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

Carlo Laj[1] (laj@lsce.cnrs-gif.fr)

Luigi Vigliotti[2] (luigi.vigliotti@bo.ismar.cnr.it)

Catherine Kissel[1] (kissel@lsce.cnrs-gif.fr)

Jean-Louis Turon[3] (jl.turon@epoc.u-bordeaux1.fr)

Josette Duprat[3] (j.duprat@epoc.u-bordeaux1.fr)

[1]Laboratoire des Sciences du Climat et de l'Environnement, CEA/CNRS, Avenue de la Terrasse, Bat 12,, Gif-sur-Yvette 91190, France

[2]Istituto di Scienze Marine, CNR, Sezione di Geologia Marina di Bologna, Via Gobetti, 101, Bologna 40129, Italy

[3]Departement de Geologie et oceanographie, Universite de Bordeaux I, Avenue des Facultes, Talence 33405, France

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

Agnes Genevey[1,2] (1-858-822-1288; agenevey@ucsd.edu)

Yves Gallet[2] (33-1-44-27-24-32; gallet@ipgp.jussieu.fr)

Monika Korte[3] (33-1-288 -1268; monika@gfz-potsdam.de)

Cathy Constable[1] (1-858-534-3183; cconstable@ucsd.edu)

[1]Scripps Institution of Oceanography, IGPP, UCSD, 9500 Gilman Drive, La Jolla, ca 92111, United States

[2]Institut de Physique du Globe de Paris, Laboratoire de Paleomagnetisme, 4 place Jussieu, Paris 75252, France

[3]GeoForschungsZentrum Potsdam, Telegrafenberg, Potsdam 14473, Germany

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

Catherine Constable[1] (858 534 3183; cconstable@ucsd.edu)

Monika Korte[2] (49 331 288 1268; monika@gfz-potsdam.de)

Agnes Genevey[1] (agenevey@popmail.ucsd.edu)

[1]University of California, San Diego, Scripps Institution of Oceanography,, La Jolla, CA 92093-0225, United States

[2]GeoForschungs Zentrum Potsdam, Telegrafenberg, 14473 Potsdam 14473, Germany

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

Monika Korte[1] (+49 331 288 1268; monika@gfz-potsdam.de)

Agnes Genevey[2] (agenevey@ucsd.edu)

Catherine Constable[2] (cconstable@ucsd.edu)

[1]GeoForschungsZentrum Potsdam, Telegrafenberg, Potsdam 14473, Germany

[2]Scripps Institution of Oceanography, IGPP, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0225, United States

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.

Adrian R Muxworthy[1] (+44 131 650 4918; adrian.muxworthy@ed.ac.uk)

Wyn Williams[1] (+44 131 650 4909; wyn.williams@ed.ac.uk)

[1]Edinburgh University, Institute of Earth Sciences, Kings Buildings, West Mains Road, Edinburgh EH9 3JW, United Kingdom

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

Yongjae Yu[1] (858-822-1288; yjyu@ucsd.edu)

Lisa Tauxe[1] (858-534-6084; ltauxe@ucsd.edu)

[1]Scripps Institution of Oceanography, 9500 Gilman Drive Dept 0220, La Jolla, CA 92093-0220, United States

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

and full hysteresis for well-defined natural and synthetic samples. Our numerical calculations and measured hysteresis provide fundamental basis in interpreting transient hysteresis and FORCs.

GP31A-03 0835h INVITED

The Other Iron Minerals: Magnetic Properties at Room and Low Temperature

Ann M Hirt (+41 1 633 2705; hirt@mag.ig.erdw.ethz.ch)

ETH-Zurich, Institute of Geophysics ETH-Hoenggerberg, Zurich 8093, Switzerland

The magnetic properties of iron oxides and iron sulfides that are carriers of paleomagnetic fields have been well studied. Less is known about the magnetic properties of iron phases that are not common carriers of remanent magnetization, or those that are paramagnetic at room temperature. They include iron (oxy-)hydroxides, iron carbonates, iron phosphates and iron sulfates. Many of these phases are not easily identifiable with traditional X ray diffraction or spectroscopic methods, due to their poor crystallinity or low concentration in soils and sediments. Since they are important indicators of the environmental conditions under which they form and are preserved, alternative methods for their identification are of interest. AC and DC magnetometry are very sensitive in detecting low concentrations of magnetic phases. A short overview will be given on the magnetic properties of less-considered iron phases, including the iron (oxy-)hydroxides goethite, lepidocrocite and ferrihydrite; siderite, an iron carbonate; the iron phosphate vivianite; and iron sulfate, schwertmannite. Factors that influence the magnetic properties, such as cation substitution, grain size and particle interaction will be discussed, as well as the environmental conditions under which they form and are preserved.

GP31A-04 0855h

Magnetite dissolution in siliceous sediments

Fabio Florindo[1,2] (390651860383; florindo@ingv.it)

Andrew P. Roberts[2] (arob@soc.soton.ac.uk)

Martin R. Palmer[2] (martin.r.palmer@soc.soton.ac.uk)

[1]Istituto Nazionale di Geofisica Vulcanologia, Via di Vigna Murata 605, Rome 00143, Italy

[2]Southampton Oceanography Centre, University of Southampton, European Way, Southampton S014 3ZH, United Kingdom

Magnetite dissolution, and consequent loss of magnetization, is widely observed in reducing sedimentary environments, where the decrease in Eh-pH values with depth is driven by bacterially mediated degradation of organic carbon. We have observed low magnetizations in sediments with elevated porewater silica concentrations that arise from diagenesis of biogenic silica and/or silicic volcanic ash. These depletions in magnetization are greater than can be accounted for by dilution with magnetite-poor sediments and suggest that post-depositional destruction of magnetite has occurred. Biosiliceous sediments usually also contain elevated concentrations of organic carbon, which makes it difficult to separate organic-carbon-related magnetite dissolution from other possible mechanisms for magnetite dissolution. However, the extent of magnetite dissolution in the sedimentary sequences that we have studied is not obviously related to the redox-state of the environment. This suggests that other mechanisms might have given rise to magnetite dissolution in these siliceous sediments. Thermodynamic calculations indicate that magnetite is unstable under conditions of elevated dissolved silica concentrations (and appropriate Eh-pH conditions) and predict that magnetite will break down to produce iron-bearing smectite. A survey of magnetic susceptibility and pore water geochemical data from widely distributed Ocean Drilling Program sites supports this observed link between high dissolved silica concentrations and low magnetic susceptibilities. This observed link also holds for environments with low biogenic silica productivity (and low organic carbon content), but with high interstitial silica concentrations due to dissolution of silicic volcanic ashes. Dissolution of magnetite is therefore predicted to be a common feature of siliceous sedimentary environments.

GP31A-05 0910h INVITED

Bitter Patterns on Glass-Ceramic Magnetite: Links Among LEM States, Saturation Remanence, and Demagnetization Processes

Susan L. Halgedahl[1] (801-272-2387; shalg@mines.utah.edu)

Brian Bollin[1] (801-585-5328; bbollin@mines.utah.edu)

[1]University of Utah, Dept. Geology and Geophysics, 135 South 1460 East, Rm 719, Salt Lake City, UT 84112

We have observed Bitter patterns on glass-ceramic magnetite particles in several states of magnetization induced at room temperature. Particle sizes range from 5 to 30 micrometers and most grains contain but a few (2-6) domains, placing them in the uppermost pseudosingle-domain to small multidomain ranges of size and behavior. Bitter patterns have been studied after the following treatments: (1) repeat demagnetizations in an alternating field (AF) with a peak amplitude of 500 Oe, (2) exposure to 25 kOe, resulting in saturation remanent magnetization (Mrs), (3) stepwise demagnetization of Mrs in back-fields of opposite polarity to the inducing field, and (4) stepwise AF demagnetization of Mrs. Similar to titanomagnetite and pyrrhotite, magnetite particles can occupy any one of a range of local energy minimum (LEM) domain states after each repeat AF treatment. However, the range of LEM states for most grains is quite narrow; for example, some grains fluctuate between only two states. Surprisingly, after AF demagnetization in a peak field of 500 Oe, some particles appear either to be saturated (no Bitter lines visible) or to contain only small, residual edge domains. Similar domain states also are observed when certain grains carry Mrs, and such saturated (or near-saturated) states can persist until demagnetization in hundreds of oersteds finally triggers nucleation of walls. The majority of particles do contain walls in states of Mrs. In these latter grains, both AF and back-field demagnetization drive three processes: wall motion, wall nucleation, and wall denucleation. Thus, remanence and demagnetization in small multidomain magnetite grains are not due to wall motion alone. Instead, these experiments suggest that, in magnetite, both the intensity of Mrs and the demagnetization of Mrs are crucially linked to LEM states and LEM-LEM transitions.

GP31A-06 0930h

The Dependence of Anhysteretic Remanent Magnetization on Alternating Field Decay Rate: Fundamental Origin and Paleomagnetic Applications

David J. Dunlop[1] (905-828-3968; dunlop@physics.utoronto.ca)

Yongjae Yu[1] (858-822-1288; yjyu@ucsd.edu)

[1]Geophysics, Physics Department, University of Toronto, 60 St. George St., Toronto, ON M5S 1A7, Canada

We have measured the intensity of anhysteretic remanent magnetization (ARM) as a function of alternating field (AF) decay rate. For synthetic and natural single-domain (SD) and pseudo-single-domain (PSD) magnetites, ARM intensity increases as decay rate decreases. Multidomain (MD) magnetites have the opposite response, ARM increasing as the decay rate increases. These are identical to the SD/PSD and MD dependences of thermoremanent magnetization on cooling rate. For all grain sizes and domain structures, ARM intensity increases as the AF decay rate used to achieve an initial demagnetized state decreases. Decay-rate differences in ARM intensity are a property of low- and medium-coercivity grains, as shown by annealing and by stepwise AF demagnetizing samples. We interpret the SD results to mean that increased AF exposure time permits a closer approach to equilibrium magnetization. An approximate thermal activation theory based on Neel [1949] and an exact theory by Egli and Lowrie [2002] predict 6-11% increases in ARM for an order-of-magnitude decrease in decay rate, in reasonable accord with the observed 12% increase for 65 nm SD grains. For MD grains, we hypothesize that increased exposure time (slower decay) permits more efficient self-demagnetization, reducing ARM. Low-coercivity grains experience the largest self-demagnetizing fields and therefore have the largest decay-rate response. Initial-state decay-rate response is attributed to longer exposure times leaving domain walls more strongly pinned in deeper potential wells (the net self-demagnetizing field is zero in the demagnetized state). Acquisition decay-rate, annealing, and initial-state responses of PSD grains are a blend of SD and MD responses. Because ARM is the most frequently used normalizer in relative paleointensity determination, it is important either to use a standard decay rate or else to remove the decay-rate dependence by demagnetizing the ARM to about 30% of its initial value (ARM0.3). A standard demagnetization level for the normalizing ARM is particularly important when comparing paleointensity records from different laboratories.

GP31A-07 0945h

Stable Remanence from Crystallographically Oriented Magnetite Inclusions in Clinopyroxene

Gary R Scott[1] (1-510-644-9200; gscott@bgc.org)

Joshua M Feinberg[2] (feinberg@eps.berkeley.edu)

Paul R Renne[1,2] (prenne@bgc.org)

[1]Berkeley Geochronology Center, 2455 Ridge Road, Berkeley, CA 94709, United States

[2]Department of Earth and Planetary Science, University of California, Berkeley, Berkeley, CA 94720, United States

The unusually stable remanent magnetization found in many gabbroic rocks actually comes from clinopyroxene crystals. While not magnetic itself, clinopyroxene acts as a crystallographic host to two arrays of magnetite inclusions, formed during slow cooling by exsolution. In the cone-sheet samples studied (Messum, Namibia), this exsolution takes place at $850^\circ \pm 50^\circ$C. The typical size of a magnetite inclusion in each array is $1 \mu m$ x $2 \mu m$ x $50 \mu m$. Even with such extreme shape anisotropy, these inclusions are too large to expect single domain behavior. However, alternating field and thermal demagnetization, hysteresis, and FORC experiments all show stable remanence behavior, significantly in excess of that predicted for single domain magnetite (e.g. mean destructive field > 80 mT). When viewed with a magnetic force microscope (MFM), the magnetite inclusions from both arrays display a regular (and fixed) internal segmentation of domains. This segmentation was the result of a second stage of exsolution, in which the oxide has segregated into two phases: one a nearly pure magnetite, and the other a Ti-rich ulvöspinel. This internal oxide exsolution was crystallographically coherent (both minerals have almost identical inverse spinel crystal structure) and has generated regularly spaced septa of ulvöspinel along {100} of magnetite. Three-dimensionally, the ulvöspinel has isolated the magnetite into rectangular boxes of approximately 50nm x 100nm x 200nm. The long dimension of each nanobox is nearly perpendicular to the magnetite inclusion length. Each box is a single domain, usually of opposite polarity to its adjacent neighbors. The domain walls are fixed in position with nonmagnetic spinel dividers. Multidomain features such as Bloch (or Neél) walls have not been observed. Thus each magnetite inclusion is an aggregate of $\sim 10^5$ closely packed magnetite nanoboxes, separated by continuous walls of ulvöspinel. The factors that control the orientation and dimensions of the magnetite boxes and ulvöspinel septa, appear to be related to the crystallographic parameters and cooling history of the clinopyroxene host. This host-dictated form of the magnetite boxes also controls the anisotropy of remanence and hysteresis, which is dipolar (not linear or double dipolar). The origin of the anomalously high coercivity appears to be the strong magnetic exchange coupling between adjacent, single domain magnetite nanoboxes. In summary, the clinopyroxene has provided an architectural framework upon which a second (internal oxide) exsolution built a coherent set of single-domain magnetites with fixed domain walls. It is this nanostructured assembly that has unusually stable remanence.

GP31B MCC: Level 2 Wednesday 0830h

Fundamental and Applied Rock Magnetism II Posters *(joint with MR)*

Presiding: **S L Halgedahl,** University of Utah**; A J Newell,** University of California, Santa Barbara

GP31B-0744 0830h POSTER

The Effect of Grain Shape on the Magnetic Properties of Magnetite: A Finite Element Approach

Wyn Williams[1] (+44 131 650 4909; wyn.williams@ed.ac.uk)

Phillip Ridley[2] (phil@informatics.bangor.ac.uk)

[1]Edinburgh University, School of GeoSciences, Kings Buildings, West Mains Road, Edinburgh EH9 3JW, United Kingdom

[2]University of Wales, Bangor, School of Informatics, Dean Street, Bangor LL57 1UT, United Kingdom

Most micromagnetic models in rock magnetism use a regular grid of cells to construct the geometry of a magnetic grain. This has the advantage of allowing rapid evaluation of demagnetising fields using fast Fourier transforms, but means that significant modelling errors are introduced for non-cuboid shaped