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We consider the early thermochemical history of the Moon and specifically address the question of how the Moon could have had an internally generated magnetic field suddenly 'switch-on' somewhat late in its evolution and then just as quickly 'switch-off'. It is commonly assumed the Moon never underwent mantle convection, given the majority of the surface geology is likely the original crust formed nearly simultaneous with the Moon. This can partially be explained by the fact that thermal evolution may well occur under the regime of stagnant-lid convection. Furthermore, there are a few clues that perhaps the Moon possessed a brief, internally generated magnetic field (Cisowski et al., 1983) and by implication, that the interior of the Moon was once convecting. Lunar samples returned from the Apollo missions provide a few which may contain a remnant thermal magnetism, possibly acquired during the Moon's 'magnetic era' (Cisowski et al., 1983). These samples also reveal the near side of the Moon contains large areas flooded with volcanic material, the lunar mare. These mare erupted during a pulse of magmatism beginning 0.5 billion years after the Moon had formed and mostly ended after 1 billion years of activity. We have recently shown (Stegman et al., 2003) that chemical overturn models suggested to explain the eruption of the Maria basalts may also account for the hitherto unexplained existence of a lunar magnetic field (core dynamo) at about the same time (3-4 billion years ago). In this presentation, we will specifically discuss the plausibility of such a model within the context of current uncertainties of Lunar properties (e.g. core size, core composition, initial conditions, etc.).

GP22A-07 1510h

Shock effects on Martian crustal magnetization near large impact basins

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The Martian crust has been subject to several very large meteoroid impacts. Shock pressures associated with these impacts may have demagnetized parts of the Martian crust to an extent determined by the shock resistance of the magnetic materials responsible for crustal sources. Impacts that form large basins generate pressures in excess of 1 GPa that extend several crater radii from the point of impact, beneath the surface. Near the surface, however, wave interference significantly reduces the pressure (1 GPa) experienced by crustal materials. Impact demagnetization experiments indicate that pressures of 1 GPa magnitude are sufficient to demagnetize most of the common magnetic minerals (magnetite, pyrrhotite). Titanohematite with ferrian ilmenite exsolution lamellae is the exception. According to our data, this mineral has the highest coercivity (>300 mT) and largest NRM intensity (1500 A/m). As such it is a leading candidate for Mars crustal magnetism, particularly in proximity to the large impact basins where pressures > 1 GPa may have been experienced. The presence of this mineral suggests that much of the deep Martian crust was oxidized at the time of acquisition of magnetic remanence. This would be an important constraint for Martian chemical evolution at the time of crustal formation.

GP22A-08 1525h

Evidence for Demagnetization of the Utopia Impact Basin on Mars

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One of the great surprises of the Mars Global Surveyor mission was the discovery of intensely magnetized crust [Acuña et al., Science 284, 790, 1999; Acuña et al., JGR 106, 23403, 2001]. The crustal fields are predominantly associated with the southern highlands, and impact demagnetization of the Hellas, Argyre, and Isidis basins indicates that Mars' crustal magnetic fields are among the oldest preserved geologic features on the planet. Much of the northern lowlands appears to be non-magnetic, except for relatively weak north polar anomalies and a few magnetic sources adjacent to the dichotomy boundary. The MGS Magnetometer measured crustal magnetic fields at altitudes from 100 to over 1000 km. Because of the long duration in the mapping orbit, the crustal field map at 400 km altitude is fully sampled on both the day and night hemispheres; however, the sampling is sparse at lower altitudes, and nearly all of those data were obtained on the sunlit hemisphere, where the solar wind distorts crustal fields and obscures those weaker than 30 nT. Thus, it is possible that weak crustal fields exist in the northern lowlands that have so far escaped detection. We have systematically searched for crustal magnetic fields in the northern lowlands using electron reflection magnetometry, which has a sensitivity similar to that of a magnetometer orbiting at 200 km altitude. We have detected several new magnetic features in the northern lowlands. Some of these appear to be northward extensions of previously identified magnetic sources along the dichotomy boundary. A group of magnetic sources form a partial ring around the Utopia basin perimeter, but no sources were detected within the basin itself. These observations suggest that the Utopia impact resulted in crustal demagnetization, and that the relatively weak magnetic sources in the northern lowlands are as old as those in the southern highlands.

GP22B MCC: 2000 Tuesday 1600h

High-Resolution Description of the Earth's Magnetic Field Time Variations Using Paleomagnetism and Archeomagnetism II

Presiding: **Y Gallet,** Institut de Physique du Globe de Paris**; M Korte,** GeoForschungsZentrum Potsdam

GP22B-01 1600h INVITED

Recent advances in the high-resolution description of time variations of the geomagnetic field in France and comparison with data of Western Europe.

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Archaeomagnetism can provide a high-resolution full-vector description of the geomagnetic field, but the uncertainties associated to the reference data pose some specific problems. Archaeomagnetic data from archaeological structures (sites) such as hearths, kilns or sets of potteries, bricks or tiles, generally exhibit large experimental errors and are associated with more or less well constrained dates given by stratigraphic sequences (relative chronology), archaeological evidences, historical records or chronometric methods (radiocarbon, thermoluminescence...). The aim is to combine these different sources of information in order to get the best estimate of the past geomagnetic field. Research in archaeomagnetism in France has been particularly productive during the last two decades and addressed different methodological aspects: data acquisition, magnetic corrections (in particular, correction of the TRM anisotropy and cooling rate effects), allowance for the dating uncertainties, curve estimation, application to dating and to geomagnetism. An efficient sampling policy in close co-operation with archaeologists (in the framework of rescue archaeology) associated with the development of new statistical tools (statistical modelling of the sampling strategies, new moving average techniques, Bayesian statistics applied to curve building), and with the study of the magnetic properties of baked clays, permits to significantly constrain the secular variation at century and millennium scales. Precise reference curves of the directional variations of the geomagnetic field over the last three thousand years can be defined. At the same time, studies of the intensity have been relaunched on sites in France and Middle East, with some particular attention on to cooling rate dependence of the thermoremanent magnetization. Comparisons with other recent results from Western Europe will be presented and applications to geomagnetic modelling and to dating will be discussed.

GP22B-02 1615h

On the possible occurrence of "archaeomagnetic jerks" in the geomagnetic field over the last three millennia

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Archeomagnetism can provide a high-resolution full-vector description of the Earth's magnetic field in the last several thousand years. We analyse the bulk of archeomagnetic data (both direction and intensity) obtained recently in Western Europe and the Eastern Mediterranean covering the last three millennia. We demonstrate a remarkable coincidence between sharp cusps in geomagnetic field direction and intensity maxima (2 clear ones at AD 200 and 1400; 2 less well constrained at about 800 BC and AD 800). These sharp changes may constitute a new feature of geomagnetic secular variation ("archeomagnetic jerks") with time characteristics intermediate between "geomagnetic jerks" and "magnetic excursions".

GP22B-03 1630h

Microwave archaeointensity results from Egyptian ceramics

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Using microwave power in place of temperature in a Thellier palaeointensity experiment we can avoid laboratory induced thermal alteration and improve the quality of palaeointensity determinations (Hill, Gratton and Shaw, 2002). In the present study we apply the microwave palaeointensity technique to a collection of Egyptian ceramics covering the time interval 3100 BC to 900 AD. We aligned the TRM field to be in the same direction as the NRM direction to avoid the effects of magnetic anisotropy. The new microwave results will be presented and compared to previous results obtained using conventional heating (Odah et al. 1995).

URL: http://www.liv.ac.uk/geomagnetism

GP22B-04 1645h INVITED

Holocene Paleomagnetic Secular Variation From Iceland (MD99-2269) : New Observations on Millennial to Centennial Scale Field Dynamics From North America to Europe

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Recent studies of lacustrine and estuarine sediments have demonstrated coherence millennial-scale paleomagnetic secular variations (PSV) patterns across

North America. New archeomagnetic observations now show centennial-scale PSV impulse changes across Europe and suggesting a new class of geomagnetic behavior at a presently unknown spatial scale. Our knowledge of how PSV continues and evolves between North America and Europe are, however, poorly constrained as there are few studies from the intervening 60 degrees of longitude. We present a new high resolution Holocene PSV record from Iceland that allows us to bridge this geographic gap. MD99-2269 (Lat: 66.37.53 N. Long. 23.51.16 W, water depth 365 m, length 2530 cm) was collected from a 25-30-m thick post-glacially derived shelf sediment body off N/NW Iceland. The sediments of 2269 are generally homogenous siliciclastic rich, silty muds with no evidence for reductive diagenesis. The chronology for 2269 is based on 18 AMS radiocarbon dates constrained by Hekla and Saksunarvatn tephras. A simple linear age model satisfies (r = 0.99) all eighteen radiocarbon dates and the Saksunvatn tephra. Therefore, 2269 extends to 12,300 cal yr BP with each centimeter of sediment representing about 5 years. The natural remanent magnetization (NRM) was studied by progressive alternating field (AF) demagnetization of u-channel samples, which indicated a strong, stable, single component magnetization. Inclinations are consistent with the expected values for the site latitude and comparisons with other regional records (Iceland & East Greenland) support the geomagnetic origin of the observed directional changes. Therefore, 2269 provides a well-dated high temporal resolution PSV record for Iceland that extends through the Holocene. Comparison of Icelandic PSV to records from North America and Europe demonstrates that declination patterns show two distinct modes during the Holocene. Over the last 2,000 years millennial-scale declination swings in Iceland are correlative with those in North America, but clearly distinct from those in Europe. While prior to around 2,500 cal yr BP declinations swings are similar from North America to Iceland to Europe. Centennial-scale impulse changes documented in European archeomagnetic records are also observed in Iceland with some traceable to North America. The most dramatic impulse occurs around 2,500 cal yr BP, observed from North America to Europe and may mark a major transition in Holocene geomagnetic field behavior. The implications of these observations will be discussed.

GP22B-05 1700h

Holocene Geomagnetic Paleointensity Records From Atlantic Ocean and Mediterranean Sea Sediments

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We have obtained new relative geomagnetic paleointensity records from high accumulation rate sediments in the Atlantic Ocean and in the Mediterranean Sea. Measurements were made using either u-channel samples or standard 2x2x2 cm single samples. A minimum of 10 steps of demagnetization was used to characterize the NRM and the ARM. The ratio NRM/ARM after demagnetization at 25 mT was used as a proxy for relative paleointensity changes. The results indicate a large degree of coherency between the different records: from present to past, the geomagnetic intensity increases reaching a maximum of about twice the present value at about 2000 years B.P., then a progressive decrease reaching a minimum with intensity in the order of the present value is observed at about 6500-7000 years BP. There is then an increase of the intensity reaching a maximum at about 8000 years BP, then a decrease lasting at least to 10-11000 years BP. Comparison with published sedimentary data from other environments and also with compilation of archaeomagnetic data will be presented and discussed.

GP22B-06 1715h

A new archeointensity data compilation for the past 10 millennia

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We compiled a new global absolute intensity dataset for the past 10 millennia. Our main goal was to improve the global time-varying geomagnetic field model CALS3K.1 (Korte and Constable, 2003) computed from the inversion of directional data only. Our compilation includes about 3400 intensity results, almost exclusively obtained from the analysis of archeological baked clay artifacts. Although 90% of the data were obtained using thermal methods derived from the one developed by Thellier and Thellier (1959), the experimental procedures which were employed (e.g. pTRM-check performed or not, correction or not for TRM anisotropy and cooling rate, heating and cooling time...) and the site definition which were considered (number of samples per object, and number of objects per dated level) notably differ among the studies leading to a quite inhomogeneous data collection. Selection criteria were applied to rank and weight the available intensity data. Based on criteria, that we will discuss, only 45% of the intensity determinations appear reasonably reliable. The temporal and geographical distributions of the archeointensity data are significantly non uniform with about 70% of the results with dates from the past 3000 years and more than 70% of the data clustered in the Eurasian continent. We will discuss the present status of our knowledge of the geomagnetic field intensity variations in different regions around the world.

GP22B-07 1730h INVITED

Temporal and Spatial Resolution in Millennial-Scale Paleomagnetic and Archeomagnetic Field Modeling

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High resolution paleomagnetic and archeomagnetic observations provide a means of extending knowledge of global and regional magnetic field variations to timescales of several thousands of years. Geomagnetic field modeling techniques routinely used for the present and historical field are now being used in paleomagnetic modeling where the temporal and spatial distribution of the observations is relatively sparse, and the data are intrinsically much less accurate. A major limitation is the highly variable accuracy of age constraints which contributes error in the form of secular variation in addition to limitations imposed by the recording media and subsequent sampling and measurement techniques. This talk will analyse the temporal and spatial resolution attainable in paleofield modeling of various kinds, and the consequences on prospects for understanding paleomagnetic secular variation.

GP22B-08 1745h

The Global Geomagnetic Field on the Millennial Scale: Improving on CALS3K.1

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The amount of high-resolution archeo- and paleosecular variation data from areas all over the Earth is continually increasing. The spatial and temporal density is high enough now to allow for continuous global modeling of this data on millennial time scale. With CALS3K.1 we presented a first attempt at a time-varying model like those using historical data. CALS3K.1 was based on directional data for the last 3k years. A new global compilation of intensity data has now been included and supersedes assumptions imposed on CALS3K.1 about the temporal evolution of the axial dipole moment. Re-assessment of older and addition of new directional data increases the spatial resolution of the model. Extension of the model to 7k years seems feasible. Dating uncertainties, however, are a major problem in evaluating the reliablity of the global field distribution and secular variation given by the models. We present new global models and discuss their reliablity and implications for core dynamics.

GP31A MCC: 2006 Wednesday 0800h

Fundamental and Applied Rock Magnetism I *(joint with MR)*

Presiding: **S K Banerjee,** University of Minnesota**; L Tauxe,** Scripps Institution of Oceanography

GP31A-01 0800h INVITED

The Role of Magnetostatic Interactions on the Anisotropy of Magnetic Remanence: Micromagnetic Modeling of Distribution Anisotropy.

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The anisotropy of magnetic remanence (AMR) is often used as a tool for examining magnetic anisotropy of rocks. However, the influence of magnetostatic interactions on AMR has not been rigorously addressed either theoretically or experimentally, though it is widely thought to be highly significant. Theoretically the problem has not been previously tackled due to the difficulty in solving the non-linear magnetostatic interaction field; it is computationally intensive. While experimentally, the problem has been avoided because of the difficulty in accurately synthesizing grains with controlled interaction spacings. Using a three-dimensional micromagnetic model we have conducted a systematic study of the role of magnetostatic interactions on AMR. We have considered both lineation and foliation, by modeling assemblages of ideal single domain grains and magnetically non-uniform magnetite-like cubic grains between 30-150 nm in size. In addition to varying grain size, we have also considered both uniaxial and cubic anisotropy. We show that magnetostatic interactions strongly affect the measured AMR signal. We have used a different micromagnetic model to those previously reported by the Edinburgh group; it is a combination model. As a first-step it determines the magnetic structure by a Fast-Fourier-transform conjugate gradient energy minimization. This solution is then refined using a dynamic solution of the Landau-Lifshitz-Gilbert equation.

GP31A-02 0820h

Micromagnetic Modeling of Transient Hysteresis

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Magnetic hysteresis has been used to characterize magnetic mineralogy and domain state in paleomagnetic research. Conventional hysteresis measurements have recently been extended to include transient hysteresis and first order reversing curves (FORCs). During hysteresis treatment, magnetic grains do not follow coherent reversal path as predicted by classical Stoner-Wohlfarth theory. Instead, paleomagnetically meaningful magnetic grains often experience non-uniform (known as either flower or vortex) states. In order to assess the effect of irreversible changes of partial hysteresis and the evolution of non-uniform states in hysteresis measurements, we have simulated both transient and full hysteresis in grains of magnetite for the size range 20-200 nm. Hysteresis loops were obtained for fields applied along three different crystallographic axes ([001], [100], and [111]) of magnetite for at least nine different configurations of axial ratio for each grain size. Transient hysteresis shows strong dependence on grain size, axial ratio, and the direction of applied field. In addition, we have measured transient