GP12A-1093 1330h POSTER

Geomagnetic Field Inclinations and Absolute Paleointensities for a 350 kyr Time gap From the 350m Core of the Kalihi Scientific Drilling Project Recovered From the Ko'olau Volcano, O'ahu, Hawai'i

Emilio Herrero-Bervera[1] (808-956-6192; herrero@soest.hawaii.edu)

Michael O Garcia[2] (808-956-6641; garcia@soest.hawaii.edu)

Jean-Pierre Valet[3] (33-1-44-17-35-66)

Eric Haskins[2] (808-956-7889; ehaskins@soest.hawaii.edu)

[1]SOEST-Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, 1680 East West Rd, Honolulu, HI 96822, United States

[2]SOEST-Department of Geology and Geophysics, 1680 East West Rd, Honolulu, HI 96822, United States

[3]Institut de Physique du Globe de Paris, 4 place Jussieu, B89 Tour 24, Paris 75252, France

In order to investigate the volcanic evolution of the Ko'olau Volcano, O'ahu, Hawai'i and the geomagnetic field behavior recorded by the lavas, a paleomagnetic and rock magnetic was conducted on a 350 m thick sequence of flows from the Kalihi Scientific Drilling Project. This drill core records geomagnetic field inclination for the period approximately between 2.75 to 3.1 Ma. The core extends deeper stratigraphically any surface exposures of the volcano and the rocks obtained have experienced less tropical weathering than surface rocks. Previous published work on Ko'olau has indicated that the volcano was formed during the Matuyama Chron (Doell and Dalrymple, 1973, GSA Bull, 84, 127-42). We drilled multiple one-inch long samples from each of the 103 flows in the drill core section. The paleomagnetic results of all the specimens were stepwise demagnetized by alternating fields from 5-100mT. Companion specimens from the same core were demagnetized at 15 temperature steps. In both cases the demagnetization diagrams obtained with each technique showed a stable and unambiguous characteristic direction of remanence (ChRM). The ChRM calculated using principal component analysis for the demagnetization diagrams with a well-defined component trending towards the origin. No bias or systematic departure from the origin was accepted and in all cases the ChRM relies on a minimum of seven successive directions isolated during demagnetization. In addtion, low-field susceptibility versus temperature (k-T) and SIRM experiments were performed on a dozen or so flows at different levels of the core. As a result of such tests, we were able to identify magnetite and and in few instances a low-temperature mineral phase (300-400 ^{o}C), reflecting the presence of titanomagnetite with low Ti content as suggested by its large susceptibility. We used the modified Thellier-Coe double heating method to determine paleointensities. pTRM checks were performed systematically one temperature step down the last pTRM acquisition in order to document magnetomineralogical changes during heating. We were able to obtain paleointensity determination for 25 lavas (out of 103 flows) which represent about 25 percent success rate. The analyses reveals two instances of near-zero and two instances of low negative inclination (reversed polarity, 7.5 uT of low paleointensity) within an otherwise normal polarity. In particular, flow units 34-50 record a horizontal inclination and may be associated with the top of the Kaena Subchron. This interpretation is supported also by two Ar-Ar age determinations for flow 14 (2.89+/-0.12 Ma) and flow 66 (3.06+/-0.15 Ma old), and subaerial lavas at several localities where the Reunion II Subchron (ca. 2.11 to 2.15 Ma) is recorded and which previous results were reported by Herrero-Bervera et al (2002, PEPI, 129, 83-98). Our findings lead us to conclude that the growth of the Ko'olau Volcano was concomitant with respect to the youngest exposed lavas of the Wai'anae Volcano and both were forming during the Kaena Subchron.

GP12A-1094 1330h POSTER

Towards a Continuous Record of Earth Magnetic Field Reversals by Secondary Pyrrhotite pTRMs

Florian Wehland[1] (0049-7071-2974698; florian.wehland@uni.tuebingen.de)

Ulrich Alt-Epping[1]

Christian Crouzet[1]

Erwin Appel[1]

[1]Institut fr Geowissenschaften, Abt. Geophysik, Sigwartstr. 10, Tbingen 72076, Germany

Partial Thermoremanent Magnetisations (pTRMs) by secondary pyrrhotite, recorded during fast cooling in contact metamorphic limestone, were used for the first time to test the possibility of recording Earth Magnetic Field (EMF) Reversals within a single sample. For this propose, samples from marly limestones of Mid-Elba (Italy) were taken in the vicinity of intrusions. Pyrrhotite was identified by the unblocking spectra of the NRM and the thermal demagnetisation of IRM. Thellier-Thellier-tests of a laboratory TRMs incl. MD checks have proven that pyrrhotite particles are in the SD range and, therefore, are able to record independent pTRMs. Thermal demagnetisation of the NRM reveals a reversed low temperature (150^{o}C-250^{o}C) and a normal high temperature (290^{o}C-320^{o}C) component. The two components include an angle of $\sim$150^{o} and are linked by a gradual transition over an average temperature range of $\sim$40^{o}C. Positive fold tests on the low (k = 10.2 ; α^{95} = 11.0) and the high temperature component (k = 20.4 ; α^{95} = 8.4) evidence that the NRM is a TRM. A scenario where the low temperature component is caused by a second heating event is unlikely due to the gradual transition of the NRM and the lack of evidence for a multiple intrusion. An estimation of the time enveloped in the transitional temperature range retrieved by thermal modelling of the contact metamorphism lies at 10000 yr. This time span is comparable with an average value for EMF reversals.

URL: http://www.uni-tuebingen.de/geo/gpi/ag-appel/projekte/palaeomag/ptrmpro/index.html

GP12A-1095 1330h POSTER

A Detailed Paleomagnetic Record From the Bahamas Bank: a Record of the Blake Event?

Conall Mac Niocaill[1] (-44-1865-282135; conallm@earth.ox.ac.uk)

Gideon Mark Henderson[1] (-44-1865-282123; gideonh@earth.ox.ac.uk)

[1]University of Oxford, Dept. of Earth Sciences, Parks Road, Oxford OX1 3PR, United Kingdom

Detailed demagnetisation of 51 Pleistocene carbonate samples from hole 1006a, ODP Leg 166, in the Bahamas Bank, yield anomalous paleomagnetic directions over a sediment thickness of 40 cm (328-368 core depth). Samples above and below this horizon are characterised by a steeply directed remanence component at low coercivities, which likely represents a drill-induced component, which is succeeded at higher coercivities by a component with a shallower inclination, close to that of the geomagnetic field at this site. In contrast, the samples from 328-368 core depth, yield negative inclinations after removal of the low coercivity component. These negative inclinations are accompanied by small swings in declination. These anomalous directions are either due to disturbance of the sediment or reflect the presence of geomagnetic field excursion; likely the Blake event. While we cannot completely exclude sediment disturbance, we believe that our paleomagnetic data marks a record of geomagnetic field behaviour for the following reasons: examination of the core yields no evidence for disturbance; relative paleointensity determinations indicate an intensity low through this part of the core; and the excursion is a double event, with an intervening positive inclination within the zone of negative inclinations, in line with other studies of the Blake event. We are currently carrying detailed U/Th age determinations on this part of the core with a view to obtaining a estimate of the timing and duration of the event.

GP12A-1096 1330h POSTER

A Study of Geomagnetic Field Variations of a Low-Latitude Station.

Eric Olusina Famutimi (1-989-774-2563; ericfamutimi@yahoo.com)

Central Michigan University, Department of Physics, College of Science and Technology, Mount Pleasant, MI 48859, United States

The field variations of a Low Latitude Station, Ile-Ife in Nigeria (Dip latitude 4o) were analyzed using data for four consecutive years (1993 1996). The study shows that the most prominent value of the geomagnetic k index is 4 and in general, the k distribution has significant peaks at k =3, 5, and 6. The daily Ak index shows that majority of days in this four-year period can be classified as either active days or days with minor storms. The study also reveals there were virtually no severe storm during the period under consideration. This behavior has been shown to be consistent with the geomagnetic field variations at equatorial electrojet zones.

GP12A-1097 1330h POSTER

Elongation in distributions of paleomagnetic field directions and corresponding poles

Tadahiro Hatakeyama[1] (+81-858-43-3828; hatake@misasa.okayama-u.ac.jp)

Masaru Kono[1] (+81-858-43-3829; mkono@misasa.okayama-u.ac.jp)

[1]Institute for Study of the Earth's Interior, Okayama University at Misasa, Yamada 827, Misasa, Tottori Pref. 682-0193, Japan

Properties of paleosecular variation (PSV), mainly derived from lava flow data for the last few million years, were often discussed in terms of the latitudinal dependence of angular standard deviation (ASD) of virtual geomagnetic poles (VGPs) distributions after Cox (1970). Generally the ASD of VGP has a feature that it is smallest in the equatorial region and becomes higher in the higher latitude (e.g. McFadden et al., 1988). However mapping of each directional datum into the corresponding VGP is nonlinear and distorted on the unit sphere. Therefore it is not feasible that both distributions become synchronously circular except for sites around the geomagnetic poles. Recent accumulation of reliable paleomagnetic directional data has enabled us to discuss the more details of the nature of PSV, not only the ASD but also the shape of the distributions (Kono, 1997; Tanaka, 1999; Khokhlov et al., 2001).

In this study, by using Bingham statistics (Bingham, 1973; Onstott, 1980) we made a comparison in the shape of distributions between actual paleomagentic data obtained from several sites on the Earth, where data from enough flows are available, and our recent PSV model (Hatakeyama and Kono, 2002) which was derived by nonlinear inverse procedures. Some important characteristics of the PSV appearing in the data and relation to the remarkable components in the Gauss coefficients were indicated as following, (1) the shape of the VGP distribution shows much circular than that of the field directions especially in the low latitude region, (2) the distribution of paleodirections is elongated to the direction of the meridian, while that of VGPs is distorted toward the perpendicular direction, and (3) the circular nature of the pole distributions depends on the "isotropic" PSV (Constable and Parker, 1988) but the elongation perpendicular to the meridian is likely to be caused by large variances of a special component (ℓ = 2, m = 1) of spherical harmonics. This component is also regarded as important for the latitudinal dependence of the ASD of VGP (Kono and Tanaka, 1995; Hulot and Gallet, 1996).

GP12B MCC: 130 Monday 1330h

The Use of Magnetic Properties as a Petrologic Tool II *(joint with OS)*

Presiding: **B MacDonald,** State University of New York, Binghamton**; O Ozdemir,** University of Toronto

GP12B-01 1330h

Late Quaternary Magnetic Mineral Accumulation in the Western Equatorial Atlantic - South American Versus African Provenance

Ulrich Bleil[1] (bleil@uni-bremen.de)

Tilo von Dobeneck[1] (dobeneck@uni-bremen.de)

[1]Earth Science Department, University of Bremen, P.O.Box 330440, Bremen 28334, Germany

Magnetic mineral accumulation at the Ceara Rise has been studied with the aim to discriminate and reconstruct fluvial South American and eolian African terrigenous fluxes to the late Quaternary western Equatorial Atlantic. Seven sediment series recovered along two bathymetric transects were investigated with standard environmental magnetic techniques. Climatically controlled fluctuations in continental detrital discharge and marine biogenic carbonate fluxes strongly modulate the susceptibility records. Their coherent precessional and higher-frequent signal components could be used to establish a high-resolution age framework for these sediments. On average 79% of susceptibility originate from magnetite of different grain size, 13% from hematite and 8% from paramagnetic matrix compounds. Hence, hematite concentrations are on average almost twenty times higher than magnetite concentrations. The longitudinal gradients of their respective accumulation rates document a delivery from two major sources characterized by largely different magnetite to hematite ratios (about 1:12 versus 1:50). A

mixing model of this scenario provided detailed insight into the past variability and origin of these separate magnetic mineral fluxes. Overall 56% of hematite and 84% of magnetite were transported in the Amazon fluvial load. Their accumulation is closely related to sea level changes confirming that the shelf areas are an important intermediary depocenter. Hematite and magnetite of African provenance, 44 and 16%, respectively, follow a distinctly different accumulation pattern with prominent maxima during cold intervals of glacial periods. By statistically linking these trace minerals to total lithogenic fluxes, we find that during the last 200 kyr, on average 79% of total terrigenous material at the Ceara Rise area originates from South American sources in the Amazon River catchment, while African dust sources contributed 21%.

GP12B-02 1345h INVITED

Magnetic Properties and Environmental Changes in Monsoonal Regime (ODP leg 184, South China Sea)

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

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

Steven Clemens[2]

Peter Solheid[3]

[1]LSCE, Avenue de la Terrasse, Bat 12, Gif-sur-Yvette 91198, France

[2]Brown University, Geological Sciences, 324 Brook Street, Providence, RI 02912-1846, United States

[3]IRM, university of Minnesota, Minneapolis, MN 55455, United States

The Indian/Asian monsoon is one of the major component of the tropical climate system. By contrast with the Arabian Sea and the Indian Ocean, the South China Sea, under the influence of the East Asian Monsoon, has been little investigated.

Here we report results for the last 1.18 Myr obtained from Site 1146 (ODP Leg 184) in the South China Sea. Changes in magnetic properties occur on both long- and short-time scales, both of which appear to be related to change in monsoon activity.

On the long-term trend, three main intervals were identified. During the oldest period (1.18-0.7Myr), the abundance of magnetic mineral decreases, while the magnetic grain size increases with large fluctuations. The coercivity of the magnetic minerals also increases consistently with data obtained by other authors from Pacific cores. During the following 500 kyr all the magnetic properties are rather uniform, with rather low abundance and relatively large grain sizes and low S-ratio. This probably illustrates a period of enhanced winter monsoon. In the most recent period (the last 0.2 Myr), the magnetic grain size decreases again with pronounced fluctuations. On the short-term scale, a 23 kyr component is identified and it is correlated to the oxygen isotope record, as shown by coherence analysis. Except or the last 200 kyr where the pattern changes, cold/warm periods coincide with low/high magnetic content, and magnetic grains are coarser during cold stages and finer during warm periods. This is consistent with the clay mineral analysis and illustrates changes in the balance between physical erosion and chemical weathering derived detrital products related to the alternation between dominant winter/summer monsoon.

GP12B-03 1405h

Magnetic Signature of Glacial Flour in Sediments From Bear Lake, Utah/Idaho

J G Rosenbaum[1] (303-236-1304; jrosenbaum@usgs.gov)

W E Dean[1] (303-236-5760; dean@usgs.gov)

S M Colman[2] (508-457-2341; scolman@usgs.gov)

R L Reynolds[1] (303-236-1303; rreynolds@usgs.gov)

[1]US Geological Survey, MS 980, Box 25046, Denver, CO 80225, United States

[2]US Geological Survey, 384 Woods Hole Rd, Woods Hole, MA 02543, United States

Variations in magnetic properties within an interval of Bear Lake sediments correlative with oxygen isotope stage 2 (OIS 2) and OIS 3 provide a record of glacial flour production for the Uinta Mountains. Like sediments of the same age from Upper Klamath Lake (OR), these Bear Lake sediments have high magnetic susceptibilities (MS) relative to non-glacial-age sediments and contain well-defined millennial-scale variations in magnetic properties. In contrast to glacial flour derived from volcanic rocks surrounding Upper Klamath Lake, glacial flour derived from the Uinta Mountains and deposited in Bear Lake by the Bear River has low magnetite content but high hematite content. The relatively low MS values of younger and older non-glacial-age sediments are due entirely to dilution by non-magnetic endogenic carbonate and to the effects of sulfidic alteration of detrital Fe-oxides. Analysis of samples from streams entering Bear Lake and from along the course of the Bear River demonstrates that, in comparison to other areas of the catchment, sediment derived from the Uinta Mountains is rich in hematite (high HIRM) and aluminum, and poor in magnetite (low MS) and titanium. Within the glacial-age lake sediments, there are strong positive correlations among HIRM, Al/Ti, and fine sediment grain size. MS varies inversely with theses three variables. These relations indicate that the observed millennial-scale variations in magnetic and chemical properties arise from varying proportions of two detrital components: (1) very fine-grained glacial flour derived from Proterozoic metasedimentary rocks in the Uinta Mountains and characterized by high HIRM and low MS, and (2) somewhat coarser material, characterized by higher MS and lower HIRM, derived from widespread sedimentary rocks along the course of the Bear River and around Bear Lake.

Measurement of glacial flour incorporated in lake sediments can provide a continuous history of alpine glaciation, because the rate of accumulation of glacial flour probably varies closely with the areal extent of glaciation. In the absence of post-depositional alteration of magnetic minerals, magnetic measurements can provide a highly sensitive tool for assessing variations in glacial flour content if glacial and non-glacial materials have contrasting magnetic properties. For Bear Lake, the required contrast is produced by differences in bedrock underlying glaciated and unglaciated areas.

GP12B-04 1420h INVITED

Petromagnetic Evidences of the Coupling between Catchment Soil Processes and Hydrobiological Change in a Tropical Lake

David Williamson[1] (33 4 42 97 15 90; williamson@cerege.fr); Jean-Paul Ambrosi[1] (ambrosi@cerege.fr); Subir Banerjee[2] (banerjee@umn.edu); Philip Barker[3] (p.barker@lancs.ac.uk); Mike Jackson[2] (irm@tc.umn.edu); Ouassila Merdaci[1] (merdaci@yahoo.fr); Maurice Taieb[1] (taieb@cerege.fr); Florian Thevenon[1] (thevenon@cerege.fr); Annie Vincens[1] (vincens@cerege.fr)

[1]Centre Europen de Recherches et d'Enseignement des Gosciences de l'Environnement (CEREGE), BP 80 CEDEX 4, Aix-en-Provence 13545, France

[2]Institute for Rock Magnetism, Department of Geology and Geophysics University of Minnesota, Minneapolis, MN 55455-0128, United States

[3]HYSED, Department of Geography Lancaster University, Lancaster LA1 4YB, United Kingdom

To better understand the response of tropical ecosystems to climate and landuse over the last 50 kyr, a petromagnetic study was carried on soils and cored sediments from lake Masoko, in the Miombo woodlands of Southern Tanzania. Low- and high-temperature measurements of remanence and susceptibility show that titanomagnetite (TM) is the dominant magnetic carrier of soils and sediments. Magnetic experiments, clay mineralogy and major element analysis of the young, well-drained parent soil indicate a relative superparamagnetic (SP) enhancement in the Ah horizon. In contrast, the lower superparamagnetic content of sediments suggests that the "pedogenic" (ultra)fine magnetic grain fraction is poorly preserved in the lake depositional environment. Changes in the a.c. field dependence of susceptibility, saturation magnetization and remanences allow to identify variable TM contributions in the sedimentary record, providing an accurate record of runoff terrigenous inputs which frequency increases during relatively humid periods. The proxy records of algal production is closely connected with changes in magnetic concentration, suggesting that runoff inputs favoured the bloom of diatoms in the oligotrophic lake environment. Finally, magnetic experiments, major element chemistry and mineralogical analysis evidence an authigenic, single-domain (SD)-like spinel component during periods of strengthened methanogenesis in the lake. Millenial-scale events of sustained methanogenesis are inferred from the proxy record of this authigenic SD-like component. Regional climatic implications are discussed.

GP12B-05 1435h INVITED

The Magnetic Fingerprint of Alaskan Loess from Their Modern and Buried Soils to Their Petrostratigraphic Markers

France Lagroix[1] (lagr0012@umn.edu)

Subir K. Banerjee[1] (banerjee@umn.edu)

Michael J. Jackson[1] (irm@umn.edu)

[1]University of Minnesota, Institute for Rock Magnetism, 310 Pillsbury Drive SE, Minneapolis, MN 55455, United States

The Halfway House loess and paleosol profile of Central Alaska is investigated with the goal of developing a magnetic approach for the recognition of (1) pedogenic mineralization of maghemite and (2) volcanic tephra. The characteristics of the modern soil will be used as a baseline for subsequent studies of buried soils at this site. The magnetic study of the Old Crow tephra (OCt) is motivated by the possibility of identifying tephra beds gone unnoticed in the field.

The magnetic fingerprint of the upper 2.00m is investigated and interpreted in terms of the observed stratigraphy. The organic O and A horizons are 0.25m thick and are underlain by a layer of well-preserved wood fragments and leaves between 0.35 and 0.50m depth. Below the wood layer, we find slightly oxidized and sandy parent material (loess), which grades into less weathered loess by 1.00m depth. Several magnetic parameters indicate that at 0.60m the magnetic mineral assemblage undergoes a compositional change, which coincides with the contact between the modern soil above 0.60m and the parent material below. Maghemite is the mineral phase increasing non-proportionally in concentration below the modern soil. This is supported by a two-fold increase, below 0.60m, in the differential isothermal remanent magnetization (IRM) measured in backfields of 100mT and 200mT normalized by the saturation IRM acquired in a field of 1T $[\Delta \mathrm{IRM}_{(-100mT,-200mT)}/\mathrm{SIRM}_{(1T)}]$. The ratio between the ferromagnetic susceptibility and the saturation magnetization (χ_f/M_s) traces the abundance of superparamagnetic (SP) particles which decreases exponentially downwards from the surface with the exception of the wood layer that has values of the same magnitude as the O horizon. The relative concentration of single-domain (SD) particles, represented by the ratio of anhysteretic remanent magnetization (ARM) and SIRM, is 2.5 times greater above 0.60m than below 1.00m, with a gradual decrease in abundance between 0.60m and 1.00m. In modern soils SP particles have a likely bacterial origin. Here, there is a good negative correlation (R=0.86) between the abundance of SP particles and the concentration of maghemite. We propose that as the bacterial zone migrates upwards with deposition finer particles and eventually larger particles are oxidized to maghemite.

The magnetic fingerprint of the OCt found at 11.50m is characterized through numerous experiments. Of these, the temperature dependence of magnetization between 25 and 700°C in a field of 1T reveals Curie temperatures at ∼400, 520 and 580°C which we attribute to titanohematite [y≈0.30], titanomagnetite [x≈0.10], and pure magnetite, respectively. Low-temperature dependence of AC susceptibility, both in-phase and quadrature components, reveals a Néel temperature at 210K which we attribute to titanohematite [y≈0.70]. The presence of an exsolution of the hemoilmenite series would be consistent with the rhyolitic nature of the OCt. Work, by others, indicates that four tephra beds are present at the Halfway House site. The OCt aside, the thickness of these beds is on the order of 1 to 5cm but is variable laterally. Along our profile, only the OCt was observed in the field, however magnetically, we have identified a second tephra at a depth that agrees with the work of others. The OCt bed is a key petrostratigraphic marker across Alaska and the Yukon. Magnetic identification of thinner discrete tephra beds along profiles would increase our ability to correlate sites and more importantly improve age models of deposition.

GP12B-06 1510h

Separation of Anisotropy Components Using a High-field Torque Magnetometer in Hematite Bearing-rocks

Fatima MartinHernandez[1] (fatima@mag.ig.erdw.ethz.ch)

Ann M Hirt[1] (hirt@mag.ig.erdw.ethz.ch)

[1]Institut of Geophysic, ETH Zurich, Zurich 8093, Switzerland

The anisotropy of magnetic susceptibility (AMS) has been used in numerous studies to evaluate qualitatively and quantitatively the effects of deformation on rocks. Low-field AMS is composed of contributions from all types of magnetic minerals. High-field methods have been used successfully to separate the paramagnetic anisotropy from the ferrimagnetic anisotropy in fields high enough to saturate the ferrimagnetic fraction.

In samples rich in hematite, only low-field methods have been used in the past, since saturation is generally never reached. The principal directions obtained by low-field method reflect the combined contribution from paramagnetic and ferrimagnetic minerals, and hematite.

Based on the different field dependence of the torque signal in the three types of magnetic minerals listed above, a method that calculates the principal directions of magnetic anisotropy for paramagnetic minerals, ferrimagnetic minerals and hematite basal planes, has been developed.

The technique has been tested on the simple case of hematite plates and applied further to hematite-bearing rocks from the Glarus complex in Switzerland. The paramagnetic fraction shows perfect agreement with the principal directions of anisotropy measured in low-field, with the magnetic lineation sub-parallel to the stretching lineation showed by macroscopic strain markers. The hematite grains lie in the macroscopic cleavage plane and the pole to the basal planes is subparallel to the direction of minimum susceptibility measured by low-field methods.

GP12B-07 1525h INVITED

AMS Fabric of a CRM in Hematite-Bearing Samples: Evidence of DRMs in Natural Red Beds

Kenneth P Kodama (610-758-3663; kpk0@lehigh.edu)

Lehigh University, Department of Earth and Environmental Sciences, Bethlehem, PA 18015, United States

Anisotropy of magnetic susceptibility (AMS) and anisotropy of isothermal remanence (AIR) in red sedimentary rocks both typically show a bedding parallel foliation with minimum axes clustered perpendicular to the bedding plane. Our studies have observed this type of magnetic fabric in red bed units that have a range of ages and come from widespread localities. These units include the Mississippian Mauch Chunk Formation from the Appalachians, the Triassic Passaic Formation from the Newark basin in Pennsylvania, the Cretaceous Kapusaliang Formation from the Tarim basin in China, and the early Mesozoic Kayenta and Chinle Formations from the Colorado Plateau in southwestern North America. Bedding parallel foliations are also observed in magnetite-bearing rocks that carry a depositional remanence (DRM), suggesting the possibility of a DRM in red beds, even though the conventional wisdom is that they carry a post-depositional chemical remanent magnetization (CRM). Before the typical magnetic fabric of red beds can be used to indicate their type of remanence, we must determine what the magnetic fabric of a CRM looks like. For this reason, I conducted a series of hematite-growth experiments following the procedures outlined by Stokking and Tauxe (1987). I grew hematite in the laboratory on stacks of glass-fiber filter papers and in slurries of quartz and kaolinite. The hematite was grown from a ferric nitrate solution heated to 95°C for 8 hours. The samples were then dehydrated in a vacuum at room temperature for approximately 38 hours. It was possible to thermally demagnetize the eight filter paper samples to 350°C, but the six kaolinite-quartz samples were grown in plastic sample cubes and could only be thermally demagnetized to 150°C, enough to remove the thermoviscous magnetization acquired by the samples during the heating at 95°C. The mean CRM acquired by the red-brown magnetic phase grown in the experiments was within its alpha-95 of the steeply inclined (inclination=60°) ambient magnetic field. The kaolinite-quartz samples had a very scattered remanence, probably due to the physical disturbance of the samples upon the initial application of the vacuum. In both the filter paper and kaolinite-quartz experiments the AMS fabric of the CRM-carrying grains was foliated with the maximum and intermediate principal axes defining a great circle that passes through the mean CRM direction and is moderately inclined (approximately 45°) to the horizontal. The moderately inclined great circle defined by the maximum-intermediate principal axes is quite distinct from the horizontal maximum-intermediate axes observed in the natural red bed samples, despite red bed characteristic remanences that range from nearly horizontal (Passaic, Chinle, Kayenta) to as steep as 30° (Mauch Chunk, Kapusaliang). This observation suggests that red bed characteristic remanence is typically a DRM, rather than a CRM. This has implications for interpreting red bed remanence since DRMs in hematite-bearing red beds may have large inclination errors.

GP12B-08 1540h

Rheology and Magnetic Fabric

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

William Lowrie[1] (41-1-633-2607; lowrie@mag.ig.erdw.ethz.ch)

[1]ETH Zurich, Institute of Geophysics, Hoenggerberg, Zurich 8093, Switzerland

Anisotropy of magnetic susceptibility (AMS) is a sensitive indicator of rock deformation, often developing before visible evidence. Apparently undeformed rocks may in fact be internally deformed. We have investigated the magnetic fabrics of apparently undeformed shales and limestones from 5 selected sites across the Appalachian fold belt where they crop out at the same locality. The AMS fabrics show different degrees of development in the shales and limestones. In the shales the AMS corresponds to a depositional fabric that shows the effects of vertical compaction but has been only lightly modified by later deformation. In the limestones the AMS minimum and intermediate axes are girdled about the maximum axes, which lie close to the regional strike of the fold axes. This kind of pattern has been observed in other studies during early stages of deformation when a horizontal shortening is superposed on a depositional fabric. Separation into paramagnetic and ferromagnetic components with a torsion magnetometer shows that the AMS is mainly of paramagnetic origin. The ferromagnetic fabric was not significant in this method. Acquisition of IRM and thermal demagnetization of a composite triaxial IRM show that the ferromagnetic mineral is mainly magnetite with minor amounts of hematite. Anisotropy of anhysteretic remanent magnetization (AARM) can thus be used to define the ferromagnetic fabric. The AARM pattern was more poorly defined than the AMS fabric, due to the low ferromagnetic mineral content, and in one limestone was not significant. The shape of the AMS ellipsoid was generally oblate in the shales and prolate in the limestones. The AARM results suggest that the ferromagnetic grains in each rock type responded more quickly to the tectonic forces than the phyllosilicates. Due to their higher phyllosilicate content the shales originally had more bedding compaction than the limestones. The layer-parallel shortening was less able to overprint the shale fabric than that of the limestone. The results suggest that tests of the suitability of a rock type for paleomagnetic studies should include magnetic fabric analysis.

GP12B-09 1555h

Petrofabric Interpretations Supported by Magnetic Anisotropy Observations for the Clavijo Intrusion, Colombian Andes

William D. MacDonald[1] (607-777-2863; wdmacdon@binghamton.edu)

Scott Muggleton[1]

Juan Jose Estrada[2] (jjestrada@epm.net.co)

Gloria Maria Sierra[3] (gsierra@eafit.edu.co)

[1]State University of New York, Vestal Pkwy East, Binghamton, NY 13902, United States

[2]OMYA Inc., A.A. 622, Rio Negro, Ant 00000, Colombia

[3]Universidad Eafit, Avenida Las Vegas, Medellin, Ant 00000, Colombia

Remanent magnetization studies on Late Tertiary shallow intrusions in allochthonous terranes of the Colombian Andes suggest two apparent modes of rotation, about vertical axes and about horizontal axes, as reported previously. The horizontal axes trend perpendicular to the regional structural trends, to judge by the dispersed remanence directions along vertical planes parallel to major strike-slip faults. Two distinct zones have been recognized, between Medellin and Manizales, and between Cali and Pasto (Risnes, 1995), extending approximately 600 km along the Andes. Research on the Clavijo body indicates the importance of combining studies of remanence with those of anisotropy of susceptibility (AMS) and of isothermal remanence (AIRM), and petrofabric studies, in interpreting the remanence directions in tectonically disturbed regions. In this body, hydrothermal alteration is associated with increased within-site scatter of AMS axes. Within-site remanence directions are however not dispersed by such alteration, while between-site remanence directions are affected. New results from electron-microprobe analyses of fresh and hydrothermally altered ferromagnetic (s.l.) and paramagnetic minerals are compared with the respective remanence and susceptibility anisotropies of altered and unaltered sites. A major objective is to determine if vertical flow directions in these shallow intrusions can be recognized, and thus utilized for tilt-corrections of remanence and improved tectonic interpretations. Risnes, K., 1995, Terre et Environnement, v. 2, 169 p., Dept. Mineralogy, Univ. Geneva.

GP12B-10 1610h

Thermoremanence and Stable Memory of Single Domain Hematites:Implications for Martian Magnetic Anomalies

Ozden Ozdemir (905-828-3829; ozdemir@physics.utoronto.ca)

Department of Physics, University of Toronto , 3359 Mississauga Road North, Mississauga, ON L5L 1C6, Canada

Single-domain (SD) hematites with grain sizes between 0.12 and 0.42 micrometer carry a strong and stable TRM. The thermoremanence is unaffected by 100 mT alternating field demagnetization and by 600 C thermal demagnetization. Most demagnetization occurs between 625 C and the Neel temperature of 680-690 C. The TRM memory recovered after low-temperature cycling is parallel to the original TRM and equally resistant to thermal demagnetization. TRM and TRM memory of SD hematites are mainly due to the hard spin-canted magnetism intrinsic to the crystal structure above the Morin transition (Tm), and not to the small and softer defect magnetism that survives below Tm. However, the defect magnetism may play a role in renucleating the spin-canted magnetism in a preferred direction during warming through Tm. TRM intensities are well predicted by Neel SD theory and increase in almost exact proportion to grain size. Although smaller than TRM intensities of multidomain hematites, SD TRMs are potent sources of remanent magnetic anomalies, particularly for larger grains (10-15 micrometer), and are likely to be more stable over geological time than multidomain (MD) hematite TRMs.

TRM memory after low-temperature cycling is relevant to Mars because surface temperatures in many parts of the planet cycle diurnally or seasonally through Tm in the essentially zero present-day Martian field. Where surface temperatures are lower than the Morin transition (240-260 K), SD and MD hematites will not contribute to Martian magnetic anomalies. Near the equator during Martian summer, the very stable magnetic memory of SD hematite, almost 40% of original TRM, could contribute partially to the Martian magnetic signal.

GP12C MCC: 130 Monday 1630h

Bullard Lecture

Presiding: **L Tauxe,** Scripps Institution of Oceanography

GP12C-01 1635h INVITED

Plumes and Earth's Dynamic History : from Core to Biosphere

Vincent E Courtillot (33-1-44272434; courtil@ipgp.jussieu.fr)

Institut de Physique du Globe, Place Jussieu, Paris 75005, France

The last half century has been dominated by the general acceptance of plate tectonics. Although the plume concept emerged early in this story, its role has remained ambiguous. Because plumes are singularities, both in space and time, they tend to lie dangerously close to catastrophism, as opposed to the calm uniformitarian view of plate tectonics. Yet, it has become apparent that singular events and transient phenomena are of great importance, even if by definition they cover only a small fraction of geological time, in diverse observational and theoretical fields such as 1) magnetic reversals and the geodynamo, 2) tomography and mantle convection, 3) continental rifting and collision, and 4) evolution of the fluid envelopes (atmospheric and oceanic climate; evolution of species in the biosphere). I will emphasize recent work on different types of plumes and on the correlation between flood basalts and mass extinctions. The origin of mantle plumes remains a controversial topic. We suggest that three types of plumes exist, which originate at the three main discontinuities in the Earths mantle (base of lithosphere, transition zone and core-mantle boundary). Most of the hotspots are short lived ($\sim$ 10Ma) and seem to come from the transition zone or above. Important concentrations occur above the Pacific and African superswells. Less than 10 hotspots have been long lived ($\sim$ 100Ma) and may have a very deep origin. In the last 50 Ma, these deep-seated plumes in the Pacific and Indo-Atlantic hemispheres have moved slowly, but motion was much faster prior to that. This change correlates with major episodes of true polar wander. The deeper (primary) plumes are thought to trace global shifts in quadrupolar convection in the lower mantle. These are the plumes that were born as major flood basalts or oceanic plateaus (designated as large igneous provinces or LIPs). Most have an original volume on the order or in excess of 2.5 Mkm3. In most provinces, volcanism lasted on the order of 10 Ma or less, often resulting in continental breakup; the bulk of the volume actually erupted in 1 Ma or less. This makes LIPs the remnants of major geodynamic events, with fluxes possibly matching, over short time scales, the crustal production of mid-ocean ridges. The correlation between trap ages, extinctions and oceanic anoxia events proposed over a decade ago has improved steadily, to the point that trap ages may form much of the underlying structure of the geological time scale. The five largest mass extinctions in the last 260 Ma coincide with five traps, making a causal connection between the two unavoidable. The plume hypothesis provides a useful and exciting complement to the now conventional plate tectonics paradigm, and can provide a unified underlying mechanism to explain the few, key times when Earths dynamics behaved in a rather catastrophic way, of which our current world bears the memory. Plumes may express couplings between the Earths very different envelopes. They are a singular mode in which the Earths engine liberates its heat when normal plate tectonics do not suffice. They may modulate the intensity of many global phenomena, from reversal frequency generated in the liquid core to major continental breakup and finally to mass extinctions. The remarkably rich, diverse and exciting geophysical disciplines of geomagnetism and paleomagnetism, which are the lecturers main practical tools, have provided many of the key observations that have led to this view.