The IRM Quarterly

SPRING 1997, VOL. 7, NO. 1 INSTITUTE FOR ROCK MAGNETISM

Rick Oches (l) and Bernie Housen (r) are wrapping up three years of IRM postdoctoral work and embarking on the next stages of their careers, with best wishes from all of us at the IRM.

Postdoctoral Transitions

Rick Oches
IRM / University of South Florida
Bernie Housen
IRM / Western Washington University

Alternating Fields: In and Out of Rock Magnetism

Rick Oches

Nearly three years ago, with my newly completed dissertation under one arm, and everything I owned in a U-haul, I arrived in Minneapolis eager to begin the next phase of my scientific career. I came to the University of Minnesota and the IRM as a post-doc with the NSF-funded "Paleorecords of Global Change Research Training Group". As the program encouraged, I was hoping to learn some new methods for evaluating paleoclimatic and paleoenvironmental records in a familiar geologic system. I had spent plenty of time kicking around in the loess of the Mississippi Valley, U.S., and in central Europe through M.S. and Ph.D. research, and I hoped to learn how techniques of environmental magnetism could be applied to loess-paleosol sequences in order to understand paleoclimatic and earth surface processes. Well, I came to the right place to learn rock magnetism, and the staff, facilities, and visitors of the IRM have made these past three winters in Minnesota bearable, or even enjoyable. This summer I'll be heading off to the University of South Florida as the newest faculty member in the Department of Geology and the Environmental Studies and Policy Program. I expect to continue my association with the IRM (from the interglacial climate of Tampa, Florida, as opposed to Minnesota's perennial

Rick Oches

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A Farewell to Irms

Bernie Housen

During my nearly three-year stint as a post-doc at the IRM, I was fortunate enough to work on many different projects, and to develop collaborations with a few of the visiting fellows at the lab. The one aspect of my stay here that has impressed me the most, though, was the additional insight I have gained into the seemingly arcane world of rock magnetism through working with Subir Banerjee, Bruce Moskowitz, Mike Jackson, Jim Marvin, and Taras Pokhil. Having arrived at the IRM in September of 1994 with the ink barely dry on my thesis, I had considered myself to be a structural geologist who uses certain techniques of rock magnetism. I will leave the IRM this summer to join the faculty at Western Washington University in the rain-sodden town of Bellingham, not as a structural geologist, but as a geophysicist. I have been truly fortunate to have had the opportunity to number myself among the folks who have been post-docs with Subir here over the years. Mike had asked me to provide some sort of summary of my stay here for this newsletter, so here goes:

When I arrived, I was fresh from participating on Ocean Drilling Program Leg 156, which cored sediments spanning the active décollement separating the subducting South (or North, depending on whose plate boundary you like best) American plate from the overriding Caribbean plate. My work on this project (which is still continuing) involved a combination of rock-magnetic measurements to characterize magnetic mineralogy, magnetic anisotropy to determine preferred-orientation fabrics, and bulk-sediment chemistry to help constrain effects of Fe-oxide diagenesis on both magnetic anisotropy and paleomagnetic results. By far the most interesting

Bernie Housen

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Visiting Fellows' Reports

April is the cruellest month, breeding
Lilacs out of the dead land, mixing
Memory and desire, stirring
Dull roots with spring rain.
T. S. Eliot, "The Waste Land" (1922).

Eliot notwithstanding, April is in fact one of the more generally pleasant months at *IRM*. Several recent visitors, however, were able to savor the superb cruelty of a Minnesota winter. Harald Petermann brought both natural and cultured magnetic bacteria, as well as a stupendous glove bag for handling them in a controlled atmosphere. Catherine Kissel added to her already amazing data set on magnetic mineralogy and anisotropy of basaltic dikes from Iceland. Maria Cioppa made detailed measurements to help decipher the signatures of climate and alteration in sediments from three Pennsylvania lakes.

Harald Petermann
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Biogenic magnetite in South Atlantic deep-sea sediments

Working several years on magnetotactic bacteria, magnetosomes and the rock magnetic signature in South Atlantic surface sediments it turned out that the regions with high productivity are of particular interest for studies of biogenic magnetite. I brought two sets of samples to the IRM. One set of sediment samples was from the continental slope off Namibia, an upwelling area characterized by extremely high concentrations of magnetotactic bacteria and low terrigenous input. Prior rock magnetic investigations revealed small magnetic grain sizes and TEM-observations of magnetic extracts suggested the dominance of biogenic magnetite. Low temperature measurements on the MPMS - i.e. Bruce's bug-test - were done to check these results. Careful sample preparation - sampling in low oxygen atmosphere and immediate freezing of the samples and storing in argon - delivered excellent results. A marked difference between field cooled and zero field cooled curves was measured at the Vervey transition confirming the dominance of magnetosomes on the magnetic signal of the top centimeter sediments in this area. High temperature measurements on the Kappa bridge showed no pronounciated decrease of susceptibility below 550°C, confirming that titanomagnetite does only play a subordinate role in these sediments.

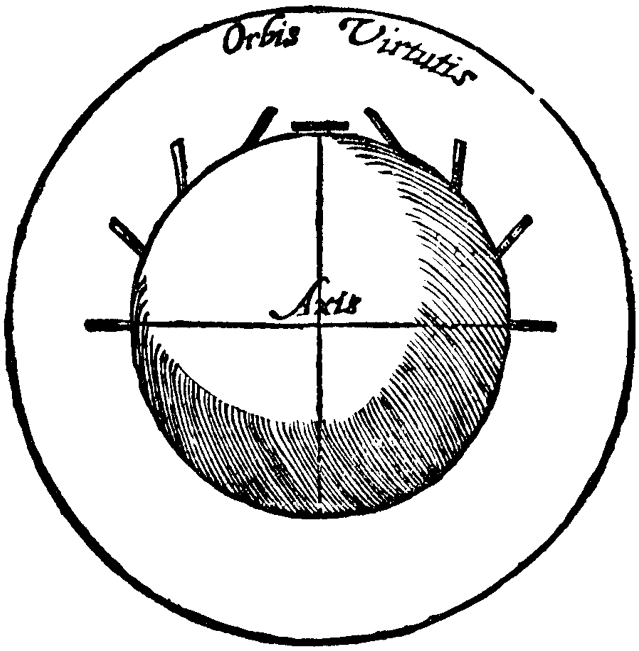
The second set of samples consisted of a culture medium for bacteria that extracellularly precipitate magnetite. Surface sediments from the continental slope off Uruguay were added to the culture bottles in oxygen free atmosphere. Stored at low temperature some of the samples exhibited an exponential increase of susceptibility with time that could be stopped by sterilizing. This implies the biologically induced formation of a highly susceptible mineral fraction. The aim of the studies at the IRM was to magnetically characterize this newly formed phase. Measurements on the Micromag and the MPMS proved the freshly formed material to be superparamagnetic with grain sizes below 10 nm. The mineralogy of these particles is not safely characterized yet, but the high susceptibility values suggest it to be magnetite or maghemite. It seems plausible from these measurements that superparamagnetic particles precipitated from bacteria form in deep-sea sediments and have to be taken into account when interpreting susceptibility logs.

Catherine Kissel
Center des Faibles Radioactivités, Gif-sur-Yvette, France

Rock magnetic properties and magnetic fabric of basaltic rocks from Icelandic dykes

The main purpose of my visit to the IRM was to characterize the magnetic carriers of the anisotropy of magnetic susceptibility (AMS) of basaltic dykes from Iceland. AMS analysis has been completed at the CFR in Gif-sur-Yvette on oriented cores sampled across 28 different basaltic dykes located in Iceland. Because the glacial erosion creating these fjords gives access to the deep part of the dykes, the aim of this study was to determine the preferential direction of the magma at depth during the emplacement of the dykes. Two different types of fabric were observed. Type 1 is characterized by a low degree of anisotropy, K_{max} vertical, K_{min} horizontal, perpendicular to the dyke plane and a L/F ratio close to unity. Type 2 is characterized by a high degree of anisotropy (P ranging between 1.1 and 1.3), K_{max} perpendicular to the dyke plane, K_{min} vertical and a L/F ratio more scattered. Sometimes, both fabrics co-exist in a dyke and in that case, the pattern is always the same: type 1 is observed at both margins of the dykes and type 2 in the central part. In these dykes, no differences in the values of the mean susceptibility and the natural magnetization were observed across the dyke in relation with the different types of fabrics. The two types of magnetic fabrics are closely related to two types of thermomagnetic behaviour (between room temperature and 700°C). Type 1 is associated with a perfectly reversible thermomagnetic curve with a single Curie point at about 500°C. Type 2 is characterized by a rapid decrease of the magnetisation at about 300-350°C followed by a slower decrease until 580°C. The cooling curve runs higher than the heating one. A few samples have been stepwise heated up to 570°C and analysis of the hysteresis parameters and of the magnetic fabric has been conducted after each step. The hysteresis parameters measured on small chips of samples from the central part of the dyke and from the margins are not significantly different. They all show an evolution toward finer grains during heating. The scatter of the directions of the main axes of the anisotropy ellipsoid increases from 200°C to 500°C and after heating at temperature higher than 550°C, the same fabric observed initially at the margins is observed systematically across the dyke. The anisotropy parameters become also very uniform across the dyke. In summary, at about 570°C, the "center effect" associated to the fabric type 2 has entirely disappeared. Our preferred interpretation of these results is that multidomain (titano–)magnetites are present in the central part of the dyke while single domain magnetite grains exhibiting an

VF Reports *continued on page 7…*



William Gilbert's depiction of "the dip of the needle on a terrella" shown "by means of a number of bits of iron wire of equal size, one barley-corn in length, and placed in a meridian. At the equator the bits of iron are directed toward the poles, and lie upon the body of the terrella in the plane of its horizon. The nearer they are placed to the poles the more do they rise from the horizon by reason of their turning poleward; at the poles they tend straight to the centre." From de Magnete*, 1600; translation by P. Fleury Mottelay, 1893, © Dover, 1958.*

Current Abstracts

A list of current research articles dealing with various topics in the physics and chemistry of magnetism is a regular feature of the IRM Quarterly*. Articles published in familiar geology and geophysics journals are included; special emphasis is given to current articles from physics, chemistry, and materials-science journals. Most abstracts are culled from* INSPEC *(© Institution of Electrical Engineers),* Geophysical Abstracts in Press *(© American Geophysical Union), and* The Earth and Planetary Express *(© Elsevier Science Publishers, B.V.), after which they are subjected to Procrustean editing and condensation for this newsletter. An extensive reference list of articles—primarily about rock magnetism, the physics and chemistry of magnetism, and some paleomagnetism—is continually updated at the* IRM*. This list, with more than 3700 references, is available free of charge. Your contributions both to the list and to the Abstracts section of the* IRM Quarterly *are always welcome.*

Anisotropy

Dragoni, M., R. Lanza, and A. Tallarico
Magnetic anisotropy produced by magma flow: theoretical model and experimental data from Ferrar dolerite sills (Antarctica), *Geophys. J. Int., 128* (1), 230-240, 1997.
Numerical models of dike emplacement with ellipsoidal magnetic grains immersed in a viscous flow produce a magnetic lineation that oscillates in the vertical plane containing the flow axis, and a magnetic foliation that changes periodically from horizontal to vertical.

Markert, H., and A. Lehmann
Three-dimensional Rayleigh hysteresis of oriented core samples from the German Continental Deep Drilling Program: susceptibility tensor, Rayleigh tensor, three-dimensional Rayleigh law, *Geophys. J. Int., 127* (1), 201-214, 1996.
Anisotropic low-field hysteresis behavior in pyrrhotite-bearing drillcore samples can be described in terms of two tensors, one for initial susceptibility χ_i and one for the quadratic Rayleigh coefficient α. For both the anisotropic case and the isotropic approximation, α = const (χ_i^2).

Biogeomagnetism

Hanzlik, M., M. Winklhofer, and N. Petersen
Spatial arrangement of chains of magnetosomes in magnetotactic bacteria, *Earth Planet. Sci. Lett., 145* (1-4), 125-134, 1997.
TEM stereomicrographs of magnetosome chains in *M. bavaricum* show that the chains always lie on opposite sides of the cell body, close to the cell envelope. This arrangement maximizes magnetic torques acting on the cell as a whole. We hypothesize that all coccoid magnetotactice bacteria contain at least two chains of magnetosomes.

Magnetic Mineral Properties

Berti, G., and E. Pinna
Microstructure of magnetite from XRPD data in relation to magnetism, *Mater. Sci. Forum, 228-2312*, 839-844, 1996.
Relationships between magnetism and microstructure of magnetite in metamorphic rocks of Tuscany have been deduced from analyses of the physical and mineralogical features of magnetite crystals.

Crew, D. C., *et al.*
Measurement of magnetic viscosity in a Stoner-Wohlfarth material., *J. Magn. Magn. Mater., 163* (3), 299-312, 1996.
The magnetic viscosity parameter λ was found to vary depending on the method used for measurement of the irreversible magnetisation. The difference in λ is found to be related to the dependence of reversible magnetisation on irreversible magnetisation.

Fontijn, W. F. J., *et al.*
Comparison of a stoichiometric analysis of $Fe_{3-\delta}O_4$ layers by magneto-optical Kerr spectroscopy with Mössbauer results., *J. Magn. Magn. Mater., 165* (1-3), 401-404, 1997.
From fits of the polar Kerr spectra of $Fe_{3-\delta}O_4$ layers we find, within experimental accuracy, a stoichiometry that is identical to that determined by Mössbauer spectroscopy. This confirms that the magneto-optical Kerr spectra can also be used to determine the stoichiometry of thin $Fe_{3-\delta}O_4$ films.

Gleitzer, C.
Electrical properties of anhydrous iron oxides, *Key Engineering Materials, 125-126*, 355-418, 1997.
The three main binary iron oxides: $Fe_{1-x}O$ (wustite), Fe_3O_4 (magnetite) and α-Fe_2O_3 (hematite) are considered in this review of electronic properties, defect structure, and magnetic and other properties.

Grimm, S., *et al.*
Flame pyrolysis-a preparation route for ultrafine pure γ-Fe_2O_3 powders and the control of their particle size and properties, *J. Mater. Sci., 32* (4), 1083-1092, 1997.
Highly dispersed γ-Fe_2O_3 powders with particle sizes down to 5 nm were directly synthesized by combustion of solutions of iron pentacarbonyl or iron(III) acetylacetonate in toluene in an oxyhydrogen flame. The particle size as well as other properties of the obtained powders can be controlled simply by varying the iron concentration in the starting solutions..

Hofmann, M., S. J. Campbell, and W. A. Kaczmarek
Mechanochemical transformation of haematite to magnetite: structural investigation, *Mater. Sci. Forum, 228-2312*, 607-614, 1996.
Neutron diffraction study of the reaction products resulting from extended low-energy wet milling of haematite in vacuum shows that about 14% of the α-Fe_2O_3 remains intact but the rest (≈86%) is found to have transformed to magnetite, $Fe_{3-v}O_4$, of vacancy concentration v=0.182. The reduction is due mainly to breaking of oxygen bonds in oxide layers and release of oxygen.

Miscellaneous

Zhang, M., T. Itoh, and M. Abe
Ultrasonic visualization of still and flowing waters using contrast agents of magnetite-encapsulated porous silica microspheres, *Jpn. J. Appl. Phys., 36* (1A), 243-246, 1997.

Abstracts *continued on page 4…*

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Porous silica microspheres, 2.2 µm in average diameter, were encapsulated by ferrite plating in an aqueous solution of FeC_{12} at 65°C, and the resultant particles used as as ultrasonographic contrast agents, to visualize still and flowing waters.

Modeling

Fukuma, K., and D. J. Dunlop
Monte Carlo simulation of two-dimensional domain structures in magnetite, *J. Geophys. Res. B*, *in press*, 1997.
Monte Carlo modeling of magnetization in a 1-µm magnetite cube, incorporating the effects of thermal agitation, produced a closure domain structure (3 body and 4 closure domains) at room temperature, after starting from a saturated (single-domain) state. An initial 2-domain configuration evolved into a lower energy vortex structure.

Paleoclimate & Proxies

Dearing, J. A., *et al*.
Magnetic susceptibility of soil: an evaluation of conflicting theories using a national data set., *Geophys. J. Int.*, *127* (3), 728-734, 1996.
Magnetic susceptibility values for topsoils across England are combined with data for soil type, geochemistry and concentrations of magnetotactic bacteria. A new model for the formation of secondary ferrimagnetic minerals links biological weathering and fermentation processes. The fundamental driving force in the mechanism is Fe supply, which may be linked to climate.

Forster, T., and F. Heller
Magnetic enhancement paths in loess sediments from Tajikistan, China and Hungary, *Geophys. Res. Lett.*, *24* (1), 17-20, 1997.
Linear correlation of J_s, J_{rs} and χ shows that magnetic enhancement is caused by increasing quantities of ferrimagnetic minerals. A two-component magnetic mixing model with different but invariable coercivities provides a good approximation to data from Hungary and for magnetically enhanced paleosol samples from Tajikistan and China.

Jordanova, D., *et al*.
Rock magnetic properties of recent soils from northeastern Bulgaria, *Geophys. J. Int.*, *128* (2), 474-488, 1997.
Holocene loess-soil sites located at different distances south of the Danube river represent various pedogenic conditions. The uppermost part of recent soil profiles is rich in stable, near-single-domain (SD) particles, while the illuvial horizons are characterized by a gradual decrease in grain sizes, from highly viscous to a true superparamagnetic (SP) domain state.

Sahota, J. T. S., *et al.*
Magnetic measurements of Greenland and Himalayan ice-core samples, *Holocene*, *6* (4), 477-480, 1996.

Paleofield Records

D'Argenio, B., M. Iorio, and D. H. Tarling
Periodicity of magnetic intensities in magnetic anomaly profiles: the Cenozoic of the South Atlantic, *Geophys. J. Int.*, *127* (1), 141-155, 1996.
Spectral properties of both published and raw magnetic anomaly data from the South Atlantic are similar to those expected from long-term orbital eccentricity, suggesting that magnetohydrodynamic processes near the core-mantle boundary may be affected by gravitational changes due to orbital perturbations.

Kelly, P., and D. Gubbins
The geomagnetic field over the past 5 million years, *Geophys. J. Int.*, *128* (2), 315-330, 1997.
Spherical harmonic field models for the past 5 Myr have an axial-dipole intensity similar to that of the modern-day field, whilst the equatorial-dipole component is very much smaller. The field is not axisymmetric, but shows flux concentrations at the core's surface under Canada and Siberia.

Laj, C., *et al*.
Relative geomagnetic field intensity and reversals for the last 1.8 My from a central equatorial Pacific core., *Geophys. Res. Lett.*, *23* (23), 3393-3396, 1996.
Core KK78030 from the central equatorial Pacific has recorded the last 4 reversals. Normalisation with ARM, IRM and χ yield no evidence for a "saw-tooth" pattern. Rather, the average field intensity record appears to display more or less symmetric peaks and troughs, superposed on a broad high between reversals.

McIntosh, G., *et al*.
A detailed record of normal-reversed-polarity transition obtained from a thick loess sequence at Jiuzhoutai, near Lanzhou, China, *Geophys. J. Int.*, *127* (3), 651-664, 1996.
A normal-reversed-polarity transition obtained from loess near Lanzhou may represent the onset of a reversed-polarity zone within the Jaramillo Normal Subchron. Relative palaeointensity determinations showed a distinctive asymmetry, with unusually high post-transitional field intensities.

Schwartz, M., S. P. Lund, and T. C. Johnson
Environmental factors as complicating influences in the recovery of quantitative geomagnetic field paleointensity estimates from sediments, *Geophys. Res. Lett.*, *23* (19), 2693-2696, 1997.
Relative paleointensities determined for the last 70 kyr from the western North Atlantic are significantly correlated with χ/ARM ratios, indicating partial control of the relative intensities by climate-driven grain-size changes.

Tauxe, L., and P. Hartl
11 million years of Oligocene geomagnetic field behavior, *Geophys. J. Int.*, *128* (1), 217-229, 1997.
Paleointensity timeseries for DSDP Hole 522 show consistent decreases in intensity at reversal boundaries, and a weak dependence of average field strength on polarity interval duration. Spectral analysis shows a persistent 30-50 kyr periodicity.

Vlag, P., *et al.*
Evidence for a geomagnetic excursion recorded in the sediments of Lac St. Front, France: a link with the Laschamp excursion?, *J. Geophys. Res.*, *101* (B12), 28211-28230, 1996.
Anomalous paleomagnetic directions accompanied by low relative paleointensities are interpreted as a record of a geomagnetic excursion that occurred at a time when the paleointensity field was low. The excursion is dated at about 37 ka BP by correlating the susceptibility and paleomagnetic logs with the nearby Lac du Bouchet sequence.

Remanence Acquisition

Tarduno, J. A., and S. L. Wilkison
Non-steady state magnetic mineral reduction, chemical lock-in, and delayed remanence acquisition in pelagic sediments, *Earth Planet. Sci. Lett.*, *144*, 315-326, 1996.
A chemical 'lock-in' process at the Fe-redox boundary can smooth paleomagnetic records on time scales ranging from <40 kyr to >400 kyr. The longer smoothing times may account for the 'asymmetric sawtooth' pattern observed in some sedimentary records.

Tectonics & Paleomagnetism

Beck, M. E. J.
On the probability of selecting a sample with inclination less than the true mean from a circular distribution: paleomagnetic and tectonic implications, *Tectonophys.*, *269* (3-4), 317-22, 1997.

Eide, E. A., and T. H. Torsvik
Paleozoic supercontinental assembly, mantle flushing, and genesis of the Kiaman Superchron, *Earth Planet. Sci. Lett.*, *144* (3-4), 389-402, 1996.

…Rick Oches
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glaciation), although now I'll have to submit those visiting fellows applications if I want access to the equipment. Subir Banerjee, Peat Solheid, and I have a long list of projects to finish, continue, and begin in the coming years, and I'm not nearly finished harassing Jim and Mike with my endless questions, equipment modifications, and requests for assistance. So, with my departure, they're not really losing a colleague, instead they're gaining office space.

My introduction to rock magnetism began at the late Pleistocene loess-paleosol sequence at Dolní Vestonice, southeastern Czech Republic. The last interglacial-glacial stratigraphy is well-subdivided at that locality, and we observed early on that the paleosol corresponding to the warmest and wettest part of the last interglacial period has relatively minor magnetic susceptibility (MS) enhancement, compared with late interglacial or early glacial paleosols preserved higher in the section. This was contrary to what had been observed in MS profiles from the Loess Plateau of China, and we proceeded with a suite of rock-magnetic measurements to characterize the magnetic grain size, concentration, and compositional variations through the profile.

Half of my second year was spent as a NSF-NATO Post-doctoral fellow at the Geological Institute, Czech Academy of Sciences, Prague, Czech Republic. During those six months I was able to visit and sample loess profiles elsewhere in the Czech Republic plus make field trips to loess regions of Ukraine and Bulgaria. I returned to the IRM with nearly 100 kilograms of sediment that needed to be packed into plastic boxes and measured. Thanks to the help of Craig Enstad and Shane Colin, the IRM undergraduate assistants, we were able to generate a variety of data that will allow us to compare the magnetic and sedimentological characteristics of sampled profiles in terms of climate-related depositional and post-depositional processes. With NSF support, our efforts have since expanded to include a comparison of loess sediments in central Alaska and the Mississippi Valley, U.S. Our ultimate goal is to understand the relationship between rock-magnetic characteristics in loess and paleosols and specific elements of paleoclimate. As part of our investigation we are focusing on the higher-resolution glacial period loess record, as opposed to the interglacial paleosols, where we seek to identify whether or not abrupt global climate change events, which have been described from marine sediment and ice core records, are similarly recorded in terrestrial loess sediments.

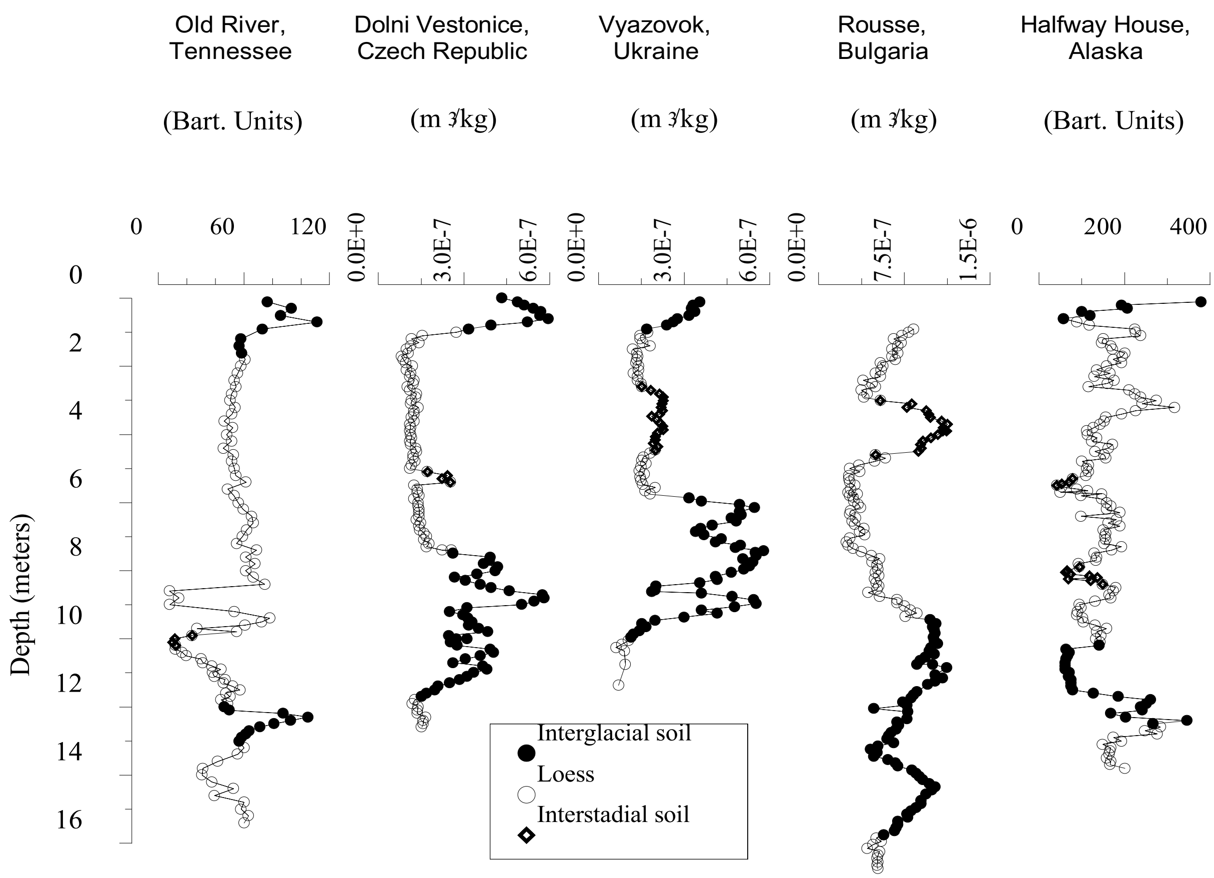
Rather than give away all of our secrets here, I've included a figure comparing just magnetic susceptibility for five loess-paleosol sequences spanning the last interglacial-glacial climatic cycle in five regions. Each profile represents approximately the same time period, according to presently available geochronologic data. We notice many similarities as well as differences in patterns of MS variations. In general, magnetic susceptibility is enhanced in interglacial and interstadial paleosols, relative to the parent material (loess). The most notable exception is in the Alaskan loess record, where MS values are higher in loess and lower in paleosols (as originally described by Jim Beget and colleagues at University of Alaska, Fairbanks). More detailed rock-magnetic measurements are underway, including ARM, hysteresis, and high- and low-temperature remanence and susceptibility behavior, which will lead to a model describing the processes responsible for the variations we observe.

Based on work in these different loess regions, we have developed three conceptual models to explain the measured variations in rock-magnetic properties:

1) Pedogenic enhancement of superparamagnetic and single domain magnetite and maghemite in interglacial and interstadial paleosols. This is what we observe in paleosols of the Chinese, Ukrainian and Bulgarian loess sequences.

2) Diagenetic "loss of susceptibility"

Rick Oches *continued on page 6…*



...Rick Oches

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under intense weathering conditions is associated with warm, humid, interglacial forest soils. The peak interglacial paleosol in the Czech Republic is a good example.

3) Concentration of coarse-grained (multi-domain) ferrimagnetic minerals varies with changes in wind intensity and possibly source area. Our initial results from Alaska suggest that this is perhaps the dominant process in that region.

Considerably more work remains to be done in order to understand the nature of the magnetic mineralogy and the processes responsible for the variations we observe in each of the regions. I hope to be a regular visitor to the IRM in the future, but I'll be happy to be doing the bulk of the work from the sunny and warm climate in Tampa. To the IRM Tea Time group - Slunge!

...Bernie Housen

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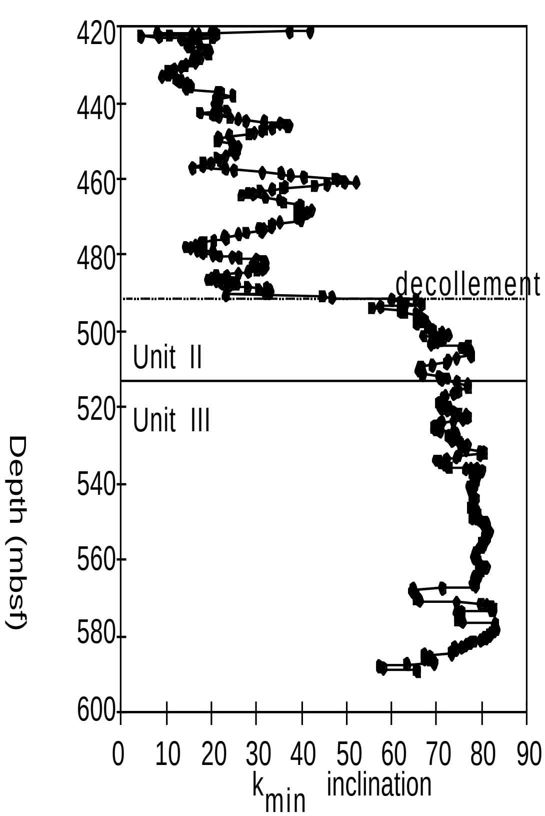
aspect of this work is the ability of magnetic fabrics to pinpoint the location and deformation style of this active fault zone. In the figure below, AMS k_{min} inclinations are plotted versus depth for Site 948, which spans the Barbados décollement. Within the accretionary prism, AMS fabrics indicate a sub-horizontal, plate-convergence-parallel bulk shortening direction. Within the space of about a meter, these orientations flip to indicate a sub-vertical bulk shortening (compaction) direction. The abrupt change in AMS orientations indicates that the Barbados décollement is effectively decoupled by near-lithostatic fluid pressures along this narrow plane, and does not represent a zone of distributed deformation. Along the way, some unusual low-temperature results from some nannofossil chalks in the Barbados prism led to an investigation of low-temperature hysteresis and exchange-coupling between siderite and intergrown magnetite, which produces offset hysteresis loops under certain conditions.



As part of my work on the paleomagnetism and rock magnetism of marine sediments at the IRM, I have managed to join the crowd looking into contributions by magnetotactic bacteria and their magnetofossils to sediment geomagnetism. Starting by working with Bruce, using his patented FC-ZFC test for SD magnetite chains, I have been looking at relationships between magnetotactic bacteria/fossils and modern redox boundaries. My own contribution to this effort is to exploit some of the consequences of the magnetic properties of elongate SD particles with regards to detection and evaluation of magnetofossil behavior in sediments. Elongate SD particles will have characteristic "inverse" AMS fabrics, and should also possess a strong gyro-remanent magnetization (GRM). Both of these properties theoretically would enable one to uniquely determine the average orientation of a population of such bacteria or their magnetofossils in a sediment sample by measuring either AMS or GRM anisotropy. Preliminary work indicates there is a strong link between Fe-redox boundaries, FC-ZFC results showing abundant chains of SD magnetite particles, and inverse AMS fabrics in marine sediments from several areas. This "nice" story is complicated by the fact that, given the orientations of the magnetofossils indicated by AMS, the chains of bacterial magnetite do not seem to be aligned with the direction of NRM in many of the sediment samples. The suggestion that magnetofossils are preferentially compacted, and do not carry much of these sediment's NRM, led to some rather lively discussion at the last Santa Fe rock magnetism conference! Stay tuned for further developments.

In keeping with the theme of redox conditions and their effects on the magnetic properties of sediments, I am in the latter stages of a couple of projects with Fe-sulfides. Working with Ian Snowball, we are trying to pin down the Curie temperature of greigite using the IRM's new MicroVSM. So far, we have a few of thermal runs (measuring a series of hysteresis loops as a function of temperature) which suggest that greigite's T_c may be above 350 C. As always, there is a complication: XRD results indicate that many of the samples have both greigite and smythite, and it appears that the most recent study of greigite (Roberts, 1995) also used samples containing smythite. So far, finding a reference to the thermo-magnetic properties of smythite has been difficult. I am also working on a project with Joel Kostka, looking at the effects of cold water temperatures on Fe-redox and the formation of Fe-sulfide minerals. These sediments were collected from the depths of several fjords off of Svalbard, and appear to contain records of magnetic Fe-sulfides which can be related to redox features in these cores.

Lastly, I sailed on yet another ODP cruise (leg 170), this time to the Costa Rica margin. Work is only just beginning on this project, which will involve a panoply of magnetic measurements designed to elucidate the deformation behavior of this active décollement and wedge system, examine the role of magnetofossils as remanence carriers, and to attempt a correlation with cosmogenic ^{10}Be concentrations and variations in the relative paleointensity of the geomagnetic field during the Blake event. To complete this work, I'll undoubtedly need to return to the IRM as a visiting fellow, and look forward to the chance to do this (even if it ends up being in the dead of Winter!)

In between all of these projects, Beth (my wife) and I managed to have two children (Rachel, born in 1995, and Wil, born in 1996), who besides being super cute, really keep us on our toes! I have also served as IRM WebMeister, and have acquired the ability manipulate photos and produce tacky graphics and animations. I also had the pleasure of some truly wonderful Minnesota winters; where else can you go to experience an air temperature of -40C, and see that when it gets that cold, paint falls off several of the campus buildings! And, finally, after amassing a collection of 62 rejection letters, I have at last found one of those elusive tenure-track jobs!

…Visiting Fellow Reports
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inverse fabric are present at the margins. The change in the parameters after heating might be attributed to the exsolution of the multidomain titanomagnetites. The presence of sulphides in the samples to explain the very high degree of anisotropy associated to type 2 was also suspected.
This interpretation was checked using the different instrumentations available at the IRM. Samples from dykes characterized by the same fabric all across (type 1 or type 2) and from dykes exhibiting both types of fabrics were examined. Hysteresis loops obtained from larger samples (300 to 400 mg) using the microVSM confirmed the results previously obtained from small chips of rocks using the micromag: there is no straightforward relationship between the magnetic fabric and the hysteresis parameters. Similarly, the anisotropy of anhysteretic remanent magnetisation did not give any clear results with a large scatter of the principal directions of the ellipsoid.
High temperature measurements of low-field susceptibility show that the mineralogical transformations occur in type 2 samples at temperature as low as 300°C, despite the use of a continuous Argon flow during the experiment. On the other hand, a clear picture arises from the study of the thermal demagnetisation from 20K to 300K of a SIRM induced at 20K. The samples characterized by type 1 magnetic fabric and the reversible Curie balance analysis all show a drop of 30 to 70% of the magnetization between 20 and 45K. This drop is followed between 50 and 300K by a slower decrease of the magnetisation down to 10-20% of the initial value. This low temperature behaviour of the SIRM is associated to a large increase of the susceptibility between 30 and 60K. Between 20K and 50K, no evolution of the SIRM was observed for type 2 samples while only a moderate decrease of the susceptibility was observed. Between 50 and 300K, the SIRM starts to decrease at 50K with a concave up shape of the curve and the magnetisation reaches about 10-20% of the initial 20K SIRM. In the same temperature interval, the susceptibility value increases progressively by a factor of ten. With the help of the colleagues from IRM, these two different low temperature behaviours were interpreted in terms of titanomagnetites with different Ti-content. The type 1 and type 2 samples seem to contain mainly low and high Ti-content titanomagnetites respectively ($x \sim 0.1$ and $x \sim 0.6$).
Although no evidence for an inverse fabric or for clearly different domain state magnetites have been obtained, the low temperature results are consistent with the suggestion that the thermal evolution of type 2 samples is due to exsolution of Ti-rich titanomagnetite.

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Magnetic Mineralogy in Three Lakes in NE Pennsylvania

As part of my dissertation, I examined paleosecular variation, mineral magnetic parameter (susceptibility, SIRM, ARM, S-ratio), and AAR (anisotropy of anhysteretic remanence) magnetic fabric data in 1.5 to 5.5 meter Holocene sediment cores from three lakes in the Pocono Mountains of Pennsylvania. I also examined mineral magnetic parameter data from possible sediment sources within each lakes' watershed (topsoil, subsoil, bedrock). These studies had two purposes: an understanding of the watershed history for each lake, and, through interlake correlation, an understanding of the region's climate history.

The results suggested that the magnetic minerals within the sediment cores in at least two of the three lakes were not derived wholly from the lake watershed, but were probably produced within the lake basin, i.e. they were authigenic, diagenetic or biogenic minerals. In order to fully understand the lake watershed history of each lake, I needed a more complete characterization of the magnetic minerals of both the core sediments and the possible sediment sources.

Intralake correlation of the magnetic mineral parameter data had outlined several distinct zones within each lake. The samples I took to the IRM consisted of wet lake sediment from each zone (6 in Lake Waynewood; 3 in Lake Giles, and 5 in Lake Lacawac), as well as samples from two soil profiles in the Lake Waynewood watershed and four soil profiles in the Lake Giles watershed. At the IRM, I ran three sets of experiments: frequency-domain susceptibility on the Lakeshore Susceptometer, temperature dependence of susceptibility on the Kappa Susceptometer, and low temperature dependence of SIRM on the MPMS.

The frequency-dependence of susceptibility measurements indicated that the Lakes Giles and Waynewood soils contained little to no superparamagnetic minerals. The lake sediments from Giles showed minor dependence in the uppermost zone. Similarly in Waynewood, only one zone showed any degree of frequency-dependent susceptibility. However, the susceptibility in Lacawac samples taken from high S-ratio (low coercivity, low susceptibility) zones showed a much higher degree of dependence on frequency.

Measurements of the (high) temperature dependence of susceptibility tended to be inconclusive, as the samples were

VF Reports *continued on page 8…*

Bitter, Francis

b. July 22, 1902, Weehawken, NJ
d. July 26, 1967, Cape Cod MA

Bitter's early work in the late 1920's on paramagnetic gases provided valuable experimental confirmation of various predictions of quantum theory. His fundamental studies of ferromagnetism and magnetic domains led him to develop the powder/colloid domain imaging technique that now bears his name. In 1939 he designed the first magnet capable of maintaining steady fields of over 100 kiloGauss for investigating the Zeeman effect. Bitter was instrumental in the establishment of the National Magnet Laboratory at MIT in 1962.

Spring & Summer Visiting Fellows

The Visiting Fellows for spring and summer of 1997 have been selected and some have begun their research visits. The successful applicants and their project titles are as follows:

Carlos Archanjo, UFRN: Magnetic Mineralogy and Anisotropy of Remanence in the Alkaline Granite Pluton of Meruoca

Andrei Kosterov, Université de Montpellier II: Temperature Dependence of Hysteresis Parameters as a Tool for Paleointensity Sample Selection

Luca Lanci, ETH Zurich: Magnetic Properties of Gleysoils

Sven Morgan, Virginia Tech: Emplacement of the EJB Pluton

Adry Van Velzen, Oxford University: Paleointensity Experiments on Historic Lava Flows

Weiming Zhou, University of Michigan: Characterizing the Magnetic Minerals of Ocean Floor Basalts

Fall & Winter Applications Due

Winter in Minneapolis. If you've always dreamed of experiencing intense, painful, even life-threatening cold weather, here is the opportunity you've been waiting for. Visiting Fellowship proposals (for stays of up to ten days between August 1997 and February 1998, and travel reimbursements of up to $500) are due by Friday, June 13. Application forms are available on our WWW site or by contacting the IRM facailities manager. Proposals will be evaluated by our Review and Advisory Committee (John King, chair), and successful applicants will be notified by mid-July.

...Visiting Fellow Reports

continued from page 7

very weak. Neither the 580°C magnetite unblocking temperature or the 680°C hematite unblocking temperature were seen. The major point of interest in almost all samples (soil and lake sediment both) was the presence of a 350-450°C peak in the spectrum, which could be indicative of a goethite-organic carbon combination (Hansch 1995).

Low temperature measurements of SIRM suggested that the high-coercivity mineral present in certain zones from all three lakes was not hematite, as no Morin transition was evident. A very minor Verwey transition was present in some samples, i.e. the high S-ratio zones from Lakes Waynewood and Lacawac. A very pronounced Verwey transition was present in one sample from the glacial silt at the bottom of Lake Lacawac. However, the results suggested that magnetite was not a major part of the Holocene sediment in any of the three lakes.

While my work at IRM did not completely answer all of the questions regarding the magnetic mineralogy and possible sources of the lake sediments in the three lakes, it certainly narrowed down the possibilities. The high-coercivity mineral which dominates the magnetic mineralogy in much of the Lake Waynewood cores is probably allogenic goethite rather than hematite, as I had first hypothesized. The high S-ratio, low coercivity, low susceptibility zones in Lacawac are not consistent with any regional soil characteristics, and are probably due to in-situ processes. The mineralogy of these zones is uncertain: small amounts of magnetite appear to be present; however, the possibility of greigite cannot be ignored.

Hanesch, M. 1995. Magnetische Eigenschaften von Böden, M.Sc. Thesis, Institut für Allgemeine und Angewandte Geophysik der Ludwig Maximilians Universität, München.

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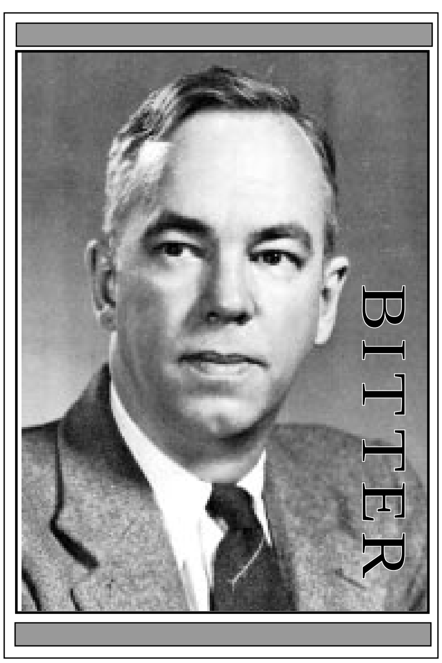

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The *Institute for Rock Magnetism* is dedicated to providing state-of-the-art facilities and technical expertise free of charge to any interested researcher who applies and is accepted as a Visiting Fellow. Short proposals are accepted semi-annually in spring and fall for work to be done in a 10-day period during the following half year. Shorter, less formal visits are arranged on an individual basis through the Facilities Manager.

The *IRM* staff consists of **Subir Banerjee**, Professor/Director; **Bruce Moskowitz**, Associate Professor/Associate Director; **Jim Marvin**, Senior Scientist; **Mike Jackson**, Senior Scientist/Facilities Manager, and **Peat Solheid**, Scientist.

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