excursion in the global seawater d13C record. Sedimentary sections at Rock Creek Canyon (Pueblo, CO), ODP Site 1138 (Kerguelen Plateau), Bass River (NJ), Totuma well (Venezuela) and Baranca el Canyon (Mexico) were chosen to examine potential trace metal patterns and gradients around the proposed source of hydrothermal inputs - the Caribbean Plateau, whose initial volcanic activity has been dated at 93-89 Ma. ICP-AES and ICP-MS elemental abundances from whole rock samples are normalized to Zr to remove the effect of terrestrial inputs. We find prominent trace metal "spikes" (up to 50 times background) for elements known to be concentrated in volatile degassing of magmas and in hydrothermal plumes resulting from seawater-rock reactions. These anomalies begin at the onset and continue well into the d13C excusion at all five sites. Furthermore, the magnitude of the anomalies decreases with distance from the Caribbean region, and the pattern of elements shifts from a wide range of metals near-source to predominantly long residence time metals far "downstream".

PP42C-07 1525h INVITED

Last ODP Legs Expand Black Shale Legacy of Scientific Ocean Drilling

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Scientific ocean drilling has been central to our basic knowledge about Cretaceous black shales and to our growing understanding of the paleoceanographic and paleoclimatic processes that participated in their deposition. Spot-coring during early DSDP legs charted the geographical and temporal occurrence of black shales in the ocean basins. The concept of Oceanic Anoxic Events (OAE) is part of this legacy. Subsequent drilling recovered continuous sequences that have identified patterns of geographical and temporal differences in black shale sequences and have encouraged reconstructions of the paleoceanographic histories recorded by these differences. Sequences recovered by the last few ODP Legs have expanded this legacy and have opened new opportunities for improved understandings about black shales. Leg 198 recovered a classic section of TOC-rich (35 percent) early Aptian black shale from the Shatsky Rise that corresponds to OAE1a. Leg 207 recovered Cenomanian-Turonian (OAE2) and Coniacian-Santonian (OAE3) black shales, some containing nearly 30 percent TOC, from five sites on the Demerara Rise. Leg 210 recovered TOC-rich (4 percent) laminated black shales from the deep Newfoundland Margin that correspond to OAE1d and OAE2. The Demerara Rise sequences are particularly impressive in ranging in thickness from 56m to 93m and in having well-developed laminations and shale-limestone cycles. The five sites constitute a 1km paleodepth transect and record both high surface productivity and enhanced organic matter preservation under an intensified oxygen-minimum layer impinging on the Demerara Rise.

PP42D MCC: 3004 Thursday 1600h

Nature and Causes of Cyclicity in Triassic Through Miocene Paleoclimate Records II *(joint with OS)*

Presiding: **K L Bice,** Woods Hole Oceanographic Institution**; T Wagner,** University Bremen

PP42D-01 1600h INVITED

Milankovitch Forcing in Equatorial, Late Triassic Pangea: (Deep River; Dan River, and Richmond Basins, Southeastern USA)

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The Milankovitch character of lake level fluctuations in the tropics of central Pangea has been well established since the pioneering work of Van Houten in the 1960's (1) that laid the foundation for quantitative analysis of core and outcrops in the 1990's (2,3). In the region from about 3° to 10° N latitude giant rift lakes fluctuated to the classic Milankovitch frequencies of precessional forcing of 20, 96, 128, and 404 ky, as well as the less well known 1.75 and 3.5 m.y. cycles. The latter are the Triassic values for the periods of g4-g3 of eccentricity related precessional forcing and the secular resonance, theta (2(g4- g3) - (s4-s3)), of precessional and obliquity related forcing. We attribute the forcing of lake depth largely to modulation of the strength of tropical convergence. Late Triassic rifts located from 0° to 3° N latitude show similar patterns, except with a strong tendency towards a doubling of the climatic precessional frequency and a lack of evaporites as previously reported from the Dan River basin (4,5,6). Here we report on new analyses of coal-bearing cores and drill holes from the Deep River, Dan River, and Richmond basin of older Late Triassic lacustrine strata that reinforce this pattern but show that the doubling of the precessional frequency is not ubiquitous at the equator and also show that very strong climatic transitions appear related to the 1.75 and 3.5 m.y. cycles juxtaposing coals and caliches in vertical sequence and sometimes coinciding with major faunal and floral transitions. (1) Van Houten FB. 1964. Kansas Geol. Surv. Bull. 169:497. (2) Olsen PE & Kent DV. 1996. Palaeogeo. Palaeoclim. Palaeoecol. 122:1-26. (3) Olsen PE & Kent DV. 1999. Phil. Trans. Roy. Soc. Lond. (A) 357:1761-1787. (4) Olsen PE & Kent DV.1996. Eos, Trans., AGU 77(46), Suppl.:301. (5) Olsen PE. 1997. Ann. Rev. Earth Planet. Sci. 25:337-401. (6) Olsen PE & Kent DV. 2000. in Bachmann G. and Lerche I. (eds.), Epicontinental Triassic, Vol. 3, Zent. Geol. Palaont. VIII:1475-1496.

PP42D-02 1620h INVITED

Organic Carbon Cyclicity in the Kimmeridge Clay (Dorset, UK)

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The type section of the Late Jurassic Kimmeridge Clay Formation (KCF) of Dorset (UK) has recently been completely cored and studied during the NERC RGGE project. The middle 250m of the formation is characterized by conspicuous metre-scale Milankovitch cyclicity, expressed primarily by marine total organic carbon (MTOC) content, and thought to record 38ka obliquity and 19ka precession cycles. The cyclicity is clearest where mean compacted sedimentation rates are <80m/Ma, the low dilution amplifying the effect of productivity and redox cycles on MTOC content. Overall the dominant first MTOC mode varies symmetrically from 0.5% at the top and base of the KCF, to 4-5% in the central eudoxus-wheatleyensis interval, reflecting the long term relative sea level trend and its effects on clastic dilution and bottom water oxygenation. Superimposed third order cycles also influence the cyclicity. Algorithms relating sedimentation rate, carbon delivery flux, bottom water oxygen, burial efficiency and TOC in modern marine sediments yield low to moderate mean paleoproductivity estimates of 40-150 gC/m2/a. Given low dilution and good preservation high absolute paleoproductivity is not required to explain typical MTOC values, but MTOC variation is influenced by the interaction of input, preservation and dilution (IPD) factors in a complex multivariate fashion. In this distal facies phytoclast and palynomorph concentration data (No. per mg rock) are primarily controlled by inorganic sediment dilution, not organic matter supply, which forces positive correlations between genetically unrelated particles; the concentration of refractory phytoclasts may thus provide an intra-cycle proxy for relative mineral dilution. Using this approach, comparison of different cycles suggests that the MTOC is also influenced by dilution at this scale, but changes in all the IPD variiables are probably important. Excess organic-walled plankton concentrations are sometimes correlated with heavier d13Com values, suggestive of short-term productivity spikes (calculated palaeoproductivities of up to 400 gC/m2/a), while other d13Com anomalies are apparently associated with higher contents of isotopically heavy sulphurised organic matter.

PP42D-03 1640h

Orbital Cycles, Climate, and Diagenesis Mimic Methane Releases: Results from a High Resolution Study of OAE2, New Jersey Coastal Plain

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The Cenomanian-Turonian (Upper Cretaceous) section from Bass River State Park, New Jersey contains a 15 m thick interval representing Ocean Anoxic Event (OAE2). Our high resolution (5cm) bulk sediment inorganic stable isotope record, can be used to define OAE2 at Bass River. The down-hole gamma log shows well-developed cycles throughout the OAE2 interval that we interpret as short eccentricity cycles, providing a chronology for the OAE2 event. Assuming a 95 kyr eccentricity cycle and that OAE2 at Bass River is defined the interval of high $\delta^{13}C$ values, the duration of this event was $\sim$700$\pm$100 kyr. The dominant eccentricity forcing in the Bass River OAE2 record suggests that a monsoonal circulation controlled the regional and global carbon cycles as evidenced by sedimentary organic carbon and $\delta^{13}C$, respectively. Our results show a series of negative $\delta^{13}C$ excursions, that are typically on the order of 3 to 5 per mil, but in two instances the excursions were >20 per mil. We initially interpreted these excursions as reflecting methane releases from gas hydrates. Closer examination shows that the $\delta^{13}C$ excursions were produced by seafloor diagenesis in the presence of elevated organic carbon levels. These transients are characterized by: 1) the lack of a corresponding decrease in organic carbon $\delta^{13}C$ values; 2) calcite infilling of foraminiferal shells; and 3) increased $\%CaCO_3$. The $\delta^{13}C$ value of the authigenic $CaCO_3$ is $\sim$-25 per mil, indicating that reducing organic-rich sediments supplied much of the CO_2. We argue that increases in organic carbon flux raised alkalinity (through sulfate reduction) and resulted in authigenic precipitation of $CaCO_3$ at Bass River. In our model, negative $\delta^{13}C$ excursions are the result of seafloor diagenesis that is forced by climate rather than from the dissociation of methane hydrate.

PP42D-04 1700h INVITED

African climate variability and organic carbon accumulation in the Coniacian-Satonian eastern tropical Atlantic: Insights how insolation-cycles in the Cretaceous were transformed to marine black shales

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There is increasing evidence from marine proxy records that tropical regions during the late Cretaceous were hotter than previously reported and were by far exceeding modern average temperatures. Tropical sea surface temperatures in the range of 32-36°C apparently lasted from the latest Cenomanian to the early Campanian. A fundamental consequence of superheated Cretaceous tropics is a vigorous hydrological cycle operating in equatorial regions. Geological evidence supporting such an enhanced hydrological cycle and a direct link to the formation of marine black shale cycles was recently reported for ODP Site 959 from the Deep Ivorian Basin (DIB) off equatorial West-Africa. Millennial-scale marine and terrigenous proxy records from that site provide a unique opportunity to investigate short-term variability of the ocean-climate system, to discuss the role of orbital forcing and to

assess the primary mechanisms how cyclic marine deposits are formed in the geological record. In the Deep Ivorian Basin formation of cyclic OAE3 black shales was favoured by the paleogeographic position of the drill site in the partly sheltered early Ivory Basin south of the paleo-equator and, most important, was directly linked to orbital-driven fluctuations in atmospheric and oceanic circulation. Dramatic changes in redox sensitive trace metal accumulation as well as the occurrence of molecular fossils of green sulfur bacteria provide evidence for extreme variations in redox conditions, with euxinic conditions occasionally even extending into the lower photic zone. The temporal establishment of a continuous euxinic water column about 200 km offshore the West-African coastline supports the conclusion that redox conditions in the Coniacian-Santonian tropical ocean at least occasionally were as extreme as during the Cenomanian-Turonian OAE-2, although much smaller in extent and restricted to short but repetitive periods. It has also been demonstrated that the terrigenous fraction represented by Si/Al and K/Al at Site 959 documents fluctuating supply of aeolian dust from a source area in southern Africa, represented by illite and quartz, and continental run-off from a tropical northern African source area, represented by smectite and kaolinite. Input from the two African source areas to the DIB is interpreted to document repetitive shifts in the position of the Intertropical Convergence Zone, which led to a succession of drier and wetter climate periods over western Africa. Recent results from climate modelling support such short-term fluctuations in African moisture balance/precipitation and allow to project the view from a single sample location off W-Africa to a regional or even global perspective.

PP42D-05 1720h

Origin of Tropical Obliquity-Dominated Sequences and Secular Trends in Deep Ocean Chemistry

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A long-standing puzzle is the presence of a strong obliquity cycle in Paleogene tropical sediment cores, since orbital theory predicts that precession should be the major signal in tropical deposits while obliquity should predominate at mid and high latitudes. Drilling in tropical and warm subtropical sequences of Paleogene and Cretaceous age shows that precession-dominated and obliquity-dominated intervals may be present in the same cores. Data are based on XRF core scanning of Paleogene sections in cores form several Atlantic sites, including recently drilled, Leg 207 sites. The seeming alternation of high and low latitude signals in tropical deposits at least partly owes its origin to variations in the extent to which the record reflects surface and bottom water processes. Because bottom waters are formed mostly at high latitudes, their flow strength, corrosiveness, and other physical properties should carry a dominant obliquity signal which can be superimposed on precession-dominated tropical sedimentary records. When the sedimentary record is not highly modified by benthic processes, the precession signal dominates tropical sedimentary records, but where there are changes in deep water flow strength (which may winnow a deposit) or corrosiveness of bottom water (which dissolves surface-derived carbonate), then the mid/high latitude orbital period predominates. Obliquity signals also dominate in Neogene and late Paleogene records in part because of the onset of polar ice growth. We might expect tropical records to show some depth dependence in the kinds of orbital signals that are recorded in sediments, with shallower, less dissolved, sequences displaying a stronger precessional cycle than deeper, more dissolved sequences. The general tendency for tropical Cretaceous and early Paleogene deep sea sediments to display precessional dominance and later Paleogene and Neogene sediments to display obliquity dominance suggests an increase in deep water corrosiveness over the Cenozoic. This increase started in the middle Eocene in agreement with global estimates of changes in the depth of the carbonate compensation depth.

PP42D-06 1740h INVITED

Implications From a new Continuous Astronomically Calibrated Geological Time Scale Back to ∼ 42 Myrs

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Precise, orbitally calibrated geological time scales form a pre-requisite to further our understanding of phase relationships between orbitally driven climatic processes, and to decipher the detailed mechanisms that interact to encode orbitally forced (Milankovitch) processes in the geological record. One of the great successes of ODP Leg 199 was the recovery of a high-resolution (∼1-2 cm/ky) biogenic sediment record, together with an uninterrupted set of geomagnetic chrons, as well as a detailed sequence of calcareous and siliceous biostratigraphic datum points. In addition, lithological measurements revealed clearly recognisable cycles that can be attributed to climatic change, driven by Milankovitch style orbital variations of the Earth. By integrating lithological, geochemical, and stable isotope data sets, we have now derived a long, astronomically calibrated, time scale from the Miocene into the latest Eocene from ODP Leg 199. Using additional data from ODP Legs 177 and 171B, we have generated a detailed continuous time scale back to ∼ 42 Myrs. We can contrast the encoding of astronomical forcing terms in sedimentary records from different ocean basins, latitudes, water-depths, and water masses. Our results show that the dominantly recorded orbital parameters vary as a function of the carbonate system response, with a very strong eccentricity component in the record from the deep equatorial Pacific, and a stronger obliquity component in the equatorial Atlantic. In addition, we investigate the phase relationship between astronomical forcing terms and carbonate preservation, with a potentially different response during "green-house" and "ice-house" conditions, separating the Oligocene and Eocene.

PP51A MCC: 3004 Friday 0800h

Global, Hemispheric, and Regional Climate Signals During the Last Millennium I *(joint with A, H, C, GC)*

Presiding: **C M Ammann,** National Center for Atmospheric Research**; P Naveau,** University of Colorado

PP51A-01 0800h INVITED

Spatially and Seasonally-Specific Responses to Forcing as Detected In Paleoclimate Reconstructions of Past Centuries

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We will review recent progress in proxy-based reconstruction and modeling of climate changes in past centuries. Empirical, proxy-based surface temperature reconstructions will be discussed, with an emphasis on the seasonal and spatial details of patterns of past variation. Estimated patterns of change will be interpreted in the context of the modeled seasonal and regional response to estimated radiative forcing changes in past centuries. The likely importance of radiatively forced changes in both the Northern Annular Mode ('NAM')/Arctic Oscillation ('AO') and the El Nino/Southern Oscillation ('ENSO') will be addressed.

URL: http://holocene.evsc.virginia.edu/Mann/research/research.html

PP51A-02 0815h

Northern Hemisphere Regional Climate Change during the Last Millenium

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We examine the regional climate response to variability in volcanic aerosols and solar irradiance in a stratosphere-resolving general circulation model (GCM). The simulated surface temperature anomalies are compared with historical data and proxy-based reconstructions at various timescales, including a new analysis of the mean climate response pattern during the cold-season following large tropical volcanic eruptions back to the beginning of the 17th century. This anomaly pattern strongly resembles the Arctic Oscillation (AO) or Northern Annular Mode (NAM), and with our four-century record, the mean response is statistically significant over much of the Northern Hemisphere land area. The dynamical climate response to injections of volcanic aerosols into the stratosphere is well simulated in many GCMs, demonstrating the robustness of the AO/NAM surface response to stratospheric temperature and wind anomalies. Due to opposing dynamical and radiative effects, we show that the long-term (decadal and longer) regional response to volcanic eruptions is not significant compared to unforced variability for either the winter or the annual average, however. Solar variations induce shifts in the AO/NAM in a similar manner to the short-term volcanic response. In contrast to the one to two year timescales for large volcanic eruptions, solar variations can persist for decadal or longer timescales, creating a long-term regional response which greatly exceeds unforced variability. Solar forcing thus appears to have been the most important external driver of long-term regional climate anomalies during the last millennium.

PP51A-03 0830h

Centennial scale climate variations and their spatial dimensions in coupled GCM simulations of the last millennium

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Multi-decadal and century scale climate variations have been proposed to occur either purely internal to the climate system or in response to external perturbations. The separation between these different sources is not only important for our understanding of past climates but it also bears significant implications for what we have to expect from the future. External forcing, such as solar irradiance variations and explosive volcanism, has recently been found to behave surprisingly linear both in terms of response to individual forcings as