

PP21C MCC: Hall D Tuesday  
0830h

High-Resolution Sediment Records of  
Coastal Upwelling Posters (joint with  
OS)

Presiding: G Wefer, Geowissenschaften  
Universität Bremen; W H Berger,  
Scripps Institution of Oceanography

PP21C-0333 0830h POSTER

Reconstruction of Benguela Current  
Ocean Productivity and West African  
Vegetation During Oxygen Isotope  
Stages 100 and 101.

Mark Maslin<sup>1</sup> (mmaslin@geog.ucl.ac.uk); Simon  
Denison<sup>1</sup> (sdenison@geog.ucl.ac.uk); Virginia  
Ettwein<sup>1</sup> (v.ettwein@ucl.ac.uk); Christopher  
Boot<sup>2</sup> (c.boot@bristol.ac.uk); Richard Pancost<sup>2</sup>  
(R.Pancost@bristol.ac.uk); Richard Evershed<sup>2</sup>  
(R.Evershed@bristol.ac.uk); Ellen Platzman<sup>1</sup>  
(E.Platzman@ucl.ac.uk); Richard Murray<sup>3</sup>  
(rickm@bu.edu); Antoni Rosell-Mele<sup>4</sup>  
(antoni.rosell@uab.es)

<sup>1</sup>Department of Geography, University College London  
26 Bedford Way, London WC1H 0AP, United  
Kingdom

<sup>2</sup>Organic Geochemistry Unit, Biogeochemistry Re-  
search Centre School of Chemistry University of  
Bristol Cantock's Close, Bristol BS8 1TS, United  
Kingdom

<sup>3</sup>Department of Earth Sciences, 685 Commonwealth  
Avenue Boston University, Boston MA 02215,  
United States

<sup>4</sup>Centre of Environmental Studies, Autonomous Uni-  
versity of Barcelona, Barcelona 08193, Spain

The intensification of the Northern Hemisphere  
Glaciation (3.2 to 2.5 Ma) is a key climatic transi-  
tion in Earth History. Deep-sea sediments recovered  
from ODP Leg 175 Site 1083 cover this important time  
period. Site 1083 has the advantage that it monitors  
both changes in the Benguela Current Upwelling sys-  
tem as well as the adjacent African continent. In this  
study we have focused on the interglacial (OIS 101)  
and glacial (OIS 100) periods that make up the final  
intensification step in this climatic transition. With  
a resolution of approximately 1 ka, we have recon-  
structed the following climatic parameters: Global ice  
volume (benthic foraminifera oxygen isotopes), wind  
strength and land aridity (HIRM, MS, Al/Ti ratios),  
upwelling intensity (UK37-SSTs), surface water pro-  
ductivity (TOC, Chaetoceros resting spores, alkenone  
abundance, pigments, Ba), surface water nutrient avail-  
ability (organic nitrogen isotopes), nutrient source (di-  
atom species abundance), and land vegetation type (n-  
alkane abundance and carbon isotopes). Two conclu-  
sions have been drawn from this unique data set: 1.  
Surface water productivity peaks during glaciation, but  
is in fact lower during the full glacial than the previous  
interglacial. It is suggested that this is caused by the  
antagonistic effects of upwelling intensity and nutrient  
supply to this area. 2. The carbon isotopic record of  
n-alkanes, which monitors the relative abundance of  
C3 (tress and higher plants) vs C4 (tropical grasses)  
plants, clearly shows that the vegetation of South West  
Africa during this time period co-varies with preces-  
sion and is independent of glacial-interglacial cycles.  
We suggest that this is due to the strong influence  
of precession on the penetration of the ITCZ-driven  
North-Central African monsoons (and resultant mois-  
ture availability) into the Congo Basin and the rest of  
SW Africa.

PP21C-0334 0830h POSTER

Holocene Evolution of two Upwelling  
Systems - Offshore Northern  
California and the Central Gulf of  
California

John A. Barron<sup>1</sup> (650-329-4971; jbarron@usgs.gov);  
James L. Bischoff<sup>1</sup> (jbischoff@usgs.gov); David  
Bukry<sup>1</sup> (dbukry@usgs.gov); Linda Heusser<sup>2</sup>  
(heusser@ideo.columbia.edu); Timothy D.  
Herbert<sup>3</sup> (Timothy\_Herbert@Brown.edu); Mitch  
Lyle<sup>4</sup> (mlyle@cgiss.boisestate.edu)

<sup>1</sup>US Geological Survey, 345 Middlefield Rd., Menlo  
Park, CA 94025, United States

<sup>2</sup>Heusser & Heusser, 100 Clinton Rd., Tuxedo, NY  
10987, United States

<sup>3</sup>Dept. Geological Sciences, Brown University, Providence,  
RI 02912, United States

<sup>4</sup>CGISS, Boise State University, Boise, ID 83725,  
United States

High resolution records from offshore northern Cal-  
ifornia ODP1019 and the central Gulf of California  
DSDP480 and BAM80E17 reveal both similarities and  
differences in the Holocene evolution of these upwelling  
systems. Common themes include: 1) an earlier  
Holocene period 11.6 – 8.2 ka with relatively high cal-  
cium carbonate deposition, probably reflecting a maxi-  
mum in summer insolation; 2) increasing diatom depo-  
sition during the middle and late Holocene, likely sig-  
naling an intensification of seasonal northwest winds;  
and 3) the onset of modern oceanic conditions between  
3.5 and 3.2 ka, possibly associated with the expression  
of increasing ENSO variability.

At ODP 1019 off northern California, cooler  
alkenone-based SSTs and the rarity of the subtropical-  
diatom *Pseudonotia dohioi* suggest that the California  
Current was rather broad during the middle part of the  
Holocene ca. 8.2 – 3.2 ka, perhaps similar to the con-  
ditions that exist during a modern La Niña. Decreasing  
wt. % CaCO<sub>3</sub> relatively low, but increasing wt. % or-  
ganic C, and low to moderate estimated opal content  
typify this middle Holocene interval. Beginning at 5.2  
ka, increasing coastal redwood pollen is evidence that  
coastal fog and coastal upwelling were becoming more  
important. Subsequently, at ca. 3.5 ka, a doubling  
of estimated opal coupled with increased coastal red-  
wood pollen suggests a further enhancement of seasonal  
coastal upwelling. At about the same time ca. 3.2 ka, a  
sustained ca. 1 deg. C increase in alkenone SST and  
3-fold increase in *P. dohioi* imply warming of fall and  
winter SSTs. An enhancement of the interannual vari-  
ability of surface water conditions at this time is prob-  
ably associated with an increasing expression of ENSO  
variability.

In the central Gulf of California between ca. 11.0  
and 8.2 ka, biogenic production was generally low com-  
pared to that of the latest Holocene, suggesting that  
wintertime NW winds were relatively weak. Stepwise  
increases in biogenic at ca. 8.2, 6.4 and 3.2 ka attest  
to a successive intensification of these NW winds, pos-  
sibly due to increasing wintertime insolation. During  
the same 8.2-3.2 ka interval, proxies for summer rainfall  
wt.% Al, Fe, Ti, Mg steadily decrease, possibly signal-  
ing a waning monsoon. The ca. 3.2 ka onset of high  
amplitude cycles of diatom-rich, terrigenous-poor sedi-  
ments alternating with sediments enriched in a terrige-  
nous component is possible evidence of the intensifica-  
tion of ENSO cycles. Diatom and silicoflagellate as-  
semblages take on modern characteristics at this time,  
suggesting an important step in the evolution of the  
upwelling system.

PP21C-0335 0830h POSTER

Coastal Upwelling off Chile: Ocean  
Productivity and Surface Sediments

Dierk Hebbeln<sup>1</sup> (49-421-2189079;  
dhebbeln@uni-bremen.de)

Frank Lamy<sup>1</sup> (49-421-2188955;  
flamy@uni-bremen.de)

<sup>1</sup>Geosciences, Univ. of Bremen, Klagenfurter Strasse,  
Bremen 28359, Germany

The coastal upwelling system of the Peru-Chile Cur-  
rent belongs to the most productive regions in the world  
oceans. In spite of this fact only very little is known  
about the sediment distribution in its southern part off  
the coast of Chile. To increase the knowledge about  
this region a multi-parameter study of the surface sedi-  
ment distribution at over 100 sampling sites along the  
Chilean continental slope between 23°S and 45°S has  
been carried out. Detailed analyses of sedimentary data  
(TOC, carbonate, and biogenic opal contents, delta  
15N) reveal a close relation to environmental conditions  
in the region.

Coastal upwelling along the Chilean coast, centered  
around main upwelling centers such as off Antofagasta  
(23°S), off Lengua de Vaca (30°S), off Valparaiso  
(33°S), and off Concepcion (35-38°S), sustains the high  
productivity observed in satellite pigment data and in  
sediment data. However, the highest pigment concentra-  
tions are found south of 40°S where prevailing on-  
shore winds of the Southern Westerlies generally pre-  
vent coastal upwelling. There, also highest estimated  
accumulation rates of organic carbon and biogenic opal  
at the sea floor are found. Thus, the general pattern  
of a southward increase of surface water productivity  
known from satellite data is closely reflected in the or-  
ganic carbon, biogenic opal and  $\delta^{15}N$  data, although  
the observation of highest productivity south of the up-  
welling area is surprising.

Probably, this high productivity in the south can  
be attributed to the advection of (macro-) nutrients  
by the Antarctic Circumpolar Current, supplying so-  
called high nutrient-low chlorophyll (HNLC) waters to  
the Chilean margin. Impinging on the Chilean mar-  
gin these waters can take up micronutrients such as  
iron from the strong riverine input and from benthic  
exchange processes. The combination of macro- and  
micro-nutrients in this area most likely results in the  
high productivity of the area between 40°S and 45°S.

From these fertile waters are transported to the  
north by the Peru-Chile Current. Although the nu-  
trients are kept in the system by coastal upwelling pro-  
cesses on their way north, total productivity is decreas-  
ing as the nutrients are gradually consumed on their  
way north and taken out of the system by sedimenta-  
tion.

PP21C-0336 0830h POSTER

Glacial Cooling in the Upwelling Region  
off Namibia: Changes in Upwelling  
Intensity or Preformed Temperature?

Stefan Mulitza<sup>1</sup> (smulitza@uni-bremen.de)

Andre Paul<sup>1</sup> (apau@palmod.uni-bremen.de)

Christian Schäfer-Neth<sup>1</sup>  
(csn@palmod.uni-bremen.de)

Söhnke Rathmann<sup>1</sup>  
(soehnze.rathmann@uni-bremen.de)

Gerold Wefer<sup>1</sup> (gwefer@uni-bremen.de)

<sup>1</sup>Fachbereich Geowissenschaften, Universität Bremen,  
Postfach 33 04 40, Bremen D-28334, Germany

We used planktic foraminiferal assemblages in 70  
sediment cores from the tropical and subtropical South  
Atlantic Ocean (10°N - 37°S) to estimate annual mean  
sea surface temperatures (SST) and seasonality for the  
Last Glacial Maximum with the Imbrie-Kipp trans-  
fer function method. The reconstructed SSTs indicate  
cooler glacial SSTs in the entire tropical/subtropical  
South Atlantic with strongest cooling in the upwelling  
region off Namibia (7-10°C), and smallest cooling (1-  
2°C) in the western subtropical gyre. Our experiments  
with a general circulation model using glacial boundary  
conditions indicate that part of the glacial cooling ob-  
served in the upwelling regions off Namibia can be ex-  
plained by upwelling of cooler central and intermediate  
waters of southern origin rather than changes in the up-  
welling intensity alone. This modified circulation pat-  
tern is the result of the reconstructed changes in South-  
ern Ocean wind stress and Weddell Sea sea surface den-  
sity. In particular, a strengthening of the Antarctic  
Circumpolar Current during glacial times goes along  
with a weakening of the Indian-South Atlantic Ocean  
exchange of warm thermocline and intermediate wa-  
ters.

PP21C-0337 0830h POSTER

Glacial/Interglacial Record of Planktic  
Foraminifera From the Upwelling  
Area off Chile

Mahyar Mohtadi<sup>1</sup> (00494212188926;  
mohtadi@uni-bremen.de)

Dierk Hebbeln<sup>1</sup> (dhebbeln@uni-bremen.de)

Gerold Wefer<sup>1</sup> (gwefer@uni-bremen.de)

<sup>1</sup>Geowissenschaften, Universität Bremen, Postfach  
330440, Bremen 28334, Germany

The southern part of the Peru-Chile Current (PCC)  
is among the least studied regions of the world ocean  
compared to other Eastern Boundary Currents (EBC).  
The PCC stands out as the EBC with the longest N-S  
extension (over 20° of latitude) and a strong contin-  
uous upwelling regime resulting in a very high biological  
productivity and an intense cycling of carbon making  
the PCC to an important part of the global carbon cy-  
cle.

We analyzed three gravity cores from the Chilean  
continental margin between 24° and 30° S to observe  
the intensity of upwelling and productivity in the PCC  
during the LGM and the Holocene deduced from plank-  
tic foraminifera assemblages. Core GeoB 3375-1 was  
recovered during the CHIPAL-Expedition of RV Sonne  
(SO-102) off the Norte Chico, while cores GeoB 7112-5  
off Antofagasta and GeoB 7139-2 off Coquimbo were re-  
trieved during the PUCK-Expedition of RV Sonne (SO-  
156). The age models for the cores are based on accel-  
erator mass spectrometry (AMS) 14C dates and sta-  
ble oxygen isotope data correlated with the SPECMAP  
stack.

Examination of the faunal composition showed the  
dominance of six species, which account on average  
for more than 90% of the total planktic foraminiferal  
assemblage. The dominant species are *N. pachyderma*  
dex. (~30%), *G. bulloides* (~27%), *N. pachyderma* sin.  
(~25%), *N. dutertrei* (~2%), *G. glutinata* (~2%) and  
*G. inflata* (~6%). Absolute concentrations of planktic  
foraminifera show a distinct maximum during the LGM.  
After lower levels during the early Holocene, the con-  
centration drops to very low middle-late Holocene lev-  
els.

The total planktic foraminifera assemblage shows  
a considerable change in the species composition be-  
tween 14 and 12 kyr BP manifested by the distinct rel-  
ative decrease of the cold water species *N. pachyderma*  
sin. and *G. inflata* opposed by the increase of the rel-  
atively warmer water species *N. pachyderma* dex. and  
*N. dutertrei*. Thus, warmer water species become dominant

at 12 kyr BP. During the LGM, the species composition and high proportions of *G. bulloides* and *N. pachyderma* sin. as well as the total accumulation rates of planktic foraminifera point to a relatively high productivity in the surface waters which can be attributed to strong, but variable coastal upwelling. After 12 kyr BP, changes in the species composition of planktic foraminifera point to a considerable warming. After 8 kyr BP, the foraminiferal accumulation rates drop significantly, indicating low productivity for most of the middle to late Holocene, which is also reflected in the species composition. Thus, the foraminiferal record suggests that more Subtropical Surface Water has been advected to the study area after 12 kyr BP.

#### PP21C-0338 0830h POSTER

##### Local and Far-Field Effects Under a Southern Californian Upwelling Cell; Trace Element Results From ODP Hole 1017E, San Lucia Slope, California.

Ingrid L Hendy<sup>1</sup> ((734) 615 6892; hendy@geol.ucsb.edu)

Thomas F Pedersen<sup>2</sup> ((250) 721 6120; tfp@uvic.ca)

<sup>1</sup>University of Michigan, Department of Geological Sciences, 2534 C.C. Little, Ann Arbor, MI 48109-1063, United States

<sup>2</sup>University of Victoria, School of Earth and Ocean Sciences, Petch Building 168, 3800 Finnerty Rd, Victoria, BC V8P5C2, Canada

Upwelling influences the marine sedimentary record by influencing organic carbon and carbonate deposition, sedimentary redox conditions. ODP Hole 1017E located under a highly active upwelling cell off Point Conception, California provides clear evidence for surface ocean productivity shifts on submillennial time scales during the last 60 Kyr. Increased productivity was largely associated with the warmer climates on the interstadials and during the Holocene suggesting that the last 50 years may not be an analogue for submillennial climate change. This no-analogue result is possibly due to complex interactions between local conditions and far-field effects in response to submillennial climate change.

Evidence based on trace elements from ODP Hole 1017E (San Lucia Slope on the California Margin) for the last 60 Ka demonstrates that significant changes in the sediment redox chemistry occurred in response to local (i.e. the wind field) and far-field (i.e. ventilation of North Pacific Intermediate Water or NPIW) conditions. Intercomparisons with multiproxy productivity indicators allow low oxygen contents associated with high organic matter input to be distinguished from low oxygen levels imported via intermediate waters. Variability in upwelling and consequently productivity occurred alongside interstadial SST shifts during the last glacial suggesting that the upwelling cell off Point Conception existed intermittently. Sulphate reduction within the sediments occurred during all warm intervals (Interstadials and the Holocene) when NPIW ventilation diminished. However Mo precipitation only occurred in association with higher productivity during the major interstadials. Iodine enrichment only occurred during the coolest stadials, when low productivity is indicated and NPIW ventilation was enhanced. These trends decouple during deglaciation when an increase in sediment porewater oxygen content is apparent from the llerd into the Younger Dryas, despite no evidence for reduced productivity. Therefore it would appear that higher 1017E sediment oxygen concentrations during the Younger Dryas were related to increased ventilation of NPIW. These results collectively demonstrate that intermediate water circulation changes occurred at this time.

#### PP21C-0339 0830h POSTER

##### The PDO and Infaunal Foraminifera Isotopic Values: Multi-Decadal Variations in Santa Monica and Santa Barbara Basins

William Berelson<sup>1</sup> (213-740-5828; berelson@usc.edu)

Lowell Stott<sup>1</sup> (stott@usc.edu)

<sup>1</sup>Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, United States

Laminated sediments within Santa Monica, Santa Barbara and Soledad (Mexico) Basins provide an opportunity to study carbon export at sites dominated by coastal upwelling. Multi-cores were collected in 2001 and sampled with mm scale resolution for both solid phase and pore water investigations. The infaunal foraminifera, *B. tenuata* was analyzed for its  $\delta^{13}C$  value; this down-core record indicates systematic changes in pore water  $\delta^{13}C$ , reflecting differences in the amount of organic carbon oxidation occurring on the sea floor. Two cores collected from Santa Monica Basin, one in the 1980s and the second in 2001 show identical trends

and structure in *B. tenuata*  $\delta^{13}C$  values between 1700 AD and the present.

Because *B. tenuata* is recording pore water  $\delta^{13}C$ , it becomes a sensitive proxy for the benthic organic carbon oxidation rate, which in-turn relates to the amount of organic carbon delivered to the sea floor. In Santa Monica Basin we see a trend from 1700 AD to the present toward greater carbon oxidation. This trend is consistent with the observation that the extent of laminated sediments has expanded within this basin over the past 300 years. Within this general trend there are some very well defined patterns and reversals, most notably is the trend toward lower rates of carbon oxidation between 1980 and the present; the documented PDO phase-shift that occurs around 1980 shows up clearly in this analyses. Other similar shifts in carbon production have occurred since 1700 AD, notably one occurred in the late 1800s and another around 1800. These both mark periods when there was a reversal from increasing inputs of organic carbon to decreasing inputs.

The increase in organic carbon delivery to the sea floor of Santa Monica Basin since 1700 has been quantified by deriving estimates of carbon oxidation rates and combining them with measurements of carbon burial rates. The range in carbon oxidized has fluctuated from about 1 to 3 mmolC m<sup>-2</sup> day<sup>-1</sup> and the overall carbon rain rate has fluctuated by about a factor of 2. Major fluctuations in the rate of carbon oxidation on the sea floor have occurred every 50-66 years and the recent phase-shift of PDO in 1980 is not anomalous.

We are examining higher resolution records of infaunal foraminifera  $\delta^{13}C$  records from Santa Barbara Basin and Soledad Basin (off Southern Baja Mexico). Sedimentation rates at these sites are at least twice that in Santa Monica Basin and thus we should see higher frequency variability in the carbon oxidation records from these sites. Preliminary results from Santa Barbara Basin indicate a similar trend toward lighter *B. tenuata*  $\delta^{13}C$  values between 1700 to 2000, indicating that the increase in organic carbon delivery to depths greater than 500 m was regionally synchronous.

#### PP21C-0340 0830h POSTER

##### Variations in Upwelling Intensity in the Benguela System from MIS3 Through Holocene: the Siliceous Signal

O. Romero<sup>1</sup> (oromero@uni-bremen.de)

G. Mollenhauer<sup>1</sup> (mollenh@uni-bremen.de)

R. R. Schneider<sup>1</sup> (rschneid@uni-bremen.de)

G. Wefer<sup>1</sup> (gwefer@uni-bremen.de)

<sup>1</sup>Dept. of Geosciences, Univ. Bremen, POBox 330440, Bremen 28334, Germany

Based on a high-resolution record of geochemical and micropaleontological proxies, we assess rapid temporal changes of upwelling intensity in the central Benguela System for the time-span between 7 and 55 kyr (<sup>14</sup>C kyr BP). Downcore variations in the content of organic carbon, calcium carbonate and opal, and the qualitative composition of diatom community preserved at the site GeoB3606-1 (off Namibia, 25°S, 13°E, 1785 m water depth, sedimentation rate = 40-44 cm/kyr) show that the intensity of coastal upwelling strongly diminished from MIS3 throughout mid-Holocene. The relative contribution of organic carbon decreased toward modern times (range 3.7-10.3%). Content of calcium carbonate increased toward mid-Holocene (range 3.1-71.2%). The relative content of opal (OC) ranged ~0.9-44.5%, and reached maximum values during the first half of MIS3, when three periods of high OC (52-49, 48.5-43, and 41.8-40 kyr) alternated with low OC. During the second half of MIS3, three periods of moderate OC (39-36.5, 33.5-30, and 28.5-26.5 kyr) were followed by lessened opal values. OC was low from the onset of MIS2 till mid-Holocene.

Diatom concentration (DC) closely paralleled OC fluctuations. Basically two distinct floral groups occur: (a) an upwelling-associated community (resting spores of *Chaetoceros*) dominating between 55 and ~13 kyr, and (b) a highly-diversified, non upwelling-related assemblage, composed by warm-water, benthic, and coastal planktonic diatoms, that became primary components from ~13 through 7 kyr. Predominance of coastal upwelling diatoms in pelagic sediments throughout MIS3 and MIS2 reflects the seaward displacement within chlorophyll filaments of organisms produced above the upper slope off Luuderitz at 25-27°S. In spite of coastal upwelling specimens being dominant in MIS2, OC and DC remained low. Injection of colder, silicate-rich waters, advected from the Southern Ocean (SO), is evidenced by the occurrence of Antarctic and Subantarctic representatives throughout MIS3, in good agreement with maximum OC and DC. This suggests that the trade wind system might have not been the only factor controlling the upwelling intensity. SO diatoms were absent from MIS2 through mid-Holocene.

Since no qualitative changes in the diatom thanatocoenosis is recorded during MIS3, we propose that the striking variations in the siliceous signal were mostly caused by dissolution of opaline parts. Well-preserved diatoms are coupled with periods of high OC and DC throughout MIS3, while poorly-preserved specimens

characterize periods of low OC and DC. This suggests short-term changes (a few thousand years) in the chemistry of the water masses off Namibia.

#### PP21C-0341 0830h POSTER

##### A new Approach for Regionalization the TOC Content in Surface Sediments - Developing Biogeochemical Provinces on a Global Scale

Katherina Seiter<sup>1</sup> (+49-421-218-8933; kseiter@uni-bremen.de)

Matthias Zabel<sup>1</sup> (+49-421-218-3392; mzabel@uni-bremen.de)

Christian Hensen<sup>2</sup> (+49-431-600-2567; lhensen@geomar.de)

Juergen Schroeter<sup>1</sup> (+49-421-218-4123; schroe@uni-bremen.de)

<sup>1</sup>University of Bremen, Department of Geosciences, Klagenfurterstr., Bremen 28334, Germany

<sup>2</sup>GEOMAR-Research Center for marine Geosciences, Wischhofstr.1-3, Kiel 24148, Germany

We present a new geostatistical approach to identify global biogeochemical provinces and to calculate the TOC content in surface sediments of the world's ocean. Organic rich continental shelves and slopes are neglected, so far, in conventional global distribution maps of the TOC content in surface sediments. Additionally, the regional variability in sedimentary benthic processes over large scales is not taken into account. Accordingly, the organic carbon content in surface sediments along the continental margins is consequently underestimated and underlying trends and processes are not visible. We compiled more than 5450 single data points of TOC surface sediment data (< 5cm sediment depth) from various literature sources as well as from retrievals of the world database PANGAEA (www.pangaea.de ~ projects). In general, the irregular distributed data show the highest sampling site density on the continental shelves and upper slopes, especially along the west coasts of the continents. If we sum up all basin areas (per. def. < 4000m WD) against all coastal areas (per. def. > 4000m WD) a data density ratio of 1 to 5 is given. Thus, 80 % of the TOC data is distributed at 8 % of the global ocean area (shelves and slopes), whereas 92 % (basins) of the global ocean area is covered by only 20 % of the data. For the developing of discriminable provinces and the calculation of the distribution of the total organic carbon content in surface sediments on a global scale the geostatistical kriging method was applied. With this method we produce visually appealing global maps from irregularly spaced data, but also incorporate and represent suggested underlying trends and anisotropies. Therefore idealized theoretical variograms were modelled, which are defined as simple mathematical functions, which relate the spatial variance of the TOC data ( $\Gamma$ ) to the distance vector in space ( $h$ ). The regional dependencies are expressed by the variograms and are used to separate adjacent areas. The selection of the TOC data for modelling the variograms is coupled to geochemical and oceanographic boundary parameters, the structure of the continental slopes, the water depth, the distance to the coast and the vegetation zones of the hinterland. However, in our approach to classify the world's ocean into finally 32 biogeochemical zones, defined by 32 variogram models, local aspects as well as global distribution patterns are weighted adequately. The kriging method uses the modelled 32 variograms of 32 zones to create a global TOC map based on a high geostatistical standard with a high accuracy of estimation of about 85% to 95%.

URL: <http://www.geochemie.uni-bremen.de/staff/seiter.html>

#### PP21C-0342 0830h POSTER

##### Vertical Distribution of Living Planktonic Foraminifera in the Northwestern North Pacific

Azumi Kuroyanagi<sup>1</sup> (+81-298-61-3765; a.kuroyanagi@aist.go.jp)

Hodaka Kawahata<sup>1,2</sup> (h.kawahata@aist.go.jp)

<sup>1</sup>Graduate School of Science, Tohoku University, Aoba Aramaki Aoba-ku, Sendai 980-8578, Japan

<sup>2</sup>National Institute of Advanced Industrial Science and Technology, 1-1 Higashi, Tsukuba 305-8567, Japan

Planktonic foraminifera reflect the upper ocean environments in terms of water temperature, salinity, food supply and so on. Fossil foraminiferal shells thus provide paleo-surface ocean information. A better understanding of the living planktonic foraminiferal ecology and the relationship between foraminifera and oceanographic conditions are important for more detailed reconstruction of paleo environments.

Since detailed information on vertical foraminiferal distribution was not available in the northwestern

North Pacific, we conducted the plankton tow in the upper 200 m for seven depth intervals (0-20 m, 20-40 m, 40-60 m, 60-80m, 80-120 m, 120-160 m, 160-200 m) at three sites (Site A (36N, 142E), Site B (41.5N, 142E) and Site b (41N, 143E)). We also measured hydrographic conditions and primary production with CTD and FRRF at the same time.

The plankton tow yielded 20 foraminiferal species (> 125 µm) at Site A and 8 species at both sites B and b. *Globigerina bulloides* (av. 19.7%), *Globigerinoides ruber* (av. 18.9%), *Neogloboquadrina pachyderma* (including *Neogloboquadrina incompta*) (av. 18.9%), *Neogloboquadrina dutertrei* (av. 14.9%), and *Globigerinoides sacculifer* (av. 6.7%) were predominant at the southern site (Site A), and *N. pachyderma* (av. 49.2 and 37.5%), *Globigerina quinqueloba* (av. 39.7 and 56.7%), and *G. bulloides* (av. 6.4 and 4.7%) were abundant at northern sites (Sites B and b).

The average standing stock of living foraminifera (0-200 m) were 24, 18, and 30 shells m<sup>-3</sup> at Site A, Site B and Site b, respectively. The standing stocks at all three sites were closely correlated with the chlorophyll concentrations except for the upper most surface layer at Site A, perhaps because major species in this study are mostly herbivores. The profiles of vertical temperature at northern sites (Site B and b) were very similar. However, the standing stock profiles at both sites showed different patterns depending on chlorophyll concentration. It suggests that foraminiferal population is more related by chlorophyll concentrations than by temperature in this study.

On the other hand, standing stocks of surface layer (0-40 m) at the southern site (Site A) were poorly correlated to chlorophyll concentrations and temperature, and well correlated to light intensity. It can be attributed to predominance of endosymbiont-bearing species which may obtain nutrition from their symbiont photosynthesis. The hosting symbiont species, *G. ruber* and *G. sacculifer* and facultative symbiont species, *N. dutertrei*, *Globigerinina glutinata*, *Pullenitina obliquiculata* and *Globorotalia menardii* have high standing stocks of 45 shells m<sup>-3</sup> at surface layer (0-20 m), mean value of 19 shells m<sup>-3</sup> (0-80 m). These species were abundant only in surface layer and diminished rapidly with depth. Predominance of endosymbiont-bearing species is the reason behind high standing stock of surface layer. Vertical distribution of foraminiferal abundance depended more on light intensity and photosynthetic activity of symbiont than on chlorophyll concentration and temperature because of predominance of endosymbiont-bearing species.

#### PP21C-0343 0830h POSTER

### Upwelling off Namibia: Approaches to Solving the Walvis Opal Paradox

Wolfgang H Berger<sup>1</sup> (wberger@ucsd.edu)

Andre Paul<sup>2</sup> (apaul@palmod.uni-bremen.de)

Gerold Wefer<sup>2</sup> (gwefer@marum.de)

<sup>1</sup>Scripps Inst Oceanography, UC San Diego, La Jolla, Ca 92093, United States

<sup>2</sup>Geowissenschaften, Bremen University, Bremen, HB 28334, Germany

Upwelling off Namibia was enhanced during glacial time in the coastal ocean off southwestern Africa, as documented in a number of productivity proxies. However, the deposition of diatoms and other siliceous plankton remains was diminished. This discrepancy is known as the Walvis Opal Paradox. Understanding this paradox is fundamental to the understanding of glacial-interglacial productivity fluctuations. Several conceptual approaches to solving this paradox have been offered. We consider two of these: (1) The suggestion that the thermocline was impoverished in silicate during glacial time, and (2) the suggestion that the change in topography that results from a drop in sea level has important implications for the rate of deposition of diatoms on the upper slope. The first approach focuses on changes in circulation and changes in overall nutrient supply. The second emphasizes regional factors affecting the position of upwelling centers and the role of recycling and redeposition of siliceous materials. Simple models incorporating the relevant processes are presented, models that can suggest observations allowing a choice between these alternatives.

#### PP21D MCC: 270 Tuesday 0830h

### The Paleogene and Cretaceous Pacific: Results From ODP Drilling I (joint with GP, OS, GC)

Presiding: D K Rea, University of Michigan; A K Tripathi, University of Cambridge

#### PP21D-01 0830h INVITED

### New Evidence for Abrupt Climate Change in the Cretaceous and Paleogene: Ocean Drilling Program Leg 198 to Shatsky Rise, Northwest Pacific

Timothy J. Bralower<sup>1</sup> (bralower@email.unc.edu)

Isabella Premoli Silva<sup>2</sup> (Isabella.Premoli@unimi.it)

Mitchell J. Malone<sup>3</sup> (malone@odpemail.tamu.edu)

Deborah J. Thomas<sup>1</sup> (dthomas1@email.unc.edu)

Leg 198 Shipboard Party<sup>4</sup> (bralower@email.unc.edu)

<sup>1</sup>University of North Carolina - Chapel Hill, Department of Geological Sciences, Chapel Hill, NC 27599-3315

<sup>2</sup>University of Milan, Department of Earth Sciences, Milan 20133, Italy

<sup>3</sup>Texas AM University, Ocean Drilling Program, College Station, TX 77845

<sup>4</sup>Ocean Drilling Program, Texas AM University, College Station, TX 77845

Sediments recovered during Ocean Drilling Program Leg 198 to Shatsky Rise in the northwest Pacific contain a record of climate and oceanography of the past 145 million years. Eight sites were drilled along a depth transect to reconstruct water column structure through the warm climate interval of the Cretaceous and Early Paleogene. The sediments recovered from this transect hold clues to a number of abrupt climate and environmental events that took place during this time interval. These transient events are recognized by major upheaval in marine communities and profoundly altered biogeochemical cycling. Shatsky Rise cores contain organic carbon-rich strata deposited during a brief interval of open ocean dysoxia or anoxia in the Early Aptian (120 Ma). Exceptional preservation of organic compounds suggests that bacterial activity helped sequester organic carbon in these strata. Graphic evidence exists in Shatsky Rise cores for the mid-Maastrichtian (69 Ma) global extinction of the inoceramids, a long-ranging, widespread group of bottom-dwelling clams. Stratigraphically expanded records of the Cretaceous/Tertiary (K/T) boundary extinction event (65 Ma) were recovered at four different sites. The cores show evidence of the response of biogeochemical cycling and the subsequent recovery of oceanic plankton in the wake of this catastrophe. A new biotic event of major evolutionary significance was found in the early Late Paleocene (58.4 Ma) possibly associated with a change in deep water circulation. The Paleocene-Eocene Thermal Maximum (PETM; 55 Ma), an abrupt warming event associated with major reorganization of benthic and planktonic communities and carbon cycling, was recovered in cores from five sites along a depth transect. PETM warming may have been induced by methane derived from dissociation of methane hydrates. The Shatsky Rise depth transect shows evidence of the expected response of such methane input: pronounced, short-term shoaling of the lysocline and calcite compensation depth (CCD). Shatsky Rise sediments also show the response of the tropical Pacific to an abrupt cooling event near the Eocene/Oligocene boundary (33.5 Ma) marking the transition from the last major greenhouse into the icehouse conditions of the remainder of the Cenozoic. This event is reflected by a marked increase in carbonate content of the sediment preserved on Shatsky Rise that signifies a profound drop in the lysocline and CCD and altered deep sea circulation patterns.

#### PP21D-02 0845h

### Molecular Proxies for Cyanobacterial Production during OAE 1a and for Cooler Waters during the Late Valanginian at Shatsky Rise

Simon C Brassell (812-855-3786; simon@indiana.edu)  
Indiana University, Biogeochemical Laboratories, Department of Geological Sciences, Bloomington, IN 47405-1403

The occurrences, distributions, abundances and isotopic compositions of preserved suites of biomarkers in organic-rich marine sediments provide proxy records that can be interpreted in terms of environmental, climatic and evolutionary change.

Assemblages of biomarkers in Lower Aptian sediments from Shatsky Rise provide evidence of variations in phytoplankton production during OAE 1a. In particular, stratigraphic variations in the prevalence of 2-methylhopanoid hydrocarbons and ketones through the event attest to significant, yet fluctuating, contributions from cyanobacteria. A prominent role for cyanobacteria among the plankton is consistent with the possibility that nutrient limiting conditions favored organisms able to fix nitrogen.

The occurrence of sterol ethers in Quaternary and Neogene sediments appears to be restricted to upwelling systems, which has prompted the suggestion, still unproven, that they derive from diatoms. Sterol ethers have also been found to occur in late Eocene through Oligocene sediments from high latitudes, suggesting an affinity with cooler water regimes. Recognition of a suite of sterol ethers in a late Valanginian organic-rich interval from Shatsky Rise therefore prompts speculation that these compounds may reflect the presence of cooler waters during this interval of the early Cretaceous.

#### PP21D-03 0900h

### The P-E Boundary Carbon Isotope Excursion in ODP Leg 198 Sites from Shatsky Rise: An Initial Test of the Methane Hydrate Dissociation Model

James C Zachos<sup>1</sup> (831-459-4644;

jzachos@es.ucsc.edu); Tim J Bralower<sup>2</sup>

(bralower@email.unc.edu); Susan Keller<sup>1</sup>

(skeller@es.ucsc.edu); Quattlebaum Thomas<sup>1</sup>

(tquattlebaum@es.ucsc.edu); T. Brill<sup>2</sup>

(tbrill@email.unc.edu); Ulla Roeh<sup>3</sup>

(uroeh1@allgeo.uni-bremen.de); Scientific Participants ODP Leg 198

<sup>1</sup>Univ. of California, Santa Cruz, Earth Sciences Dept., Santa Cruz, CA 95060, United States

<sup>2</sup>Univ. of North Carolina, Dept. of Geology, Chapel Hill, NC 27599, United States

<sup>3</sup>Universitt Bremen, Fachbereich Geowissenschaften, Bremen 28334, Germany

The Paleocene-Eocene Thermal Maximum (PETM) was characterized by rapid (<40 kyr) global warming (5-10°C), and by shifts in precipitation patterns and intensity. These changes were relatively short-lived lasting for less than <200 kyr. Several lines of empirical and theoretical evidence suggest that this perturbation resulted from an equally rapid (<10<sup>4</sup>-10<sup>5</sup> y) release of a greenhouse gas(es) into the ocean/atmosphere system. The most significant clue is a large (>3.0 ‰) negative carbon isotope excursion as recorded in both marine and terrestrial environments. The rate and magnitude of the excursion indicate an injection of a massive quantity of isotopically depleted carbon. One plausible source is the bacterially produced methane stored in marine hydrates. Numerical modeling shows that release and oxidation of 2000 Gt of methane (δ<sup>13</sup>C = -60‰) could create the observed δ<sup>13</sup>C anomaly. Such a perturbation would also create several other notable effects including an abrupt shoaling of the lysocline/CCD followed by a gradual recovery.

Ocean Drilling Program (ODP) Leg 198 recovered a series of pelagic sediment cores from Shatsky Rise in the western Pacific that enable testing of this hypothesis, in particular the predicted response of the lysocline/CCD. The PETM was recovered in 4 sites, 1208, 1209, 1210, and 1211, spanning a paleodepth range from 2.2 to 3.6 km. Each PETM horizon is marked by a distinct "dissolution" layer with lower carbonate content. Carbon isotope records constructed for each hole provide tight constraints on the timing of this carbonate dissolution layer. In essence, these records show the base of the dissolution layer to be coincident with the initial negative δ<sup>13</sup>C excursion at all sites. The timing of recovery, however, varies as a function of depth with resumption of carbonate deposition at the deeper site, 1211, delayed by 50 kyr relative to the shallowest site, 1209. Both the magnitude and rate of change in the lysocline are, within certain limits, consistent with those predicted by numerical simulations of the methane-related carbon cycle perturbation discussed above.

URL: <http://www-odp.tamu.edu/publications/198-IR/198ir.htm>

#### PP21D-04 0915h

### Climate of the Early Paleogene Tropics: The "forecast" from a coupled climate model

Mai-Britt Kronborg<sup>1</sup> (mbk@dcass.ku.dk)