in phase at the two sites. The cause of the apparent coeval shifts of the ITCZ on both the African and South American continents during the past thousand years is yet to be explained. While North Atlantic temperature gradients may contribute to climate variability over northern South America (Haug et al., 2001), it is difficult to imagine this mechanism having a direct effect in East Africa.

PP71A-0383 0830h POSTER

Holocene ITCZ Migration Recorded in Stalagmites from Southern Oman

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Until now there has been a lack of long high-resolution terrestrial records monitoring Indian Ocean monsoon variability in Southern Arabia and the neighbouring regions. A potential source for information about Indian Ocean monsoon variability is stalagmites from caves in Southern Arabia. One monitor of monsoon variation are the oxygen isotope ratios of stalagmites measured in caves where drip water accurately reflects the oxygen isotope ratios of monsoon precipitation, such as stalagmites from Qunf Cave and Defore Cave in Southern Oman. The area sits at the northern limit of the summer migration of the ITCZ and the associated Indian Ocean monsoon rainfall belt. Annual precipitation in this region is highly seasonal, more than 80% of total annual precipitation (400-500 mm/yr) falls during the summer monsoon months when dense clouds and mists cover the region. Today, convective cloud development is controlled by the height of a temperature inversion, which is created by the convergence of hot dry northwesterly winds and low-level southwest monsoon winds. The height of this temperature inversion is dynamically linked to the mean latitudinal summer position of the ITCZ and to the southwest monsoon pattern over Southern Arabia. A northward migration of the ITCZ into the Arabian Peninsula would lift the height of the temperature inversion, leading to stronger convective cloud development and higher monsoonal rainfall over Southern Oman. Due to the amount effect, $\delta\ ^{18}O$ values of precipitation become more negative (depleted). Hence, stalagmite $\delta\ ^{18}O$ values are a proxy for the amount of monsoon precipitation, which is controlled by the mean summer latitude position and convection intensity of the Intertropical Convergence Zone (ITCZ). Three Uranium-series dated stalagmites, sampled in two caves in Southern Oman, provide a continuous high-resolution (temporal resolution varies between 1-5 years) terrestrial record of Indian Ocean monsoon variability from 10.3 to 2.8 kyr BP. The oxygen isotope profiles show that changes in monsoon precipitation between 10.3 and 8 kyr BP are in phase with high-latitude temperature fluctuations recorded in Greenland ice cores, indicating that early Holocene monsoon intensity is largely controlled by glacial boundary conditions. After 8 kyr BP monsoon precipitation decreases gradually in near linear response to changing Northern Hemisphere summer insolation. Finally, results of spectral analyses of all proxy records show statistically significant cycles of 1000 yr, 420 yr, 220 yr, 136 yr, 100 yr, 45 yr, 13-10 yr and 8-3 yr. These cycles support the hypothesis that monsoon variability during the Holocene is closely tied to solar activity.

PP71A-0384 0830h POSTER

Arctic Oscillation-like Teleconnections During the Late Holocene and the Last Interglacial Documented in Subtropical Corals

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Seasonal-resolution proxy records of past climate variability are mostly restricted to tropical corals, and often provide information on interannual to decadal ENSO variability through time. In contrast, coral oxygen isotope records from the subtropical northern Red Sea (28°-29°N) document regional ocean-atmosphere variability which in turn is linked to large-scale extratropical atmospheric circulation patterns. A strong 5-6 year oscillation detected in a bimonthly-resolution coral time series covering the past 245 years is strongly linked to regional variability of sea surface temperature and surface winds in the Middle East, which in turn are controlled by the Arctic Oscillation, the dominant mode of Northern Hemisphere atmospheric varability. The correlation of the coral time series with global sea level pressure and sea surface temperature fields, all filtered in the 5-6 year period band, reveals the signature of the Arctic Oscillation over the Northern Hemisphere. Corals from the subtropical northern Red Sea therefore provide a unique archive of atmospheric variability over the middle- and high-latitude regions of the Northern Hemisphere during the pre-instrumental period.

New bimonthly-resolution oxygen isotope records from fossil corals suggest that Arctic Oscillation-like teleconnections also controlled Middle East climate variability during the late Holocene and the last interglacial period. Both a 98-year coral time series from 3 ka and a 44-year coral time series from 121 ka (based on TIMS Th/U-dating) show a strong 5-6 year oscillation. The application of the coral Sr/Ca paleothermometer indicates cooler mean conditions in the northern Red Sea at 121 ka. We speculate that this is the result of a prolonged high index state of the Arctic Oscillation at this time. The high index state usually leads to colder temperatures over the Middle East and warmer temperatures over most middle- and high-latitude Northern Hemisphere continental regions.

PP71A-0385 0830h POSTER

Fluctuation in Sedimentation of Organic Carbon and Inorganic Elements in the Eastern Indian Ocean During the Late Quaternary

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The oceanographic environment of the eastern Indian Ocean is influenced by the Western Pacific Warm Pool, the Indonesian throughflow and the fluctuation of land-ocean material interaction due to river inputs. Sedimentation of biogenic and abiogenic components was studied in cores Fr10/95-GC5 (14S, 121E; 2,472 m) and Fr10/95-GC14 (20S, 112E; 997 m) from the eastern Indian Ocean to verify the fluctuation of paleoenvironment. Organic carbon (OC) and Al contents have been always much higher in core Fr10/95-GC5 than those in core Fr10/95-GC14 during the last 150 kyr. Content of OC in the former core increases from oxygen isotope stage (OIS) 3 to boundary of OIS 1/2 although that in the latter core does not change largely. The mean OC/TN ratios in both cores (10.3 in Fr10/95-GC5 and 9.1 in Fr10/95-GC14) indicate that terrigenous OC has been minor contribution to OC in the sediments, which means mass accumulation rate (MAR) of OC would be a proxy for paleoproductivity. The fact that core Fr10/95-GC5 has high MAR of OC at boundary OIS 1/2 is compatible with stronger upwelling in the Java region (or shallower thermocline) during the last glacial maximum estimated by Martinez et al (1999) based on analysis of planktonic foraminifer assemblage. Al content in core Fr10/95-GC5 slightly fluctuates from 2.73 to 4.92 wt.% with high values in early OIS 5. In core Fr10/95-GC14, Al content varies between 0.36 and 1.79 wt.% with maxima in OIS 1, boundary OIS 5/6, and OIS 7. As Site Fr10/95-GC5 is located in the Timor Passage, the main outlet of Indonesian throughflow, and a reduced eolian dust input because of high precipitation, terrigeous components should be transported mainly by rivers and ocean currents. In the West Caroline Basin situated in an inlet of the Indonesian throughflow MAR of Al has increased during OIS 1, middle OIS 2 to OIS 3, early OIS 5 to late OIS 6 and middle OIS 7 (Kawahata, 1999), which is a different pattern compared to the results from core Fr10/95-GC5. The correlation coefficient of Al and Ti in core Fr10/95-GC5 is not high (r=0.90), which suggests existence of several sources for terrigenous components. Average Ti/Al ratios in core Fr10/95-GC5 display different values in OIS; 0.035-0.038 in OIS 1, 3, 4 and 5, 0.051-0.052 in OIS 2 and 6, while those in core Fr10/95-GC14 have nearly the same values (average 0.053), which implies that the terrigenous source of former core during OIS 2 and 6 are the same to the latter core. These results may be attributed to that Site Fr10/95-GC5 has been more influenced by terrigenous input from Australia in OIS 2 and 6, and that paleoproductivity has been promoted because of stronger upwelling at least during the LGM.

PP71B MCC: Hall D Sunday 0830h

Tropical to Midlatitude Paleoceanography and Paleoclimatology Posters *(joint with A, OS, GC)*

Presiding: **F A Mekik,** Grand Valley State University**; W P Chaisson,** University of Rochester

PP71B-0386 0830h POSTER

Validation of Coral Temperature Calibrations by Cyclostationary Methods

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Geochemical analyses of coral skeletons are used to estimate past sea surface temperatures (SSTs). In brief, a linear regression between the local SST and $\delta^{18}O$ is established for an interval (the calibration interval), for which we have instrumental data, and is then applied to predict the temperature during past times in which we have isotope data.

Crowley et al (1999) demonstrated that the regression coefficients differ markedly between calibrations involving annual mean data and the standard seasonal calibration. Furthermore, when both methods were tested in a validation interval (in this case the early 20th century), it was found that the seasonal calibration seriously underestimated early 20th century cooling while the annual calibration gave a reasonable hindcast. Hindcasts made with the annual calibration, however, underestimated the seasonal cycle.

In fact neither method is mathematically satisfactory, as the relation between the two variables may be nonlinear. In this work we employ a different method, that of Cyclostationary EOFs (e.g. Kim and North 1997). By performing a regression not between each time series, but rather between the principal components of each time series, this method separates the causal and non causal components of the correlation between SSTs and $\delta^{18}O$, allowing a reconstruction which captures both the long-term change in Temperature and the seasonal cycle. This method both captures the strength of the seasonal cycle and gives a good hindcast of the early 20th century cooling.

PP71B-0387 0830h POSTER

High-resolution Accumulation Rate Variations on the Bermuda Rise During Marine Isotope Stage 3

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North Atlantic sediment accumulation rates are sensitive to climate change due to variable supply from glacial delivery, wind-borne dust, productivity, dissolution, and sediment redeposition. Excess Th-230 profiling allows us to build a high resolution record of regional accumulation rate variations, as the flux of Th-230 to the seafloor beneath a region is known and

lateral sediment reworking does not alter the primary sediment/Th-230 flux ratios. The Bermuda Rise contains a high resolution record of climate change during marine isotope stage 3 revealed through changes in %CaCO3, alkenone undersaturation index, benthic foraminiferal Cd/Ca, and accumulation rate variations. The average sedimentation rate between interstadials IS5 and IS16 is33 cm/kyr. We have made 350 excess Th-230 determinations for this interval giving an accumulation rate resolution averaging one century per sample. Combined with %CaCO3 data, this data allows for the calculation of regional carbonate and noncarbonate detritus accumulation rates. In this interval, noncarbonate accumulation rates vary by a factor of three, and carbonate accumulation rates vary by a factor of four. The highest non-carbonate peaks occur just before %CaCO3 peaks associated with interstadial IS8 (H4?) and IS12 (H5?) and perhaps surprisingly, also in the middle of the %CaCO3 peak associated with interstadial IS10, and in a doublet near the end of the %CaCO3 peak associated with interstadial IS6 and just before interstadial IS5. Smaller but significant noncarbonate accumulation peaks occur just before the carbonate peaks associated with IS16 and IS14, and at other times throughout MIS 3.

After making some simple assumptions about sediment focusing, it is possible to use this accumulation rate information to construct linearized time scales that are independent of correlations with other climate records. Proxy indicators such as %CaCO3, Cd/Ca, and alkenone temperatures estimates will be compared to other climate records using these independent linearized time scales.

PP71B-0388 0830h POSTER

Plant Functional Traits as a New Tool for Reconstructing Past Climate from Vegetation Data at a Global Scale

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We investigated the potential of a new method to reconstruct the mid-Holocene climate in the Mediterranean region based on the relation of 12 readily observable plant traits to winter temperature (as measured by the mean temperature of the coldest month, MTCO) and water availability (as measured by the ratio of actual to equilibrium evapotranspiration, ALPHA). We compared the present distribution of plant traits and sets of plant traits according to MTCO and ALPHA with their distribution at 6000 yr BP using canonical correspondence analysis (CCA) of the pooled modern and 6000 yr BP data set.

The abundance of plant traits in modern and past vegetation is estimated from 677 modern and fossil pollen assemblages. MTCO and ALPHA reconstructed from the CCA-regression coefficients and the ordination scores of the pollen sites correlate well with ALPHA (r=0.70) and MTCO (r=0.56) observed at the modern pollen sites. Reconstructed values of ALPHA and MTCO at the fossil pollen sites indicate that the climate in the Mediterranean region was generally cooler (-4.1 degrees C) and slightly wetter (+13 %) at 6000 yr BP. These results are in agreement with previous reconstructions for the Mediterranean region.

Because it is based on the relative abundance of plant functional traits, this method should be equally applicable to different continents with different floras. Comparisons between plant trait distribution in the western USA and the Mediterranean region climate spaces will be explored and should demonstrate the potential for such a method to reconstruct past climate at a global scale.

PP71B-0389 0830h POSTER

Reconstructing Open Ocean Calcite Fluxes for the Eastern Equatorial Pacific [EEP]: LGM to Present

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Understanding carbonate preservation cycles and their relationship to biological production and ocean chemistry in the EEP has been a long-standing oceanographic problem. We reconstructed calcite fluxes for the Last Glacial Maximum [LGM] from two cores in the EEP [ODP 846B and Y69-71] using percent calcite preserved and 230Th-based calcite accumulation rate data. Percent calcite preserved was determined with a newly published transfer function involving a G. menardii fragmentation index [MFI] and biogeochemical modeling. Calcite flux was calculated by dividing the 230Th-based accumulation rates by percent calcite dissolved.

Calcite accumulation rates decreased 43% from the LGM to the Present, but percent calcite preserved also decreased from near 50% to less than 20%. Combining these data shows that calcite flux to the seabed was lower than at Present during LGM by 35 to 40%. We tested our results with biogeochemical modeling. This test shows that modeled flux estimates are consistent with our set of observations and reconstructions for organic carbon flux, calcite flux, delta calcite, calcite accumulation rate, sediment percent calcite and percent calcite dissolved.

Reconstruction of accumulation rates with traditional methods (using sedimentation rate and dry bulk density) does not produce results consistent with observations and modeling. We find that LGM conditions (compared to the Present) were: (a) Org. C flux 25% lower, (b) calcite flux 35% lower, and (c) bottom water delta calcite increased by 20 to 25 umol/kg. Thus, contrary to the dominant view, particle fluxes were lower in the EEP during the Glacial maximum.

PP71B-0390 0830h POSTER

An Intermediate Water Mass Geometry for the Glacial South Atlantic From Benthic Foraminiferal Cd/Ca and δ^{13}C

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Cd/Ca and δ^{13}C of benthic foraminifera (from Brazilian Margin marine sediment cores spanning a water depth of 441 to 1627 meters) were used to reconstruct the shallow to intermediate water mass geometry of the South Atlantic during the last glacial maximum (LGM). Additionally, paired Cd and δ^{13}C results were used to estimate the portion of the δ^{13}C signal attributable to air/sea exchange of CO2 ($\delta^{13}C_{as}$), which can be used as a conservative water mass tracer. Three distinct water masses were identified using this approach. A high-nutrient water mass was centered at 1105 m and was bordered above and below by low-nutrient water masses. The nutrient-poor water mass at about 1600 m was identified as Glacial North Atlantic Intermediate Water (GNAIW), which is shown to extend at least to 27^{o}S in the glacial Atlantic. The shallowest water mass was most likely Central Water derived from the South Atlantic gyre, as it is in the modern ocean. However, glacial $\delta^{13}C_{as}$ values for this water mass were lower than modern estimates from nearby GEOSECS Station 57 δ^{13}C and PO_4 data, indicating that it formed in a different manner at the LGM. The high-nutrient water mass centered at 1105 m also had lower $\delta^{13}C_{as}$ than modern Upper Circumpolar Deep Water (UCDW), which resides at about this depth today. It exhibited an average glacial $\delta^{13}C_{as}$ value of 0.21$^o/_{oo}$, compared to approximately 0.83$^o/_{oo}$ calculated for modern UCDW at GEOSECS Station 57, implying a different formation mechanism at the LGM. These reduced glacial air/sea exchange values suggest that the glacial, high-nutrient water mass was poorly ventilated at its source region and may have been formed from different source waters. A comparison of glacial intermediate waters from the Brazil Margin and other oceans also implies that a uniquely formed version of UCDW was present in the South Atlantic. $\delta^{13}C_{as}$ values for the glacial high-nutrient water mass are lower by 0.49-1.33$^o/_{oo}$ than those for waters in the Sub-Antarctic Indian Ocean at a similar depth, but are similar to slightly deeper (1373 and 1814 m) waters in the Eastern Tropical Pacific (Boyle, 1992; Lynch-Stieglitz *et al.*, 1996), establishing them as a possible source. Another possibility, again deduced from similar $\delta^{13}C_{as}$ values, is that the glacial high-nutrient water mass was formed partly by GNAIW that upwelled in the South Atlantic before sinking and flowing north as glacial UCDW. Changes in intermediate water mass formation such as these may have affected poleward heat transport by the ocean and North Atlantic Deep Water return flow during glacial conditions.

PP71B-0391 0830h POSTER

Youthful Belize Barrier Reef: Strengthening the Model for a Mid-Brunhes Global Establishment of Modern Barrier Reefs

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During a late June 2002 transit from Panama to Cancun on the R/V Marion Dufresne, a spectacular 37.6 m-long piston core MD02-2532 was retrieved from a water depth of 333 m at 3 km in front of the central Belize Barrier Reef. The core penetrated the distal part of a seismic wedge, made up of five distinctive subunits, and the upper part of an underlying seismic unit characterized by sub-parallel seismic reflectors. The age of the oldest sediment at the bottom of the core ranges, based upon nannofossil assemblage, between 720 and 450 kyr. Moreover, nannostratigraphy analyses at 1.5 m sample intervals yield three nannofossil age markers, LAD of Pseudoemiliania lacunosa, FAD and the Acme zone of Emiliania huxleyi were identified between 22.5-24.0 m, 12.0-10.5 m, and 4.5-3.0 m, respectively. Early interpretation of shipboard color reflectance and magnetic susceptibility data sets, in addition to visual core description and smear slide observations, seem to identify in the upper 24 m of the core five distinct light subunits characterized by low magnetic susceptibility separated by four darker subunits characterized by high magnetic susceptibility. In contrast the lower 13 m of the core are characterized by calcareous oozes rich in angular quartz and lithogenic grains, and a magnetic susceptibility signature clearly distinct from the upper 24 m of the core. The five subunits in the upper 24 m of the core are interpreted to consist of distal barrier reef deposits and correspond to late Quaternary interglacial marine isotope stages 11, 9, 7, 5, and 1. Those five subunits overlie an early Brunhes mixed siliciclastic-carbonate unit representing a deep open continental shelf.

The establishment of the Australian Great Barrier Reef was recently dated to be Brunhes in age and was given an age of 600 +/- 280 ka. Moreover the coralgal Key Largo limestone overlying quartz-rich early Pleistocene shelf deposits in the Florida Keys was estimated to late Pleistocene age. The initial analyses of core MD02-2532 associated with results of earlier research along the Belize margin point out, therefore, that, as for other modern barrier reefs offshore Northeast Australia, and South Florida, the Belize Barrier Reef represents young (late Pleistocene) and thin carbonate sedimentary deposits covering a series of late Pliocene and early Pleistocene lowstand prograding siliciclastic paleo coastlines (deltas and possibly beach ridges). According to our model, these extraordinary findings can be explained by two unique, global, and systematic floodings of early Pleistocene lowstand tropical paleo fluvial plains during the onset of interglacial marine isotope stages 11 and 9. These two exceptionally high amplitude (more than 100 m) sea level transgressions are the first such transgressions since the onset of the main northern Hemisphere glaciations 2.8 Ma. Moreover, those mid-Brunhes high amplitude sea level transgressions and high-sea-level intervals dramatically contrast with the late Pliocene and early Pleistocene overall lowering of the marine base level tied to the establishment and the expansion of the northern hemisphere major continental ice sheets.

PP71B-0392 0830h POSTER

Mid-Quaternary Sea Surface Temperature and Reef Development inferred from Shallow-water Carbonates in Northwestern Pacific

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The oxygen and carbon isotopic compositions of shallow-water carbonates and their fossil components can be important tools for understanding Quaternary paleoceanographic conditions of marginal seas, including coral reef regions. However, most previous paleoceanographic studies using isotopes have been based on pelagic or hemipelagic sediments of open seas, because the original oxygen and carbon isotopic values of shallow-water carbonates are usually altered by post-depositional diagenesis.

This study shows that open- to marginal - ocean isotopic (original) signals are preserved in mid-Quaternary low-Mg calcitic planktic foraminifers of shallow-water carbonates, even when the isotopic values of the carbonate host rock have been altered by meteoric fluids and subaerial exposure.

The oxygen isotopic records of planktic foraminifers from the Ryukyu Islands, Japan, imply that sea-surface temperature in the northwestern Pacific increased $\sim$ 2.0 $^{\circ}$C at the beginning of oxygen isotope stage 19, during the Mid-Pleistocene Revolution (MPR). This warming may have triggered the expansion of reef-complex deposits as large as those now in the Ryukyu Islands, and was approximately coeval with origination of the Australian Great Barrier Reef at 600 $\pm 280ka(postMPR)$.

Reef initiation and development during the MPR evidently was a global event.

PP71B-0393 0830h POSTER

A Reconstruction of Seawater δ^{44}Ca From Foraminiferal Records of the Western Equatorial Pacific Ocean

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We present δ^{44}Ca records of three different foraminifera species (*G. ruber/subquadratus, G. trilobus* and *Globigerinella spp.*) from the western equatorial Pacific (ODP Site 871 and 872) corresponding to the last about 25 Ma. Assuming a constant calcium isotope fractionation factor (α) between seawater and the foraminiferal calcium carbonate the δ^{44}Ca of the past seawater ($\delta^{44}Ca_{sw}$) can be reconstructed. The $\delta^{44}Ca_{sw}$ records of *G.ruber/subquadratus* and of *Globigerinella spp.* are similar. The two records show a decrease of the $\delta^{44}Ca_{sw}$ between 25 and 16 Ma of about $0.5\,^{o}/_{oo}$ followed by an increase of about $0.5\,^{o}/_{oo}$ between 16 and 3 Ma. Between 3 Ma and the present the $\delta^{44}Ca_{sw}$ decreases again by about $0.25\,^{o}/_{oo}$. The $\delta^{44}Ca_{sw}$ calculated from the *G. trilobus record* shows a similar trend between 22 and 6 Ma but is isotopically lighter by about $0.2\,^{o}/_{oo}$ compared to the other two records: The $\delta^{44}Ca_{sw}$ of Site 871 is positively related to its $^{87}Sr/^{86}Sr$ record. This indicates that the $\delta^{44}Ca_{sw}$ is triggered by the balance of the input of continental weathering products and submarine volcanism and the output of biogenically driven calcium carbonate precipitation.

From *G. sacculifer* being closely related to *G. trilobus* it is known that calcium isotope fractionation is temperature dependent (Nägler et al. 2000; Gussone et al. 2002). Thus the differences between the $\delta^{44}Ca_{sw}$ from *G. trilobus* and the mean of the $\delta^{44}Ca_{sw}$ of *G. ruber/subquadratus* and *Globigerinella spp.* can be interpreted as a temperature related signal. Using the correlation of the fractionation factor (α) and temperature (T) of *G. sacculifer* the calculated temperature varies between 26.5 $^{\circ}$C and 29 $^{\circ}$C over the past 23 Ma. The calculated temperatures of the *G. trilobus* record show a cooling trend between 23 and 16 Ma followed by slight warming between 16 and 3 Ma. Between 3 and 1.5 Ma a rapid warming can be observed. These observed temperature variations are in the order of $1-2\,^{\circ}$C. In contrast, the δ^{18}O record of Site 871 and the global evolution of the δ^{18}O record of benthic foraminiferas show a cooling between 16 Ma and 1.5 Ma being in contradiction to the δ^{44}Ca based temperature reconstructions of the *G. trilobus* record. References:
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PP71B-0394 0830h POSTER

Fluctuations in Productivity and Denitrification Intensity Along the Southwestern Continental Margin of India Since the Last Glacial Maximum

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Variations in the organic carbon (OC), total nitrogen (TN), $CaCO_3$ and nitrogen isotope (δ^{15}N) records in a sediment core from the southwestern continental margin of India are used to reconstruct fluctuations in the productivity and the intensity of denitrification during the late Quaternary. Palaeoproductivity proxies like OC, TN and $CaCO_3$ indicate higher primary productivity at about 22 ka BP and late Holocene with a low around 10 ka BP. The δ^{15}N fluctuates from lighter values of 5.8 and 5.4 per mil., suggesting reduced denitrification around 22 and 10 ka BP to heavier values of 7.3 and 6.7 per mil., indicating enhanced denitrification at about 17 and 7 ka BP. Higher primary productivity at about 22 ka BP might be due to convective winter mixing resulting in increased nutrient supply and also oxygenating the subsurface waters. This would have suppressed the denitrification intensity. Towards the end of the last glacial maximum (17 ka BP), however, the subsurface denitrification intensified, presumably due to a decrease in oxygen supply from the surface. Reduced primary productivity at about 10 ka BP is surprising as this period is known to be one of intensified SW monsoon. It is likely that the enhanced precipitation fortified near-surface stratification reducing productivity but the oxygen concentration could have been elevated through an intensified undercurrent. Denitrification seems to have intensified again once such conditions relax. No major fluctuation in subsurface oxygen distribution appears to have occurred since then.

URL: http://www.SEArabianSea.org

PP71B-0395 0830h POSTER

Carbon Isotope Abundances in Lichen Deposits Might Reflect Past Moisture Trends

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The stable carbon isotope composition of lichens is governed primarily by moisture conditions. Lichens lack water transport systems that are characteristic of higher plants; therefore, maximum productivity occurs during periods when an equilibrium has been established between the water content of the organism and the environment. The amount of water required to initiate and maintain photosynthesis influences the carbon isotope content due to fractionation caused by diffusion of carbon dioxide through the water filled membranes, as well as morphological changes in the lichen thallus. Thus, lichens growing in relatively wet conditions have a lower carbon 13 content than those growing in drier conditions.

We suggest that the carbon isotope composition of stable lichen byproducts, such as calcium oxalate that is common on rock surfaces, can be used to predict past fluctuations in moisture conditions. We are exploring this hypothesis via studies of living, oxalate producing lichens, and calcium oxalate deposits from on rock surfaces in the Lower Pecos River region. The results of these studies demonstrate that (1) lichens growing on limestone do not incorporate carbon from carbonate substrates; thus ambient carbon dioxide is the dominant, if not sole source of metabolized carbon; and (2) calcium oxalate produced by lichens is consistently enriched in carbon 13 by 6.5 permil compared to the lichen tissues.

We also present here a plot of oxalate carbon 14 ages versus the stable carbon isotope ratios from analyses of 19 calcium oxalate rock coating samples from the Lower Pecos region. This graph shows a general increase in the oxalate carbon 13 content through the middle Holocene that peaks about 3000 years ago, followed by a rapid decrease in the abundance of the heavier isotope. We suggest that the increased carbon 13 content corresponds to a decrease in the amount of moisture transported to the region during this period, a trend that rapidly reversed about 3000 years ago. Moreover, the variability of the stable carbon isotope data becomes greater with increasing carbon 13 content (and thus increased dryness), which might suggest climate variability increased in concert with the overall drying trend.

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Millennial-scale variation of upper-ocean thermal stratification in subtropical northwest Atlantic during MIS 10 through 12

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Regular high-frequency variability has been identified in planktonic foraminiferal oxygen isotope records spanning Marine Isotope Stages (MISs) 10 through 12 (330-440 ka) at ODP Site 1056 on the Blake-Bahama Outer Ridge (32°29'N, 76°20'W; 2166 m water depth). This site is located beneath the Gulf Stream in a region that experiences seasonal hydrographic changes. In the summer when the Gulf Stream is furthest north and west and transport is greatest, thermal stratification in the surface ocean is at a maximum. In the winter when the Gulf Stream is further south and east and transport is lowest, thermal stratification is at minimum.

Here we use the oxygen isotopic composition of *Globigerinoides sacculifer*, a surface-dwelling species, and *Neogloboquadrina dutertrei*, a seasonal-thermocline-dwelling species as a proxy for the thermal stratification of the surface ocean. The difference between the oxygen isotopic values of these two species represents the temperature gradient between their respective habitats in the upper water column (e.g., the sea surface and the seasonal thermocline). Our goal is to investigate whether hydrographic changes analogous to modern seasonality are present in the geologic past at a millennial time scale.

Samples were measured every 5 cm to yield a temporal resolution of 200-300 years during glacial MIS 10 and 12 and 600-800 years during interglacial MIS 11. Spectral analysis of the data set reveals that the amplitude of the temperature gradient fluctuates at periods of approximately 7.5 k.y , 3.0 k. y. and 1.5 k.y (in MIS 10 and 12). We speculate that the character of the Gulf Stream varied at these millennial scale periods in a manner analogous to the seasonal pattern described. Regular variation in the Gulf Stream system is noteworthy because of its important role as a conveyor of tropical heat to the subpolar North Atlantic.

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Volcanic Forcing of Global Warming during the Pleistocene?

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The volcanic forcing hypothesis is a new model of global climatic change that may have significance for the history of the Earth and palaeoclimate. The rapid injection of CO2 into the atmosphere during volcanic eruption through underlying massive carbonate appears

to trigger global warming through the emission of this greenhouse gas.

The record of eruptions (10-20 Kya) of 6 volcanoes overlying 900-10,000 meters of carbonate of the Cordillerian geosyncline in the American Southwest is synchronous with the Late Pleistocene marine transgression record. The record of volcanic eruptions through massive carbonates (20-71 Kya) in Italy, Indonesia and the American Southwest appears to be synchronous with the Wisconsin interstadial events. The extension of the volcanic eruption and climatic records to 71 Kya and inclusion of other volcanic regions represents additional supporting of evidence of the volcanic forcing hypothesis.

As an example of these processes, the thermal dissociation of carbonate by magma forming a volcanic conduit (0.4 km high, 0.5 km radius) and subsequent release of carbon dioxide would increase the atmospheric carbon dioxide by 25%. The emitted CO2 would trigger a series of other processes, ocean-atmospheric CO2 exchange, increased photosynthesis and changes with terrestrial biome and global warming. [Recent field reconnaissance of Sunset Crater (erupted 1064-65 AD) indicates the evidence for thermal dissolution of limestone during basaltic extrusion.]

Carbon dioxide emitted from volcanic-carbonate sources meets several observed conditions: a rapid increase (<20 years) in atmospheric carbon dioxide, abrupt increases of marine (isotopic) carbon, dilution of atmospheric radiocarbon activity independent of fluctuations of the geomagnetic field and cosmic ray fluxes, temporal covariation of sulfate, Ca+2, and CO2 in ice core records and random, interstadial events during glaciation.

Volcanic forcing hypothesis represents a new model and synthesis of natural processes involving recycling of marine carbonate through volcanic eruption leading to global warming.

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The mid-Brunhes Carbon Isotope Excursion - Evidence of Low Productivity in the Ocean?

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Evidence from both marine and continental records suggests that isotopic stages 11, 13 and 15 were particularly warm interglacials [*Burckle*, 1993; *Droxler and Farrell*, 2000]. The temperature during these interglacials may have been as much as 5°C warmer than today in North China, up to 3-6°C in the Himalayas, up to 3°C in Siberia and 4°C in the eastern Urals. Climate conditions in Siberia seemed to have been very stable during a time period of 110'000 yrs. One of the most striking observations in the oceanic realm is an increased carbonate accumulation in the North Atlantic, South Atlantic and North Pacific and enhanced carbonate dissolution in the Equatorial Pacific. New data from the stable isotopic composition of planktic foraminifera and the carbonate fine fraction reveals a pronounced positive δ13C excursion in all cores analyzed from the Atlantic and the Western Equatorial Pacific. This excursion, which coincides with the global dominance of *Gephyrocapsa caribbeanica*, started synchronously at the boundary of isotope stage 16/15 (620 ka ago) and ended at the boundary of isotope stage 8/7 (245ka). Such an excursion has been hitherto not generally observed in the record of benthic foraminifera and planktic foraminifera. The cause of this excursion is still not known. However, the evidence currently available suggests that major changes in the global environment took place, which we relate to an overall reduction in the primary productivity of the oceans.

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PP71B-0399 0830h POSTER

The Relationship Between Lake-Filling Cycles in the Western Great Basin and Pleistocene Epoch Climate Changes

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Evidence of the most recent lake cycle persists throughout the western Great Basin and has been studied intensively for over 100 years. In contrast, little is known about the longer-term history of the basin. Most workers agree that lake filling events were somehow related to glacial periods, when amounts of precipitation and stream runoff into lakes were higher. Dating ancient shorelines in the western Great Basin is valuable because it allows for a better understanding of both the timing and the magnitudes of lake-filling events. Two competing hypotheses have been put forth to explain the response of the western Great Basin to the forcing of Pleistocene climate changes. One is that there were large basin-filling events during oxygen isotope stages 16, 6, and 2 with long periods of aridity in the intervening times. The second is that the basin responded in a predictable manner to global climate cycles by filling during these glacials as well as the other glacial periods in the sequence. This study tests these hypotheses by dating paleoshorelines in the western Great Basin.

Dating ancient shorelines in the western Great Basin is valuable because it allows for a better understanding of both the timing and the magnitudes of lake-filling events. Geomorphic and soil properties suggest that the ages of several shorelines above the latest Pleistocene level increase as a function of elevation. Shoreline deposits at three sites in western Nevada were sampled for cosmogenic nuclide (^{36}Cl and ^{10}Be) dating to test this apparent increase. ^{36}Cl results from sites near Walker Lake, Nevada and in Newark Valley, Nevada corroborate the geomorphic and soil evidence. Furthermore, ^{36}Cl results suggest that Lake Lahontan filled to nearly the same level during oxygen isotope stages 2 and 4; the results also suggest large filling events occurred during stages 6, 8, and at least one even earlier stage. From these results, we can conclude that the Lahontan Basin filled more frequently and to higher levels than previously thought and that, generally, lake levels were progressively lower with time.

PP71B-0400 0830h POSTER

The Mid Pleistocene Climate Transition Recorded in a Hemipelagic Sediment Drift (ODP Leg 194): Implications for the Understanding of Continental Margin Sediment Sources and Sinks

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The Marion Plateau (NE Australia margin) provides an ideal setting to study continental margin paleoceanographic history. It is not significantly current scoured and is located at upper continental slope depths, freeing it from the influence of large sediment gravity flows. Atop the plateau, a hemipelagic sediment drift is perched and was drilled on Ocean Drilling Program Leg 194 (site 1198). The lithologic record and other shipboard-acquired data sets (physical properties, downhole logging), as well as the site-survey seismic data all suggest that cyclicity dominates this sedimentary section, which encompasses the Mid Pleistocene climate transition (0.9 to 0.92 Ma). This period contains the transition from a 41 k.y. cycle (ice volume and temperature) to 100 k.y. (ice volume and temperature) cycle dominated world.

Preliminary results indicate that the basic stratigraphic units of this drift record terrestrial climate, continental margin, and pelagic processes. Mass accumulation rates of the siliciclastic, neritic carbonate, and pelagic carbonate components represent orbitally-forced cycles that form a predictable sedimentary architecture, and grain size variations are a proxy for fluctuations in bottom current strength. The terrigenous flux varies as a function of both aridity/humidity variation on the adjacent continent and sea-level fluctuations, while the carbonate flux varies as a function of paleoproductivity of the overlying water column plus lateral input from the developing Great Barrier Reef. Examination of the changing sedimentary architecture of this drift during the Mid Pleistocene climate transition will further the understanding of sedimentary sources and sinks along continental margins, including their sensitivity to sea level, climate, and circulation changes.

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Examining the Pacific Airmass Model of Holocene Aridity in the Mid-Continent of North America

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Fossil pollen data and estimates of past lake-levels have long shown that conditions in the mid-continent of North America were drier during the mid-Holocene than today. The enhanced aridity has often been explained by increases in the dominance (frequency or duration) of Pacific airmasses accompanying low-amplitude zonal flow patterns. To test this hypothesis (that enhanced westerlies delivered dry airmasses and, therefore, drier conditions), we analyzed modern episodes between 1959-1997 when westerly flow was anomalously strong. The analysis of modern climate data focusing on these periods demonstrates that anomalous dry conditions do not result. Rather, anomalous dry conditions in the mid-continent develop due to the dynamic interplay between surface conditions and atmospheric processes. Regional moisture-balance depends not only on the flux of atmospheric moisture into the region, but also the recycling of soil moisture and the atmospheric mechanisms that enhance or suppress precipitation. Today, a consistent relationship exists between vertical motion in the atmosphere and precipitation. During both anomalous dry and wet years, Gulf of Mexico moisture is transported into the mid-continent. However, without an uplift mechanism, precipitation is suppressed during anomalous dry years even though moisture is available. Consequently, both moisture availability (determined by atmospheric moisture flux and soil moisture recycling) and a mechanism for precipitation (vertical motions in the atmosphere) are involved in establishing wet or dry conditions today, as well as during the mid-Holocene.

URL: http://geography.uoregon.edu/envchange/clim_animations/index.html

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Indian Ocean Dipole-Like Pattern in Late Pleistocene Sediments off Sumatra

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Sediments off Sumatra (Indonesia) provide biological, biogeochemical and sedimentological evidence of past changes in the Southeast Asian monsoon system as well as indications for exchange of water masses between Indian and Pacific Oceans. For the past 300,000 years, the monsoon system has been externally forced by cyclic changes in solar radiation. Variations in carbonate productivity are caused by glacial-interglacial variability whereas organic matter productivity (expressed by the organic carbon content) is precession controlled. Cross-spectral analyses demonstrate that organic matter productivity is at its maximum nearly 6000 years after maxima in precessional radiation. Although sea surface temperature (SST; derived from alkenones) variability is dominated by the eccentricity frequency band (with up to 5°C temperature difference between glacial and interglacial phases), SSTs indicate that during TOC maxima temperature decreases by up to 1.5°C. These cooler SSTs are attributed to intense phases of upwelling. Recently it has been shown that these enhanced upwelling phases are due to (the irregular occurrence of) interannual dipole mode events. These are associated with zonal wind anomalies along the equator and alongshore wind anomalies off Sumatra which lead to floods in east Africa and droughts in Indonesia. Thus, we infer that these periods of cooler SSTs (lagging the precessional radiation by 6000 years) are related to periods of more frequent dipole events.

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Seawater Phosphorites of the Seamount, Southwestern Pacific

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Phosphatized carbonate rocks associated with ferromanganese crusts (Fe-Mn crust) were investigated for better understanding of diagenetic evolution of the seamount (one of the Margellan Seamount Trail), southwestern Pacific. Three stages of phosphatization are inferred on the basis of paragenetic relation with Fe-Mn crusts, which are divided into four layers by their textures; 1) layer 1, massive, columnar growth structures with some porosity, 2) layer 2, porous, digitate growth structures with brown Fe-oxide filling, 3) layer 3, digitate and ovoidal growth structures with carbonate sediments filling, 4) layer 4, massive, parallel to undulatory laminated textures.

Early phosphatization (phosphorite I) occurred before the formation of the oldest layer 4 crust. Foraminiferal-nannofossil limestones and shallow-water bioclastic limestones, encrusted by layer 4 crusts, are replaced by phosphorite I. Strontium isotope ratios (0.70743 to 0.70766) indicate that this phosphorite is formed at Late Cretaceous (85.2 to 73.5 Ma). Oxygen isotope values (-0.6 to 0.1 PDB) and shale-normalized REE pattern suggest that phosphorite I was formed in normal seawater. Phosphorite I appears as subhedral to euhedral, prismatic hexagonal crystallites approximately less than 5 m in length.

The second phosphorite (phosphorite II) is formed during the cessation of layer 4 crusts. Foraminiferal-nannofossil limestones filling the fractures developed within layer 4 crust are phosphatized during this episode. Age of phospatization II is defined as Late Eocene to Early Oligocene (36.5 to 31.6 Ma) from strontium isotope ratios (0.70777 to 0.70793). Oxygen isotope values (-2.9 to 2.9 PDB) and shale-normalized REE pattern of phosphorite II also suggest normal seawater origin. Phosphorite II replaced carbonate grain appears as anhedral, submicron-sized crystallites, whereas euhedral, prismatic hexagonal crystallites are filling the open space. Global climatic transition from a nonglacial to glacial period during Late Eocene to Early Oligocene intensified oceanic circulation and upwelling in deep-sea environment. Under this circumstance, phosphorite II may have been formed by redistribution of dissolved phosphous, accumulated in deep-sea during stable condition, to shallow environment.

The last phosphatization (phosphorite III) occurred during or after the formation of layer 3 crust. Foraminiferal-nannofossil limestones filling the porosity and interstices within digitate layer 3 crust are phosphatized during this stage. Strontium isotope ratios (0.70827 to 0.70882) suggest that phosphorite III is formed from Oligocene/Miocene boundary to Middle Miocene (23.6 to 13.1 Ma). Shale-normalized REE pattern indicates this phosphorite was formed in normal seawater. Exclusively low oxygen isotope values (-10.7 to -2.4 PDB) suggest phosphorous ions responsible to phosphorite III probably provided during diagenesis of surrounding layer 3 crust.

PP71B-0404 0830h POSTER

Late Pleistocene Paleoenvironment Indicated by Stable Isotopes and Elemental Compositions of Bivalve Shells from Southern Taiwan

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We have analyzed the isotope and element compositions of two modern and two Late Pleistocene *Anadara granosa* shells to quantitatively characterize the paleoenvironment in Szekou Formation, Hengchun, southern Taiwan. δ^{18}O values of modern shells (-2.2±0.8 permil; mean±1σ; N = 76) are in good agreement with those calculated values based on available seawater δ^{18}O and temperature data, thus reach apparently isotopic equilibrium.

Fossil shells, retaining the originally aragonitic mineralogy, indicate that these shells are not altered by diagenesis. Mean δ^{18}O and δ^{13}C values of the Lower Szekou Fm. (LSz) shell are respectively -0.6±0.7 permil (N = 82) and -3.6±0.7 permil. Average δ^{18}O and δ^{13}C values of the Upper Szekou Fm. (USz; 25 m above LSz) shell are -0.7±0.7 permil (N = 47) and -2.6±0.8 permil, respectively. Both LSz and USz show positive linear correlation between δ^{18}O and δ^{13}C values with different slope (intersect at δ^{18}O= -5.4, δ^{13}C= -6.8 permil). Therefore, samples from Szekou Fm. show significant fresh water-seawater mixing signals.

Average δ^{18}O value of fossil specimens is 1.5 permil greater than that of modern ones and is most likely due to global glaciation effect. Assuming the δ^{18}O of seawater was 1.5 permil, the winter seawater temperature of studied area was about 24°C. The calculated temperature is comparable to that of modern seawater. With the seasonal temperature range of 5°C, the river water δ^{18}O values were estimated between -6.4 and -7.5 permil.

Average Mg/Ca, Sr/Ca, and Ba/Ca ratios are respectively 0.22±0.02 mmol/mol, 1.48±0.15 mmol/mol, and 24.64±5.01 μmol/mol for LSz (N=16) and 0.28±0.09 mmol/mol, 1.67±0.25 mmol/mol, and 11.57±3.14 μmol/mol for USz (N=24). Episodic minima of Mg/Ca ratios are generally coinciding to δ^{18}O maxima. Thus, Mg/Ca ratio may be also varied as a function of temperature in the aragonitic shells. Metabolic activity of *A. granosa* should be the major factor controlling Sr/Ca ratio of the shells. Ba/Ca ratio of fossil shells may be an indicator of ambient water nutrition. Average Ba/Ca ratio of USz is 13 μmol/mol less than that of LSz, whereas δ^{13}C value of USz is 1 permil greater than that of LSz. Nutrient supply may have decreased when Szekou Formation paleoenvironment changed from open lagoon (LSz) to estuary (USz) environment.

PP71B-0405 0830h POSTER

Organic Matter Preservation Control in Modern Deep-Sea Environments: Luderitz, Benguela Upwelling System

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High organic matter accumulation occurs at all depths on the Namibian margin (South-East Atlantic), particularly under the highly active Luderitz upwelling cell (25, 7°S). Records of the past 200 ky were studied from two cores, MD962086 (25, 8°S, 12, 13°E) and MD962087 (25, 6°S, 13, 38°E), from 3606 and 1029m water depth respectively. Analyses included organic carbon contents, Palynofacies associated with TEM, carbon isotopes, chemical composition of kerogen (infra red absorption, C:N ratio and Rock Eval) and clay fractions. In this abstract, principally petrographical data are presented.

TOC concentrations reach 17% at 1000m and 8% at 3600 m water depth, exceptionally high for hemipelagic sediment. Several preservation pathways, which vary according to water depth, can be invoked to explain the OM accumulation pattern on the Luderitz continental margin:

(1) At both depths, selective preservation-related structures (*ultralaminae* and cell walls) are observed. However, this is not a major preservation pathway in the study area (10% at most).

(2) Protection by mineral matrix occurs at both sites but shows differences depending on water depth. In the shallow core, mineral-OM association microfabrics occur as large smectite and carbonate aggregates a few μm in diameter, containing discrete OM blebs (0.1 μm diameter). In contrast, the deep core is characterized by microaggregates (50 nm diameter) in which OM is intimately associated with clays. This disparity could be explained by a difference in nepheloid layer thickness between the two sites. Clay-aggregation appears to be the principal preservation mode at the deep site.

(3) Amorphous organic matter (AOM) smears were found at both depths but principally within the shallow core. These could form either by degradation-recondensation or lipid vulcanization. From 40 to 90% of the OM is preserved as amorphous smears at 1000 m water depth compared to 0 to 40% in the deeper site. AOM smears constitute between 0 and 16% of the bulk and covary with TOC both downcore and between cores. The accumulation of AOM, probably derived from labile OM, could depend on OM export flux and sinking rate.

High export flux seems to be the main cause of OM accumulation as AOM smears at 1000 m water depth. Variations in productivity conditions and, to a lesser extent, sea level changes could explain downcore AOM fluctuations. The steady accumulation (2 to 4%) of clay-protected-OM suggests that this preservation mode is efficient from the subsurface and depends not on flux or sinking rates but rather on clay content. However, water depth seems to impact the oxidation and the form of clay-associated OM.

PP71B-0406 0830h POSTER

Provenance of Atlantic Surface Sediment Based on Sr and Nd Radiogenic Isotopes

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The composition and character of terrigenous sediments can be used to trace eolian and marine transportation processes such as winds, surface currents and deep currents. We analyzed more than 80 surface sediment samples from the pelagic realm of the Atlantic Ocean for variations in terrigenous grain size and major element geochemistry. A subset of these were also analyzed for radiogenic Nd and Sr isotopic ratios. These radioisotopic data were key in recognizing samples with distinctly different source regions and when viewed in conjunction with grain size and elemental data, broadly define several different regional transport modes. Terrigenous sediment transported to the tropical and subtropical Atlantic in deeper regions away from the continental margin is composed of a mixture of eolian and hemipelagic sediment supplied from the Sahar-Sahel regions of northern Africa. At sites closer to the continental margin a similar provenance is found but turbidites and hemipelagic processes appear to dominate the transport of terrigenous material to the seafloor. In the southern Atlantic between 20 and 60°S latitude, deep advective currents have an important influence on terrigenous transport and deposition.

PP71B-0407 0830h POSTER

Coral skeletal Tin and Copper Concentration at Pohnpei, Micronesia, as a potential proxy for marine pollution

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Coral reefs are increasingly threatened by human activities such as industrialization, sewage discharge, dredging, deforestation and so on. The annually-banded coral (*Porites* sp.) collected from Pohnpei Island, Micronesia, recorded fluctuations of copper (Cu) and tin (Sn) contents in ambient seawater for about last 40 years. Both the elements are present in antifouling marine paints. Especially, Sn has often been used in the form of tributyltin (TBT) compound. In general, pretreatment of coral skeleton is conducted in order to remove contaminations due to coral coring and/or sample storage and then lattice-bound metals are determined as a potential proxy for marine pollution. We conducted a preliminary experimental treatment consisting of 9 cleaning steps. Based on a stepwise pretreatment examination, we found that skeletal Sn and Cu, not only inside but also outside of aragonite lattice, have potential for use as pollution indicators. High values of extra-skeletal Cu/Ca and Sn/Ca atomic ratios were found between late 1960s and late 1980s during a period of active use of TBT-based antifouling paints worldwide. However, significant decrease in both the ratios since the beginning of 1990s can be attributed to regulation of use of TBT on cargo ships by the developed countries such as the USA, Japan and Australia.

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PP71B-0408 0830h POSTER

Fluctuations in the Ocean Environment within the Western Pacific Warm Pool during the Late Quaternary: Evidences from the Banda Sea

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Multiple proxies have been applied for study of fluctuations in the ocean environment within the western Pacific warm pool during the Late Quaternary. Time series records of $^{230}Th_{ex}{}^{0}$ -normalized fluxes of carbonate, biogenic opal, and organic carbon in core MD012380 were reconstructed to examine environmental responses to glacial-interglacial climatic changes in the region of the western Pacific warm pool. The core was collected from the water depth of 3232 m within the Banda Sea by R/V Marion Dufresne during its IMAGES 2001 cruise. The proxies of biogenic productivity were clearly responded to glacial-interglacial alternations, although oceanic surface temperature fluctuated within a narrow range. The results are similar to other studies that have reported higher glacial productivity in low-latitude regions. The C_{org}/N atomic ratios in core MD012380 ranged between 5.7 and 11.6, indicating a typical sedimentary marine organic matter signals. The nitrogen isotopic records of the sediments from the Banda Sea showed glacial increase of the input of deep-water source into the surface water implying glacial increases of upwelling intensity. Thus, wind-related mixing or upwelling would have increased primary productivity within the western Pacific warm pool during glacial periods when the Asian winter monsoon was more developed.

PP71B-0409 0830h POSTER

Recent Canyon Heads at the Bosphorus Outlet

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The Black and Marmara Seas have witnessed increased scientific interest in last decade due to improved cooperation between the riparian countries and western scientific institutions but also due to the controversy existing about the origin of the reconnection of the Black Sea and Mediterranean seas after the last Glacial Maximum and its ensuing sea level rise. The Black Sea is linked to the global ocean only through the Bosphorus-Dardanelles system of straits. The Bosphorus is narrow (0.76 to 3.6 km wide) and shallow (32 m) at the sill, restricting the two-way water exchange between the brackish Black Sea and the very saline Mediterranean Sea. The Bosphorus sill was responsible for the behaviour of the Black Sea during the global glaciations and deglaciations, during which the Black Sea level followed the global sea level changes as long as they were higher than the sill. When global sea level was lower than the Bosphorus sill the variations of the Black Sea level reflected specific regional climate conditions without being coupled to the ocean changes. Recent studies suggest that a rapid flooding event may have occurred in the Black Sea during the Holocene. In 1998, a French-Romanian survey collected 4500 km of high-resolution seismic profiles, multibeam bathymetry, and sediment cores on the northern margin of the Black Sea where the shelf is sufficiently wide to preserve ancient shorelines in the vicinity of the shelf edge. If rapid flooding occurred through the Bosphorus Strait to drown these shorelines, it should have created a cataract. In August 2002, the French research vessel Le Suroit equipped with a EM 300 multibeam echosounder and a TritonElics Chirp Sonar mapped the Bosphorus outlet at the shelf edge. The results show a large retrogressive canyon deeply incised into the shelf which can be followed landward towards the Bosphorus outlet. Coring on the shelf and in the canyon revealed mega-ripples of shell debris of recent origin.

PP71B-0410 0830h POSTER

Carbon and Nitrogen Stable Isotope Composition of OM From Florida Bay, the Initial Results of a Paleoenvironmental Seagrass Reconstruction

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The shallow marine waters of Florida Bay provide an ideal environment for seagrasses, which are the most common benthic community in the region. However, these communities are susceptible to a variety of anthropogenic disturbances, particularly changes in water quality, and environmental conditions in Florida Bay have become a concern due to recent increases in salinity, the frequency of algal blooms, and seagrass die-off. These changes have been attributed to 20th century decreases in freshwater discharge from the Everglades to Florida Bay, deteriorated water quality, and changes in exchange between Florida Bay and the Atlantic Ocean. In order to better understand environmental change over long timescales, sediment cores were collected in the summer, 2002, from four locations in Florida Bay for multiple proxy analyses of seagrass abundance, which is an excellent indicator of water quality. Sediment depths ranged from 96 to 244 cm, potentially representing a 5000-year time series. Cores were sampled in 2-cm increments representing an average of 2-10 years for bulk isotopic analysis of sediment organic content. In 2 cores analyzed, $\delta^{15}N$ values ranged between 3.2 and 7.6$^{o}/_{oo}$, following an oscillating pattern over time. $\delta^{13}C$ values ranged between 11.2 and -8.6$^{o}/_{oo}$ along a progressive enrichment trend that is inconsistent with the adjacent development of the metro Miami area and agricultural activities. These patterns show evidence of decoupling between carbon and nitrogen isotopic systems, although values throughout suggest that buried organic matter at these 2 sites is seagrass-derived. Further bulk isotopic analyses of remaining cores, together with organic biomarker analyses, diatom and foraminiferal community analyses, and development of an age model for the cores, will allow more definitive interpretation of the isotope patterns with implications to seagrass productivity levels, and thus, water quality, over time in Florida

PP71B-0411 0830h POSTER

Paired ^{230}Th - ^{14}C Ages of Deep-Sea Corals From the Huon Gulf, Papua New Guinea

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In August/September of 2001, a group of scientists from the University of Minnesota Duluth, the University of California Santa Cruz and the University of Papua New Guinea used the ROV Jason to sample submerged carbonate platforms constructed by reef building corals in the Huon Gulf, Papua New Guinea. We were fortunate to find and sample several deep-sea corals growing on top of the submerged platforms. We collected several samples of *Madrepora arbuscula* which were concentrated at two depths: 250-300 meters and 1100-1200 meters.

These branching deep-sea corals range from 10 to 30 cm tall; some have thick basal stems of up to 5 cm. We sampled the branch tips for ^{14}C and ^{230}Th dating. ^{14}C ages for the samples at depths of 288 and 255 meters are 980 and 2530 years, respectively, while samples found at depths of 1133, 1218, 1216, and 1161 meters had ^{14}C ages of 13180, 20760, 22480, and 24010 years, respectively. ^{230}Th dating resulted in ages of 16670 years for coral at 1133 meters, and 28670 years for coral found at 1161 meters depth. The ^{230}Th age of the 1133 meter coral sample may be inaccurate as the $\delta^{234}U$ value (158 $\pm$ 3) is above the modern value (146). The $\delta^{234}U$ value of the 1161 meter coral is within error of the modern value, suggesting the ^{230}Th age is reliable. Our data suggests a calendar age of 28670 $\pm$ 150 years for a ^{14}C age of 24010 $\pm$ 300 years. This result is similar to paired ^{230}Th - ^{14}C ages from Lake Lisan (Schramm et al.,2000) and Lake Suigetsu (Kitagawa and van der Plicht, 1998), but does not account for a ^{14}C residence time of the water. A younger ^{14}C age for the 1161 meter coral would bring the paired ages in line with the Bahamian speleothem data (Beck et al., 2001).

^{230}Th ages will be determined for each of the samples for which we have ^{14}C data. Additional samples will be taken from both the inner and outer growth rings of corals with thick bases for further ^{14}C and ^{230}Th dating. These measurements will make it possible to evaluate growth rates and to constrain the ^{14}C residence time.

Beck et al., Science 292, 2453 (2001). Kitigawa and van der Plicht, Science 279, 1187 (1998). Schramm et al., EPSL 175, 27 (2000).

PP71B-0412 0830h POSTER

Fertilizing the Ocean Deserts During the LGM: Is There Evidence for Increased Paleoproductivity and Redfield Decoupling in the Glacial Tropical/Subtropical World Ocean?

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Twenty-five cores were taken from all three tropical and subtropical ocean basins to evaluate changes in surface water productivity as a function of Dd13Ccalcite G. ruber (LGM-HOL) of the low latitude biological pump in a cool glacial world. Corrections applied to the data included a -0.32 carbon reservoir effect, as well as correcting for temperature dependent atmospheric-oceanic CO2 equilibrium. Evidence for productivity in excess of Redfield Dd13Ccalcite G. ruber : [PO4-] limitations is taken where Dd13Ccalcite G. ruber (LGM-HOL) in excess of Redfield = Dd13Ccalcite G. ruber (LGM-HOL) -0.93 _umol*kg [PO4-]. Dd13Ccalcite G. ruber distributions allow for three main conclusions regarding the strength of the biological pump in tropical and subtropical HNLP and LNLP zones during the Last Glacial Maximum:

1.) Nutrient fronts associated with HNLP regions today expanded further into subtropical oligotrophic gyres, where iron deposition in a dustier glacial world freed phytoplankton from iron limitation, thus allowing for enhanced carbon export out of surface waters. Almost all sites demonstrated increased export in these regions in accordance to and within detectable bounds of presently understood Redfield nutrient dynamics.

2.) Evidence for decoupling of Redfield occurs in the oligotrophic world ocean along HNLP-LNLP transitional niche ecotomes. Redfield decoupling in these zones can be associated with sites of large diatom paleo-depositional events limited in spatial extent, but very intense in production through time during the Last Glacial. Diatom species associated with large Dd13Ccalcite G. ruber isotopic excursions beyond Redfield constraints are non-obligate diazotrophs Rhizosolenia sp and Ethmodiscus Rex. Decoupling of Redfield at these sites leaves unique isotopic signatures in marine sedimentary records despite lack of preservation for other diazotrophs such as cyanobacterial Trichodesmium sp.

3.) Despite the presence of smaller diazotrophs in the modern LNLP ocean, productivity within deeply oligotrophic gyres operate at steady state export on glacial-interglacial timescales as a consequence of a

deeper mixed layer, thus making phosphate reserves inaccessible to larger diazotrophs.

Correlations between phosphocline depth and changes in productivity over glacial-interglacial timescales suggest that productivity changes track mixed layer depth. Mixed layer depth should be a function of atmospheric-surface ocean feedback, secondary to sustained wind strength. If intensity of export productivity tracks both thermocline and phosphocline depth, then rates of carbon fixation by increased efficiency of phosphate uptake due to lifting of iron limitation as well as rates of non-Redfield productivity increases should oscillate and lag changes in the hydrological cycle on both Milankovitch and suborbital timescales. Spatial correspondence between occurrences of diatom mats of Rhizosolenia sp. and Ethmodiscus Rex to export productivity in excess of Redfield constraints on carbon fractionation is encouraging for arguing enhancement of both the biological pump, and possibly, N-fixation in a cooler glacial world.Increases in the silica pump allow for greater pCO2 drawdown without corresponding changes in ocean alkalinity. Whether or not such increases in export productivity at low-latitudes can actually account for PCO2 drawdown remains to be modeled.

PP71B-0413 0830h POSTER

Seasonal Changes in the Arabian Sea for Last 19 ka: Evidence From δ^{18}O Values of Individual Planktonic Foraminifera Shells

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Oxygen and carbon isotope analyses of individual *Globigerinoides sacculifer* and *Neogloboquadrina dutertrei* were carried from the ODP Site 723A in the Arabian Sea to unravel the seasonal changes for the last 19 ka. *G. Sacculifer* is a surface dweller and *N. Dutertrei* has a deeper depth habitat (100m) and thus it is expected that the range in d18O changes of an individual shells of two species provide seasonal changes in surface and subsurface water through time. δ^{18}O values of individual *G. Sacculifer* and *N. Dutertrei* ranges from 0.54 to 2.09 per mil and from 0.38 to 1.37 per mil respectively. Both species have shown maximum inter-shell δ^{18}O variability and high standard deviation from 16 to 9 ka suggesting strong seasonal δ^{18}O changes in surface and subsurface water in the Arabian Sea. Inter-shell δ^{18}O variations were greater in *G. Sacculifer* than that of *N. Dutertrei*, which suggest that seasonal variability is more in the surface water compared to the subsurface water. From 19 to 16 ka and 6 to 1 ka the δ^{18}O variations in both species were low, which reflects less seasonality during this time.

Globigerina bulloides, Pulleniatina obliquiloculata and *Uvigerina excellens* show sharp depleted δ^{18}O excursion around 9 ka, ascribed to the distribution of melt water flux of Termination IB to this region. A synchronous δ^{18}O shift in surface, subsurface and bottom water living foraminifera around 9 ka reveals a rapid transfer of Termination IB signal through the vertical circulation of the Arabian Sea in response to peak monsoon intensity.

PP71C MCC: 131 Sunday 0830h

The Climate Record of the Last Two Millennia I *(joint with A, OS, GC)*

Presiding: **L Stott,** University of Southern California**; B Buckley,** Lamont-Doherty Earth Observatory of Columbia University

PP71C-01 0830h

Solar Variability and Climate Change in the Last 2000 Years

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Studying past climatic data can help us better understand present natural variations and predict future trends. Identification of cycles can be useful to forecasting. However, various reconstructions of the climate of the last 1000 years have given only broad similarities, with large variances in time and space [Briffa JGR 106, 2929, 2001]. For example, during the Little Ice Age (ca. 1600-1800) severe winters were frequent in Europe and China, but not over Greenland [Sci. Amer., 2/1992, 21]. The differences in modeling results are partly due to uncertainties in the past radiative forcing [Mann, Eos 82 (46), 2001]. Another outstanding question is whether we are in a time similar to Medieval Warm Period.

From the frequencies of sunspot and aurora sightings, abundance of carbon-14 in the rings of long-lived trees, and beryllium-10 in the annual layers of polar ice cores, we have reconstructed the recent history of a variable Sun. In the past 1800 years the Sun has gone through nine cycles of changes in brightness. While these long-term changes account for less than one percent of the total irradiance, there is a clear evidence that they affect the climate.

During the Maunder Minimum (1645-1715) few sunspots were seen–about 1 in 10 yr from China or Europe–indicative of a weak Sun. Eddy [Science 192, 1189, 1976] used historical aurora, C-14 and climate data to confirm its reality, and link it to the Little Ice Age.

Using new historical sunspot catalogues [Yau, Quart. J. Roy. Astron. Soc., 29, 175, 1988], we have identified or confirmed earlier solar minima at 200-300, 400-500, 580-820, 980-1070, 1280-1350, 1410-1590; and maxima at 1080-1280, 1350-1400, etc. All these features are coincident with respective minima or maxima in the frequency of aurora sightings from Europe or Asia. Both time series are in turn consistent with radioisotope data [Pang, Eos. 9/2002].

Carbon-14 and beryllium-10 are made by cosmic rays high in the atmosphere. When the Sun is active the solar wind (energetic electrons and protons), and it's associated turbulent magnetic field, repels the cosmic rays better, and less of the radioisotopes are made, and vice versa. Abundance of C-14 in the rings of long-lived trees and Be-10 from polar ice cores thus have deviations from long-term trends (due to secular variations in the geomagnetic dipole moment) that are coincident with, but in the reverse sense, from the abovementioned features in the historical sunspot and aurora time series.

For times without thermometer data, temperatures can be estimated from, e.g., O-18 isotopic abundance in ice cores, which in turn depends on the ocean temperature it evaporated from. We have linked the Medieval Minimum to a cold spell, dated to ca. 700 by Dansgaard [Nature, 255, 24, 1975]. Students of records of advances and retreats of glaciers, have previously linked it to a cold spell in the preceding two centuries, thus requiring a shift in time scale.

The 5th-Century Minimum is consistent with the cold climate that prevailed over Eurasia [Pang, Eos, 80 (46), F220, 1999]. The cold apparently forced massive southward migrations of Teutonic ad Asian barbarians into the Roman Empire, ending it in 476. Europe was plunged into the Dark Age, from which it did not recover until the climate warmed up at the end of the millennium [Randsborg, The First Millennium AD in Europe and the Mediterranean, 1991].

The warm and clement climate of the 20th century, and perhaps the immediate future, appears to resemble that prevailed 2000 years ago, when great civilizations flourished over the Eurasian continent, e.g., the "Golden Age" of Rome and the Han dynasty in China.

PP71C-02 0845h

Climate Radiative Forcing Changes Over the Last 4000 Years

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Radiative forcing changes have been shown to explain about 50% of decadal-scale variance over the interval 1000-1850 and can either link hemispheres or affect regions separately. While solar and greenhouse gas changes are fairly uniform globally, volcanism can link hemispheres only if the eruptions are in low latitudes. I have compiled information from long ice cores on both Greenland and Antarctica to infer low latitude eruptions over the last 4000 years by identifying coincident peaks in sulphate loading from both ice sheets. Results have been combined with independent evidence for changes in greenhouse gases and solar irradiance. Although the southern hemisphere volcanism record is more uncertain prior to 2000 BP, between 1,000-2,000 BP only three volcano peaks co-occur in Antarctic and Greenland ice cores, while 15 occur in the last millennium, and two others are known from eruptions of the last two decades. These eruptions tend to cluster in the 13th, 17th, and early 19th centuries times when other evidence indicates the northern hemisphere was cold. Both regions have relatively low incidence of volcanism from 900-1200 AD a time of relative warmth in the northern and (possibly) southern hemisphere. The northern hemisphere volcano record also shows a cluster of eruptions in the 7th century, when other evidence again indicates some cooling. These results suggest that volcanism may modulate the coupling of climate change between the hemispheres.

Results from all sources of radiative forcing were used to drive an energy balance climate model simulation for the last 4,000 years. The coldest simulated intervals are 1500-1250 BC, the 800-650 BC Iron Age Cold Period, and the Little Ice Age (1300-1850 AD). Cooling is also simulated for parts of the early Middle Ages. All of the Bond advances of the last 4000 years agree within 200 years of times of simulated net cooling in the energy balance model. These results reinforce earlier conclusions that radiative forcing perturbations explain a very substantial amount of decadal-centennial scale variance in the late Holocene.

PP71C-03 0900h

The EASTNET Project: Extending the Network of Climate-Sensitive Tree-Ring Chronologies From the Eastern United States for Reconstructing the Spatio-Temporal Characteristics of Climate and Drought Over the Past Millennium

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Recently, a network of gridded PDSI reconstructions for the contiguous United States was produced, based on the available network of drought-sensitive tree-ring chronologies (Cook et al. 1999). Analyses were constrained to the common period of 1700 1979 due to the limitations of the available tree-ring data. While several chronologies from the western U.S. span 1,000 years or more, very few chronologies from the eastern U.S. covered even the past 500 years. The objective of this project, funded by the National Science Foundations ESH program, is to extend the tree-ring chronology network from the eastern U.S. with chronologies spanning the past 500-1,000 years. This aim is being achieved by sampling in areas that have escaped the effects of development, logging and major disturbance such as fire. The two main target species are Thuja occidentalis (eastern white cedar) and Juniperus virginiana (eastern red cedar). The primary terrain types are on cliffs, rocky outcrops, and other areas that have been difficult to access. We have already developed chronologies from Wisconsin, New Hampshire, Pennsylvania, West Virginia, and Virginia that span from 500 to 1500 years. The temporal depth of these chronologies is being extended through the exploitation of "sub-fossil" wood found at these sites, in the form of standing-dead stems and downed and buried logs. We are also currently pursuing leads in Maine, Vermont, Massachusetts, Connecticut, New York, New Jersey Pennsylvania, Kentucky and North Carolina where old cedar trees have either been reported or where terrain types match criteria developed for this project. In this paper we discuss the current status of the network, and explore the spatio-temporal characteristics of climate and drought across the eastern US for the past 500 years and more. We use our preliminary network to explore the regional expression of climate anomalies such as drought. Our analyses so far demonstrates multicentennial variability suggestive of Medieval Warm Period (MWP) and Little Ice Age (LIA) type signatures from an eastern red cedar chronology from West Virginia that spans the past 1,500 years. This is the oldest chronology so far developed from this project, though we anticipate the development of several more millennial length time-series within the next year.

References Cook, E.R., Meko, D.M., Stahle, D.W., and Cleaveland, M.K. 1999. Drought reconstructions for the continental United States. Journal of Climate 12:1145-1162.

PP71C-04 0915h INVITED

The 8th Century Megadrought Across North America

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