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Over the last 3.5 million years major climatic and tectonic changes have resulted in high frequency fluctuations in relative sea level adjacent to the northern California shoreline. A detailed record of these changes is preserved in two sedimentary sequences currently exposed along the coast: the neritic to nonmarine Merced Formation near San Francisco and the bathyal to neritic Rio Dell Formation north of Cape Mendocino. With the goal of deciphering the Plio-Pleistocene paleoenvironmental histories of these expanded ocean margin sequences, detailed stratigraphic sections were measured and described from the lower portion of the Merced Formation and from the Upper Rio Dell Formation. Samples are being analyzed for benthic foraminiferal assemblage, palynological assemblage, stable carbon and oxygen isotope composition of foraminiferal carbonate, and organic geochemistry. These data provide insight into paleo-water characteristics and paleobathymetry, global ice volume and climate, terrestrial and marine ecosystem composition and structure, specific sources of sedimentary organic material, the frequency and magnitude of wildfires on land during deposition, and redox conditions during early diagenesis.

Variations in these climate and environmental proxies appear to demarcate glacial and interglacial cycles. These results generally support previous interpretations of glacio-eustatic control on the cyclicity of sedimentary facies within the Merced and Rio Dell formations. Ongoing work aims to explore the relationship between local and global climate proxies and to develop a more detailed model of northern California ocean margin sedimentary response to rapid Plio-Pleistocene sea-level change.

PP11A-0305 0830h POSTER

The Freezing Conditions of Planets: Effect of Obliquity

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Condition for the occurrence of the completely frozen state (a "snow-ball" state) might be a critical measure related to the habitability of the planet. It is investigated with a particular reference to the obliquity for both a land planet case and an aqua planet case. Obliquity change may cause freezing and unfreezing of planet if the freezing condition depends on the obliquity. Effect of obliquity on the freezing is also an important issue for the investigation of the paleo-Mars.

Here we investigated the freezing condition by a general circulation model, CCSR/NIES AGCM 5.4g. We applied the Earth condition, but assumed no topography and applied a bucket model with the saturation depth of 10 cm for ground water calculation for the land planet case and 50m slab ocean for the aqua planet case.

The results are summarized as follows: 1. A land planet shows stronger resistance to the complete freezing than an aqua planet. 2. A land planet in an oblique regime falls in the completely frozen state at a smaller solar constant than an upright regime. 3. On a land planet in an oblique regime, low latitude area is more susceptible to freezing than the mid latitude area. Implication for the paleo-Mars will be discussed in the presentation.

PP11A-0306 0830h POSTER

Spatial and Temporal Variations of the Indidura Formation (Cenomanian-Turonian) in Northeastern Mexico, Coahuila State

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Rock sequences of Cenomanian-Turonian age commonly assigned to the Indidura Formation in northeastern Mexico, Coahuila State, are shown to include distinct facies indicative of significant spatial variability over the carbonate platform of that region. The type section at Las Delicias is characterized by very-pale orange (10YR8/2) bedded biocalcirudites (10-30 cm thick), without internal structures, and comprises fossil assemblages rich in epifaunal groups, as well as nektonic and planktic taxa. Total inorganic carbon (TIC) varies between 48 % and 94 % , with fluctuation in total organic carbon (TOC) between 0.73 % and 1.58 %.

The section at la Casita Canyon, farther southeast, consists of pale yellowish brown (10YR6/2) interbedded biocalcilutites and olive gray (5Y3/2) shales between 3 and 30 cm thick. They also show no apparent original internal structures, and allochems consist essentially of sparse fragments of planktonic foraminifera and radiolarian. TIC content varies between 0.84 % and 59.3 %, whereas TOC changes between 0.17 % and 5.85 %.

In contrast, in the Parras Mountains, located south of La Delicias and northwest of la Casita, the succession occurs under a characteristic sequence showing interbeds of light olive gray (5Y6/1) and brownish black to olive black (5YR2/1 5Y2/1) shales and marly biocalcilutites 30 to 100 cm thick. They display distinct internal structures arranged in nearly even parallel varve-like dual lamina (<3 mm thick). Few planktonic foraminifera are present, but epifaunal remains are absent, except for occasional rare pelecypods (Inoceramus) that occur intermittently. Laminae from either the shales or limestone facies show that they are formed by differences associated with varying abundance of micro spheres and micro-ooids, interpreted to be of cyanobacterial origin. TIC content varies from 43 % to 78.3 %, while TOC content remains relatively high with values between 7.35 % and 24.39 %, but more consistently higher than 20 %.

Assuming that these facies are coeval, microfacies studies of these rocks as well as acid etched polished rocks, and scanning electron microscope examination (secondary and backscatter imaging) further substantiate these spatial differences. TOC-rich black shales in the Parras region further document unique paleoceanographic conditions, which was also characterized by oxygenation of oceanic waters less effective than usual. These unique paleoceanographic conditions imply that oxygenation of oceanic waters remained apparently less effective than usual throughout the sequence. Temporal distribution of the epifauna and carbon/carbonate variations in the Parras region suggest the effects of strong dysoxic/anoxic bottom conditions on the biota with rhythmical production and disappearance of cyanobacterial mats which remained dominant throughout.

PP11B MCC: Hall D Monday 0830h

Interhemispheric Climate Change I Posters *(joint with A, OS, GC)*

Presiding: **J R Toggweiler,** NOAA Geophysical Fluid Dynamics Laboratory**; P U Clark,** Oregon State University

PP11B-0307 0830h POSTER

Does Poseidon Keep the Holy Grail? Changes in Southern Ocean and North Atlantic Deep Water Production as the Driver of the Deglacial CO2 Rise

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The 'Holy Grail' of glacial/interglacial CO_2 research is to identify the cause for variations in atmospheric CO_2 on this time scale. A simple mechanism has hitherto remained elusive. Here I use an entirely new approach to the problem, namely a global vertical advection-diffusion balance of tracers in the ocean that includes effects of deep water production and the biological pump on atmospheric CO_2. The model adequately reproduces modern $p\mathrm{CO}_2$ and vertical profiles of temperature, $\Sigma\mathrm{CO}_2$, Alkalinity, PO_4, and O_2 in the ocean. A reduction of the ocean's deep water production and an associated decrease of O_2 and the remineralization efficiency for organic matter in the water column leads to the glacial $p\mathrm{CO}_2$ of 200 μatm. Assuming changes in Southern Ocean and North Atlantic deep water production consistent with proxy records over the deglacial transition, model results excellently reproduce the observed temporal evolution of the deglacial atmospheric CO_2 rise and deep ocean $CaCO_3$ saturation. The magnitude and timing of the ocean's deep water production rate in the northern and southern hemisphere is hence identified as the dominant driver of glacial/interglacial CO_2 variations through its effect on the vertical distribution of heat and elements in the sea.

PP11B-0308 0830h POSTER

Black Body Temperature in Terms of Earth's Orbital Elements and the Milankovitch Precession Index

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The temperature T of a black or gray body orbiting the Sun can be expressed in terms of spherical harmonics in latitude and longitude, its Keplerian orbital elements, and a variable describing rotation about its axis. Assuming that the Earth is a gray body, the resulting equation for T exhibits previously unrecognized odd-degree zonal terms dubbed Seversmith psychroterms. They cause a hemispheric temperature gradient which depends upon e sin w, where e is the orbital eccentricity and w is the Suns argument of perihelion measured in an Earth-centered frame. The hemisphere containing perihelion is the cooler. For a gray body with the Earths average albedo of 0.3, an emissivity of unity, and an obliquity of 23.5 degrees, the pole-to-pole temperature difference for the combined first and third degree spherical harmonic psychroterms can reach 3.4 K for the present eccentricity of 0.016, and 12.9 K for the maximum eccentricity of 0.06. While a black body with its boiling hot subsolar point and nights at absolute zero is a poor model for the Earth, the Seversmith psychroterms survive in more realistic models (although with smaller amplitudes) because the Earth radiates nonlinearly in T. The psychroterms acts in the direction opposite to the Milankovitch precession index, which also depends on e sin w: by warming the cool northern summers, the psychroterms make it harder for the traditional Milankovitch mechanism to operate. It may in fact be the Seversmith psychroterms which are actually responsible for the ice sheets which cycle with e sin w, instead of the Milankovitch mechanism. By cooling the southern hemisphere when perihelion is in the south, the psychroterms may somehow cause the southern hemisphere to control the northern ice sheets associated with the 19 kyr and 23 kyr periods (kyr = kiloyear), possibly through ice-albedo feedback in the sea-ice surrounding Antarctica.

PP11B-0309 0830h POSTER

Interhemispheric Variation in the Response to Solar Forcing Over the Past 1000 Years

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The difference in atmospheric ^{14}C levels in the Northern and Southern Hemispheres (NS offset) has recently been shown to vary between 1 and 10 over the last millennium (1, 2). More than 80 % of the variation is explained by three quasi-periodic cycles with ca. 200, 130, and 80-year periods.

The 205-year de Vries cycle in atmospheric ^{14}C levels can confidently be ascribed to a solar origin based on comparisons to cosmogenic isotope records, (3, 4). Additionally, a significant 130-year cycle is found in the ^{10}Be ice core record of the South Pole. Observing these cycles in the NS offset requires either variable input of 14C into the troposphere in each hemisphere or a differential response of the carbon reservoirs to solar variations.

The amplitude of the de Vries cycle increases throughout the past millennium in the individual records of Northern and Southern Hemisphere tree-ring ^{14}C. The Southern Hemisphere amplitudes are smaller until ca. AD 1500 when the amplitudes in both hemispheres are roughly the same. This interhemispheric difference in amplitudes results in pseudo-cyclic behavior in the NS offset that disappears after AD 1400. Because the de Vries cycle in the South Pole ^{10}Be record has nearly constant amplitude during this same time period, the increase in the amplitude in the atmospheric ^{14}C records must include a climatic component possibly related to millennial-scale ocean circulation changes.

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1. A. G. Hogg et al., Radiocarbon (submitted). 2. F. G. McCormac et al., Radiocarbon (submitted). 3. E. Bard, G. M. Raisbeck, F. Yiou, J. Jouzel, EPSL 150:453-462 (1997). 4. G. Wagner et al., GRL 28:303-306 (2001).

PP11B-0310 0830h POSTER

Last glacial climate change correlated with sea-level changes recorded in the coral terraces

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Huon Peninsula, Papua New Guinea, is a tectonically unstable, uplifting shoreline ringed by emergent coral terraces. The terraces were formed during episodes of rapid sea-level rise when corals constructed large, discrete platforms that were subsequently uplifted. Uranium series ages of four prominent Huon Peninsula last glacial (OIS 3) coral terraces coincide with the timing of major North Atlantic climate reversals at intervals of 6000 to 7000 years between 30,000 years and 60,000 years ago. Terrace elevations, when combined with uplift, indicate 10 to 15 m high sea-level excursions at these times. We attribute the growth of the terraces directly to sea-level rises arising from discharge of continental or shelf-grounded based ice from major North Atlantic ice-sheets and the Antarctic ice-sheet that precipitated extremes of cold climate called Heinrich events. These periods are associated with major discharges of land-based ice and enhanced concentrations of ice-rafted debris in deep-sea cores. Sea-levels at this time were 60 m to 90 m lower than present.

PP11B-0311 0830h POSTER

Modelling climate evolution over millenia : cryosphere-atmosphere-ocean interactions

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Modelling the mechanisms of climatic evolution over thousands of years, such as during the building of the mid latitude northern hemisphere ice-sheets, the large climatic oscillations of the last ice age or the deglaciation, requires taking into account the cryosphere as well as the atmosphere and the ocean. We have built one such model by coupling the model of intermediate complexity CLIMBER2.3 (developed at PIK, Germany, Petoukhov et al. 2000) to the three-dimensional ice-sheet model developed at LGGE. Using this new tool, we will investigate the mechanisms at work during the last deglaciation.

PP11B-0312 0830h POSTER

Were the North and South Climate Changes Asynchronous Over the Entire Last Glacial Period?

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Establishing a common time scale for climate record from different hemispheres is a challenge to understand how the northern and southern hemispheres are coupled during climate events. A classical method is based on the correlation between Greenland and Antarctic ice cores records of atmospheric composition changes. Here we present a new approach based on the use of a single Antarctic ice core from which different measurements, methane concentration and isotopic composition of nitrogen and argon, give access to the timing of a rapid change in the North and of its Antarctic counterpart. This method has the advantadge to circumvent the difficulties due to gas age ice age difference and to provide information further back in time than the classical method. We applied it to the 5d/5c transition at the start of the last glaciation around 108 ka BP (thousands of years Before Present). Our results indicate that the Antarctic temperature increase occurred 2.7 ka before the onset of the methane which is used as a time marker of the corresponding warming in the northern hemisphere. This suggests that the bipolar seesaw mechanism documented between 23 and 90 kyr BP [Blunier and Brook, Science, 2001] was probably active over the entire last glacial period.

PP11B-0313 0830h POSTER

High-Resolution Records of Southern Hemisphere Variability During the Past 340 kyr and Interhemispheric Linkage: IMAGES Core MD97-2120, Chatham Rise (SW Pacific)

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Planktonic δ^{18}O and XRF scanning records along 36 m long IMAGES Core MD97-2120 (45°32.06'S, 174°55.85'E, 1210 m water depth) have been generated at a mean temporal resolution of 200 yrs (min. 70 yrs, max. 1 kyr); planktonic Mg/Ca was measured at a mean temporal resolution of 900 yrs. The records reach the MIS 9/10 boundary and display millennial to submillennial variability that shows similarities with both the Greenland and Antarctic ice core records. In addition to variations associated with prolonged Dansgaard/Oeschger (D/O) interstadials 8, 12, 14 that are also prominent in Antarctic ice cores, planktonic δ^{18}O in MD97-2120 displays shorter variations that are remarkably similar to the shorter D/O events seen in Greenland ice cores. Amplitudes of the transient excursions are lower in the planktonic δ^{18}O record than in the Greenland record, thus the records represent a connecting link between high-amplitude, millennial-scale North Atlantic oscillations and low-amplitude, longer-term Antarctic climate changes. The Mg/Ca record, even though generated at lower temporal resolution, likewise displays rapid variations and runs in parallel to the δ^{18}O record, suggesting a prominent temperature control during abrupt climate fluctuations at this location. Mg/Ca-derived SST ranges from 6.5°C during glacial periods to 15-16°C during the interglacials. The occurrence of a North Atlantic-type climate pattern in the SW Pacific implies a tight interhemispheric linkage that persisted also during the shorter D/O events. The deglacial sections of the records display more structural similarity with the Antarctic records, with the initiation of warming preceding that documented in the northern North Atlantic region and Greenland. Submillennial changes are also seen in the earlier sections of the records indicating that abrupt change was a persistent feature during the past 340 kyrs.

PP11B-0314 0830h POSTER

Deglacial Sea-Surface Temperatures off New Zealand

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Glacial geologic and geochronologic data from New Zealand indicate a re-advance of mountain glaciers synchronous with the Younger Dryas (YD) Chron. Yet pollen studies do not support any appreciable cooling at this time, suggesting that the glacial advances may have resulted from enhanced precipitation rather than decreased temperature. A paucity of detailed marine climate records from the region leave an uncertain picture of deglacial climate change in the vicinity of New Zealand. The question remains open whether abrupt deglacial climate changes so prominent in the North Atlantic region involved the southwest Pacific Ocean. Here we present a detailed record of deglacial and Holocene sea-surface temperatures (SSTs) off the north island of New Zealand using the alkenone paleotemperature technique and show evidence for cooling synchronous with the Younger Dryas Chron.

Core MD97-2121 was recovered in 2314 m of water at 40°S, 178°E, southeast of Hawke Bay, New Zealand. The 35-m core contains a continuous record of sedimentation spanning the last 136 kyr. Age control for the deglacial period and the Holocene is provided by 26 radiocarbon dates on planktonic foraminifera and tephra layers. Exceptional rates of sedimentation averaging 36 cm/kyr during the last 25 kyr are maintained by large fluxes of terrigenous detritus from New Zealand resulting from pronounced seismicity, volcanism and continental weathering. Presently the site is under the influence of the southward-flowing East Cape Current, which transports 10-25 Sv of warm, salty, subtropical water. The northward flowing Wairarapa Coastal Current flows just west of the core site and transports 1.6 Sv of cool, low-salinity water derived from Australasian Subantarctic Water via the Southland Current. Although a relatively minor influence today, this cool, fresh current system may have influenced SSTs over the core site at times in the past.

Late Holocene alkenone-derived SSTs of 17 deg C are consistent with atlas mean annual SSTs. Temperatures during the LGM were 13 deg C. Deglacial warming was 5 deg C, with maximum temperatures of 18-18.5 deg C attained 9-10 cal kyr ago. This deglacial SST change is consistent with other estimates from marine records in the vicinity. Cooling of 1.5 deg C occurred in the mid-Holocene, between 4-8 kyr ago.

A cool episode occurred 12.3-11.6 cal kyr ago, during the Younger Dryas Chron. As evidenced by oxygen isotopic ratios in multiple species of planktonic foraminifera, the cool phase occurred at the end of an interval of enhanced stratification of surface waters ($<$ 400 m) that commenced during the Antarctic Cold Reversal and lasted from 14-12 cal kyr ago. The deglacial climate record east of New Zealand thus displays common features with those in both the North Atlantic region and in Antarctica.

PP11B-0315 0830h POSTER

Tropical Influence on High Latitude Climate Change During the Last Deglaciation

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Ice core data and marine records suggest an interhemispheric out of phase relationship during D/O events during the last glacial period, and during the last deglaciation. Here we present multi-proxy results from sediment cores from the Nordic Seas and the North Atlantic that can be directly compared with ice core records and Sea Surface Temperature (SST) records from the tropics. We are now able to document at decadal resolution that every cold reversal in the Greenland Ice cores has an imprint of strong meltwater input to the North Atlantic/Nordic Seas. These gave a strong feedback on the climate by several times reducing the potential of deep water convection in the North Atlantic. A similar scenario as described for the H1, and the following rapid warming, can be shown for the Younger Dryas period. Paleo-records from high northern latitudes also clearly indicate that the warming following the last glacial maximum took place simultaneously with the warming in the Southern Hemisphere at about 19kyr (cal.yrs), as a respond to the same forcings, i.e. increased insolation and increased release of CO_2 to the atmosphere. At 18kyr the northward heat transport was disrupted during Heinrich event 1 in the North Atlantic as a result of the incipient warming that triggered melting of surrounding continental ice sheets, which led to melt water run off and near to a collapse of the Thermohaline Circulation (THC). The strongly reduced convection in the north lasted for about 2-3kyr yrs and led to a cooling in the North Atlantic region.

Simultaneously, heat was building up in the tropics as less heat was distributed northward. As soon as the THC recovered in the North Atlantic, the heat that was built up in the tropics during H1, could be advected northward, leading to a series of rapid warmings in a flickering fashion in the North Atlantic region. Simultaneously with the warming at high latitudes, the tropics and the Southern Hemisphere experienced a cooling (Antarctic Cold Reversal-ACR) due to the heat gained in the Southern Hemisphere during the H1 is distributed northward. All known forcing mechanisms should at this point drive the climate globally into an interglacial mode. However, several times the climate at high northern latitude is punctuated by several cold periods, like the Younger Dryas cold period.

PP11B-0316 0830h POSTER

The 19-ka Meltwater Pulse

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Sea level records from Bonaparte Gulf suggest that the start of the deglacial sea-level rise began with an abrupt 10-15 m sea-level rise occurring over less than 500 years. We present evidence from the Irish Sea coast that seems to corroborate this event. We suggest that warming that began 21 ka led to the abrupt collapse of a part of the Northern Hemisphere ice sheet system at 19 ka, perhaps through destabilizing ice shelves. A large increase in atmospheric radiocarbon, the start of Oldest Dryas cooling in the GISP2 record, and responses in the Cariaco Basin and Lake Malawi, Africa, are consistent with this freshwater pulse being released into the North Atlantic at this time (19 ka), disrupting North Atlantic deep water formation. Subsequent cooling and reduced Atlantic thermohaline circulation throughout the Oldest Dryas was sustained by Heinrich event 1 at 17.7 ka. During this interval, global sea level rise slowed to an imperceptible rate, which could be explained by the widespread Northern Hemisphere cooling. The large reduction in NADW, combined with an increase in atmospheric greenhouse gases, caused warming in parts of the Southern Hemisphere, including regions of Antarctica. We suggest that the next major increase in sea level rise, MWP-1A, which originated largely from Antarctica, may be the result of the prolonged warming around Antarctica that destabilized fringing ice shelves. We also suggest that MWP-1A freshwater forcing caused a major reduction in Antarctic deep water formation, which in turn caused a major increase in the Atlantic THC and associated warming of the Bolling. Subsequent sea level rise continued through the remainder of the deglaciation as Northern Hemisphere ice sheets retreated in response to the warming.

PP11B-0317 0830h POSTER

Termination II Climate Records From Santa Barbara Basin, California Support Solar Forcing Mechanism and Milankovitch Theory

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Several climate records of the penultimate deglaciation exhibit change well before orbitally-related insolation variations thought to pace the Pleistocene ice ages. A few authors have attributed these changes to the glacial termination and suggest that this evidence of early deglaciation poses a challenge to Milankovitch theory. Additionally, millennial- to centennial-scale and glacial-interglacial climate oscillations have recently been linked to proxies of solar luminosity suggesting that solar forcing may be an important driver of climate change on both of these time scales.

High-resolution (50 yr) planktonic and benthic foraminiferal oxygen and carbon isotope records from Santa Barbara Basin reveal pronounced millennial- and centennial-scale climate variability during MIS 6 and Termination II. This includes greater variability during MIS 6 than during MIS 2, a stadial-interstadial millennial-scale climate oscillation immediately preceding Termination II, and a Younger Dryas-like climate oscillation during the penultimate deglaciation. The suite of millennial and centennial periodicities found in the Santa Barbara Basin climate records are similar to those found in cosmogenic nuclide production rates, North Atlantic drift ice, and many other climate records during the Holocene. Similarities in structure and timing of the Santa Barbara Basin and Vostok deglacial climate records are present.

The remarkable correspondence between the different Santa Barbara Basin climate records on millennial time scales suggests a tight coupling of climate system components as occurred during MIS 3. The rapid shifts in the California Current system were probably related to fluctuations in the atmospheric tele-connections of the California margin region to other areas of the Earth rather than a regional response to gradual changes in Laurentide ice sheet size. The specific centennial and millennial-scale periodicities and the greater climate variability during MIS 6 than during MIS 2 suggest that a solar forcing mechanism may have been important on both time scales. The records of early deglaciation during Termination II can be explained by the major interstadial and other centennial- to millennial-scale variability that immediately preceded the deglaciation and therefore do not pose a threat to Milankovitch theory. Finally, the similarities in the Santa Barbara Basin and Vostok deglacial climate records provide evidence for globally synchronous or near synchronous millennial-scale climate change during this time interval.

PP11B-0318 0830h POSTER

Timing and Pattern of the Abrupt Development of the Subarctic North Pacific Stratification During the Late Pliocene: Implications for Atmospheric CO_2 and the Onset of Major Northern Hemisphere Glaciation.

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The surface waters of the modern Pacific are isolated form the nutrient-rich waters below by a steep vertical gradient of salinity (halocline), a feature that is a dominant control on upper-ocean stratification in polar environments. The stratification of polar surface waters influences the exchange of CO_2 between ocean and atmosphere. Here we report high-resolution (3 cm sample spacing) biogenic opal accumulation rates and nitrogen-isotope data from sediments from ODP sites 882 (NW Pacific) and 887 (NE Pacific), which indicate that the subarctic halocline developed in less than 10 ka over the entire North Pacific Ocean. The density contrast would have prevented large-scale upwelling of nutrient-rich intermediate water masses. The photic zone was therefore partially isolated from its nutrient reservoir. This would have reduced biological productivity and subsequent organic matter export as suggested by a dramatic drop in biogenic opal accumulation rate. However, increased nutrient utilization indicated by a 2.5 $^o/_{oo}$ positive shift in δ^{15}N values would have led to an increased efficiency of the biological pump. After 2.73 Ma, this more complete utilization of the major nutrients across the North Pacific removed or significantly reduced one important subpolar oceanic leak of CO_2 back into the atmosphere, thereby lowering pCO_2. We infer that this coupled mechanism acted as a positive feedback on the gradual cooling trend between 3.2 and 2.73 Ma by decreasing atmospheric CO_2 concentration and it may have provided a critical threshold to keep the climate system cooler since 2.73 Ma, when major glaciation in the Northern Hemisphere commenced.

PP11C MCC: 130 Monday 0830h

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

Presiding: **N Exon,** Geoscience Australia**; G Filippelli,** Indiana University/Purdue University, Indianapolis

PP11C-01 0830h

Paleogene tectonics and the sediments deposited as Australia and Antarctica separated: ODP Leg 189

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The break-up of Gondwana led to major changes in global climate that were addressed by ODP Leg 189 by drilling on foundered continental blocks off Tasmania. The leg cored marine sediments spanning the entire Cenozoic, and detailed sedimentological changes as Australia moved north from Antarctica. Despite general similarities, the sedimentary history at each site differs in detail, depending on tectonic history and depositional setting. Maastrichtian (70 Ma) to Eocene cores were dated by dinocysts and siliceous microplankton, and younger sequences by calcareous microplankton. Earlier DSDP cores had indicated that the final separation in the early Oligocene contributed to global Cenozoic climate cooling, with the developing Antarctic Circumpolar Current (ACC) isolating Antarctica from warm surface currents and helping to form an Antarctic ice sheet. The Drake Passage between South America and Antarctica also played a key role in the development of the ACC, and recent studies suggest similar early Oligocene deepwater flow there.

Breakup between Australia and Antarctica started in the early Campanian (83 Ma), Tasmania and eastern South Tasman Rise (T-STR) slid slowly northward past Wilkes Land along a transform fault, and the ocean entered the eastern Australo-Antarctic Gulf (AAG) from the west. Simultaneously, Lord Howe Rise moved away eastward from T-STR. STR was stretched and subsided, but formed an imperfect land bridge to Antarctica. Leg 189 cores show that rapidly deposited deltaic mudstones kept up with subsidence in Cretaceous to Eocene rifts, during both slow separation (70-43 Ma) and fast spreading (43-37 Ma). Winnowed late Eocene glauconitic siltstones record condensed sedimentation and subsidence in shallow seaways during the final separation of the two continents (37-33.5 Ma). Thereafter, Oligocene and younger pelagic carbonates were deposited slowly on rapidly subsiding blocks as Australia moved northward. The sediments show that the narrow AAG was relatively warm and poorly oxygenated into the late Eocene, as compared to the cooler proto-Pacific Ocean east of the land bridge.

The greatest changes occurred over the Eocene-Oligocene transition. Older sediments are shallow marine, organic-rich, dark gray, brown or green mudstones and siltstones, and were deposited largely in poorly ventilated marine deltas in relatively warm conditions. The younger sediments are pale gray or white pelagic carbonates deposited in deepening water as the continental blocks subsided in an open and cool ocean.

PP

PP11C-02 0845h

Was Antarctica kept warm by subtropical waters in the Eocene? Part 1: Evidence from biotic endemism

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