GP62A MCC: 121 Saturday 1330h

Stratigraphic Chronologies: Determination, Interpretation, and Quality Control I *(joint with OS, PP)*

Presiding: **D McMillan,** Scripps Institution of Oceanography**; P Huybers,** Massachusetts Institute of Technology

GP62A-01 1335h INVITED

Orbital Tuning and re-Tuning; Art and Science

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It is difficult to imagine a situation in which (a) a geological record built up at a constant rate or (b) a geological deposit built up at a rate that was independent of climate. In addition all geological proxies for climate parameters are subject to both observational noise, and non- stationarity in their relationship with climate. Hence considerable judgement is needed in first selecting geological records that will be amenable to "tuning" to a record of the changing distribution of solar insolation as calculated by an astronomer, and then in carrying out the operation. Tuning a geological record to an incorrect insolation record, or to the wrong time interval in a correct insolation record, or to a simplified "caricature" of the true insolation record can all provide considerable insights in some circumstances. Nevertheless from the point of view of the geological time scale it is important to carry out the procedure correctly, with the best available astronomical data. It is also important that one can use the tuning to verify the astronomical calculations. We have recently re-tuned a number of records on the basis of the new calculations discussed by Laskar (2001). Astronomical Solutions for Paleoclimates Studies. Eos Trans. AGU, 82(47), Fall Meet. Suppl. Abstract U11A-01. In the Pliocene re-tuning is generally straightforward and uninformative because the astronomical changes are small and the tuning is so unambiguous that little judgement is required. In the Early Miocene and Oligocene the situation is more interesting. During this time available data suggests that the climatic variability is dominated by 41-thousand year (ky) obliquity cycles but attaining a correct tuning requires identification of the weaker precession signal and making use of the longer-term (100-ky and 400-ky) eccentricity modulation. A surprising aspect of the tuning published by us in 1999 was that between 20 and 24 My ago there was long-term (about 1.1 My) modulation of the obliquity signal that matched that predicted; this match broke down in the earlier part of the record.

Re-tuning the records for this interval required a slight "stretching" to take account of the fact that 400-ky eccentricity maxima in the Oligocene are around 100 ky older than in the previous astronomical solution. This obviously required the addition of a very small number of additional obliquity cycles; thus it was necessary to make a judgement anew regarding the interpretation of each cycle. This in turn enables us to assess the degree of robustness of the tuning. The fact that in the new tuning the amplitude modulation of the obliquity signal between 20 and 24 My ago still matches the calculated obliquity modulation is not surprising, since in this time-window the amplitude envelope of obliquity has moved back in age to about the same extent as the eccentricity signal, as a result of the new calculations. However, the fact that the re-tuned data demonstrates a 1.1 My amplitude modulation of the obliquity signal that now remains in phase with the calculated signal all the way back to 30 My ago, despite the fact that the re-tuning did not entail significant re-interpretation of the record, strongly suggests both that the new solution represents an "improvement" and that the coherence with this long-term modulation constitutes a very strong independent validation of this approach to geological time scale development.

GP62A-02 1350h INVITED

Astronomical Tuning: Successes, Failures, Virtues and Limitations

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After over 20 years of success, the very concept of astronomical tuning is now under attack. New data and new dates are available that enable us to review the past practice, and evaluate where it succeeded and where it failed. The issue is not just in the procedures used, but whether we know the climate target model well enough to use it as a tool rather than as a theory to be tested. The ultimate goal is to find a better time scale, and use that to uncover the mysteries of climate change.

In the early days of tuning, the potential dangers of circular reasoning in orbital tuning were well appreciated. It was considered important to keep the number of tuneable parameters low, and then to test the approach by its success in matching the variations. But as tuning became more demanding, the number of parameters used increased. Imbrie has recommended that one should use one parameter for each data point. This would be a valid procedure if, in fact, the climate model was solidly established. But most analysts who accepted the Milankovitch tuning model recognized that, at best, it was only an approximation that still needed major work. If the wrong climate target is used, the timescale is invalid.

Some of the early procedures to test the success of the theory proved to be flawed. It was once believed that the amplitude and phase variations in the climate signal were independent, that tuning could be tested by seeing if the amplitude variations were automatically matched. However, analysis by Neeman, Muller & MacDonald, and Huybers show that the process of tuning can also modulate the amplitude of the narrow-banded signal, thus reproducing the modulation that had been once considered unimpeachable proof of success.

I will examine historical attempts at tuning in light of modern knowledge, including the Pacemaker, Specmap, and Low-Latitude stacks, and the "minimally tuned" Benthic stack. The outstanding success of tuning was the correct prediction of the age of the Brunhes-Matuyama reversal by Shackleton and colleagues. Modern day analysis of that success shows that it resulted from the coherence of the 100 kyr cycle – not on the correctness of the Croll-Milankovitch insolation theory, as has often been assumed.

A further problem comes from the fact that climate has proven to be multidimensional, with climate records in different proxies showing distinctly different behaviors. When the identical tuning target is used for all proxies, then the possibility of uncovering and clarifying such structure is rendered virtually impossible.

New radiometric dates also provide an independent test of the effectiveness of past tuning. Ages of sea-level high stands have been determined for six glacial terminatons in the Pleistocene by Karner. The Devils Hole radiometric dates, combined with new determinations of the ages of sea level high stands from corals in the Atlantic and Pacific, conflict with dates tuned to the Milankovitch model, leading to a causality crisis for the original tuning approach.

URL: http://muller.lbl.gov

GP62A-03 1405h INVITED

How to date an Ice Core Without Breaking a Sweat

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A variety of methods can be used to determine the age of the ice in an ice core. Each method has advantages and disadvantages and is only usable in certain situations. Several methods are commonly used on the same core. This talk is an overview of the commonly used methods. Methods that will be reviewed include, annual layer counting, event biased stratigraphy (nuclear weapons tests, volcanic eruptions, beryllium 10), continuous stratigraphy (atmospheric gasses and ice chemistry), carbon 14, and ice flow modeling.

GP62A-04 1420h INVITED

Influence of Stratigraphic Uncertainty on the Reconstruction of Cosmogenic Nuclide Production Rates and Geomagnetic Field Intensity From Marine Sediments

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The reconstruction of geomagnetic field intensity and of deposition rates of cosmogenic radionuclides such as ^{10}Be from marine sediment cores is generally based on oxygen isotope stratigraphy, complemented by ^{14}C datings for the past up to 40 kyr. Ice cores offer an increased stratigraphic resolution but atmospheric transport processes of cosmogenic radionuclides need to be taken into account when reconstructing radionuclide deposition. Combination of ice core chronology and oxygen isotope stratigraphy has produced promising results at locations of very high sedimentation rates.

However, beyond the ^{14}C dating range it is for most sediments not possible, even at locations where high resolution oxygen isotope stratigraphies are available, to achieve a reliable higher resolution stratigraphic framework than the transitions between the main marine isotope stages (MIS). The determination of substages is generally accompanied by relatively large uncertainties which are reflected by large errors in the calculation of accumulation rates. For the past 200 kyrs the $^{230}Th_{xs}$ constant flux method offers an improvement by enabling the calculation of mass accumulation rates for every sample analysed and at the same time allowing a correction for sediment redistribution processes. Uncertainties in the stratigraphy are only reflected by small uncertainties in the age correction of the $^{230}Th_{xs}$ data but not by large errors of the accumulation rates.

This improved approach does, however, not remove effects of differences in boundary scavenging intensity and advective redistribution of ^{10}Be by ocean currents. For paleointensity records there is still significant scatter in reconstructions of geomagnetic field intensities in and between single cores despite considerable improvement of the normalisation techniques. In order to account for these factors stacked records of Be-deposition rates and geomagnetic field intensity have been generated, which are generally considered more reliable than single records. Limitations of the applicability of such stacked records will be discussed.

GP62A-05 1435h

A First-Order Correction for Relative Paleointensity Profiles Obtained From Sediments

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Relative paleointensity records are usually obtained from sediments by directly normalizing the NRM by the susceptibility or by the laboratory induced ARM or IRM. This procedure, however, allows to retrieve reliable paleointensity records only when the magnetic carrier is magnetite exhibiting rather limited changes in abundance and grain-size along the studied sedimentary sequence. This is a serious limitation to the method, because environmental usually have a significant impact on the nature , the abundance and the grain-size of the magnetic contents of sediments. Given the importance of paleointensity records not only for geomagnetic studies but also in view of their increasing use as a global correlation tool, it is therefore important to develop methods allowing to discriminate in these records the part due to environmental changes from that directly related to changes of the geomagnetic field. We present here a method to minimize the correlation between the fluctuations observed in the normalized NRM/ARM (or NRM/IRM) record and those of the normalizer, considered as a proxy for environmental changes. The method determines which fraction F of the normalizer has to be added to (or subtracted from) the normalized record so that the corrected record exhibits fluctuations as much as possible orthogonal to those of the normalizer. Comparison with the uncorrected record allows to determine the intervals in the paleointensity record where direct normalization may not successfully remove environmental influences, and to propose a first order correction to the normalized record. The only assumption of the method is that the geomagnetic field has varied independently from environmental factors, which is a common hypothesis. Examples from published records will be discussed.

GP62A-06 1510h

Magnetic record of Lake Baikal sediments (Baikal Drilling Project 1998)

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Magnetic remanence vectors from 1500 samples taken from a 600 m core through Lake Baikal sediments are reported along with a complete magnetic susceptibility profile obtained from a pass-through system. Matching the stable remanence directions to the standard geomagnetic polarity timescale (GPTS) provides a robust chronology from the present back to 6.7 Ma and yields a remarkably constant sediment accumulation rate of 3.9 cm/ka. For earlier times - represented by depths below 270 m - correlation to the GPTS is more problematic. Susceptibility fluctuations reflect climatic changes that can be matched to the marine oxygen isotope pattern for the last 6.7 Ma. Spectral analysis of the resulting susceptibility time series then indicates that, for the most part, the Milankovitch obliquity signal dominates. However, when the temporal evolution of the frequency content is investigated by analysing sequences of time windows, a complex picture emerges in which eccentricity and precession power appears during some intervals. Furthermore, there is persistent evidence for significant power in a "non-Milankovitch" band between 28 and 35 ka.

GP62A-07 1525h INVITED

Comparison of Paleomagnetic Records with Different Mean Sedimentation Rates From the Rockall Plateau (ODP Sites 980-982)

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North Atlantic high-sedimentation-rate marine "drift" deposits with mean sedimentation rates of about10 cm/kyr, or greater, often exhibit rather constant sedimentation rates on scales of 0.1-1 Myr. On scales less than 100 kyr, however, sedimentation rates vary by a factor of at least 5 in cases where detailed oxygen isotope data offer precise age control. Guyodo and Channell (2002) have modeled the influence on geomagnetic paleointensity records of variable quality age control for a range of mean sedimentation rates. The simulations illustrate that high-quality age control and mean sedimentation rates in excess of a few cm/kyr are necessary to resolve wavelengths shorter than 25 kyr in stacked u-channel paleointensity records. The numerical simulations are compared with u-channel data from three ODP sites (Sites 980/981 and 982) drilled on the Rockall Plateau and off its eastern edge. The site located on the plateau (Site 982) has a magnetic record extending into the Gauss Chron and a mean sedimentation rate of 2 cm/kyr. One of the sites located at the edge of the plateau (Site 980) has a mean sedimentation rate to the Cobb Mountain Subchron (1.2 Ma) of about10 cm/kyr. The other site at the edge of the plateau (Site 981) reaches the base of the Reunion Subchron with a mean Matuyama sedimentation rate of 5.6 cm/kyr. The age models were derived by matching the benthic oxygen isotope data to an orbitally-tuned target curve. The boundaries of the Jaramillo, Cobb Mountain, Olduvai and Reunion subchronozones occur consistently in the expected marine isotope stages but appear consistently older at Site 982 by about 10 kyr. This implies an effective lock-in depth of several tens of centimeters, at least at Site 982 where the lock-in depth represents more time due to the lower sedimentation rate. Normalized remanence data can be correlated to paleointensity records from ODP Sites 983/984 (700 km to the NW from Site 980-982) and with paleointensity data from the Pacific Ocean, although large chronological offsets are apparent for Pacific records with imprecise age control.

GP62A-08 1540h

The Use of Extraterrestrial ^{3}He as Constant Flux Proxy in Paleoceanography

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A fundamental need in interpreting sedimentary records with respect to climatic aspects is the accurate knowledge of sediment mass accumulation rates. In this context, the development of constant flux proxies (CFP) has created an important asset and has led to reinterpretation of previously published paleoceanographic results with dramatic consequences.

Traditionally, mass accumulation rates are determined from stratigraphic methods (i.e. ^{18}O) and are often biased by sediment redistribution processes. Constant flux proxies represent an alternative approach to reconstruct fluxes of sedimentary constituents by exploiting the fact that the supply rate of the CFP is known to within well-defined limits. CFPs offer two fundamental advantages compared to normal stratigraphic methods. (i) Traditional stratigraphic methods are unable to evaluate the net gain or loss of sediment by lateral transport (focusing and winnowing by deep-sea currents). Fluxes derived using a CFP are insensitive to lateral redistribution of sediments. (ii) Fluxes can be constructed with higher temporal resolution. Whereas it is necessary to assume a constant sediment accumulation rate between age control points in traditional stratigraphic methods, normalizing to a CFP allows a temporal resolution that is limited only by bioturbation.

The currently most established CFP in paleoceanography is ^{230}Th. However, the use of ^{230}Th is limited by its 75 ka half-life to sediments deposited during the past $\sim$ 300 ka. Beyond this time-scale, extraterrestrial ^{3}He that is delivered to the earth surface by interplanetary dust particles (IDP) is a potential candidate. As the cosmic dust is enriched in ^{3}He by ca. 8 orders of magnitude compared to bulk terrigeneous matter, IDPs are the main contributor to the total ^{3}He concentration in many pelagic sediments and can be readily detected. If a constant IDP flux is assumed, the ^{3}He distribution in sediments can be used to determine instantaneous sediment accumulation rates. As ^{3}He is a stable isotope and it is extremely well preserved in marine sediments over at least 10^7-10^8 years, it holds huge potential for application as a CFP well back into the Mesozoic.

GP62A-09 1555h INVITED

Alternative Chronologies for Paleoclimatic Events Based on Excess 230Th and Grain Size Measurements in Marine Sediments.

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The constant production and rapid deposition on the seafloor of 230Th from the radioactive decay of 234U allows the possibility that this excess(230Thxs) can be used as a chronometer in deep-sea sediments. In locations of adequate vertical settling particles and negligible lateral remobilization, the integrated sedimentary inventory of 230Thxs can be used to establish a chronology over an interval as well as instantaneous fluxes for each depth. In such ideal situations, 230Thxs profiling provides a "clock" as well as a "stopwatch". Particle rain in the North Atlantic is generally sufficient to strip 230Thxs from the water column today, and has been greater in the past. Core V28-82 (49°N, 22°W. 3935 m) has approximately the mean regional sedimentation rate, and appears to have a focusing factor near 1.0. It thus serves as a likely location to establish an absolute chronology based on the measured inventory of 230Thxs. The 230Thxs chronology provides an independent estimate for the duration of warm intervals during marine isotope stage 5 (MIS 5). In particular, warm sea surface temperatures persist at the site of V28-82 for approximately 20 kyr, significantly longer than the elapsed portion of Holocene warmth at that location. At ODP Site 984 on the Reykjanes Ridge, lateral redeposition associated with a sediment drift deposit does not allow 230Thxs profiling to be applied for chronology. At this location, the persistence of a millennial oscillation in bottom current strength provides a chronometer beyond the useful life of U-series disequilibria. Here, the MIS 11 interglacial has been examined and shown to have similar variability of bottom flows as in the Holocene, based on the sortable-silt proxy for current velocity. A hanging chronology based on the millennial oscillation yields an estimate for the duration of warm interglacial conditions of approximately 20 kyr. Both methods of estimating the duration of peak interglacial conditions during MIS 5e and MIS 11 yield results that are consistent with orbital tuning, and both far exceed the elapsed duration of the Holocene. In addition, the 230Thxs profiling method yields absolute age estimates for events during the last ice age, including the Heinrich event iceberg discharges H4 and H5, which had previously eluded firm chronological constraints.

GP62B MCC: 121 Saturday 1615h

Magnetic Database Developments: Public Forum *(joint with OS, V)*

Presiding: **S Banerjee,** University of Minnesota

No abstracts available.

GP71A MCC: Hall C Sunday 0830h

Stratigraphic Chronologies: Determination, Interpretation, and Quality Control II Posters *(joint with OS, PP)*

Presiding: **D McMillan,** Scripps Institution of Oceanography**; P Huybers,** Massachusetts Institute of Technology

GP71A-0972 0830h POSTER

Magnetostratigraphical dating of the Majuangou Paleolithic site in the Nihewan Basin, North China

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Two adjacent sections named Haojiatai (HJT, 130.8 m thick) and Majuangou (MJG, 128.8 m thick) in the Nihewan Basin, North China were paleomagnetically examined. Field observations revealed that an artifact layer occurs in the MJG section at 65 m. Stratigraphy patterns between these two sections were correlated by variations in susceptibility as well as two distinctive marker beds, including a conglomerate layer (45-m-depth at MJG and 105-m-depth at HJT) and a greyish-yellow clay layer with mollusc fossils (66-m-depth at MJG and 122.4-m-depth at HJT). Four magnetozones were recognized at the HJT section: two normal, N1 (0-49 m) and N2 (78.8-80.2 m); and two reversed, R1 (49-75.8 m) and R2 (80.2-128.8 m), and six magnetozones were identified at the MJG section: three normal, N2 (17.2-22.2 m), N3 (85-89 m), and N4 (126.6-130.8 m); and three reversed, R1 (0-17.2 m), R2 (22-85 m), and