a work in progress, it is an important first step towards a new framework into which radiometric dates and major global events (e.g. glaciations and associated sea level fluctuations) can be fit and upon which other marine geochemical proxies (e.g. $^{87}Sr/^{86}Sr$ and $\delta^{34}S$), biostratigraphy, and paleomagnetic data can be hung. In this manner, data from many fragmentary sections may be incorporated (albeit interpretively) into a single, integrated geochronology. Several interesting features of the record already stand out, including evidence for three major glaciations between ~745 and 570 Ma and a variable relationship between these events and associated negative $\delta^{13}C$ anomalies. Also of note are the occurrence of other major isotopic variations both prior to 745 Ma and after 570 Ma, which appear unrelated to glaciation. A more complete, but also more complex, picture of Neoproterozoic Earth history is emerging.