The IRM Quarterly

WINTER 1993–94, VOL. 3, NO. 4 INSTITUTE FOR ROCK MAGNETISM

Inside…

Photo: Chris Faust

Scott Rubin *taking time with his TRM furnace, complete with thermocouple, atmosphere control, and Sri Lankan mask.*

Tasks at the *IRM* Take Time, Part III

Stefanie Brachfeld, Sherry Foss, Chris Hunt, Gin Kletetschka, Jim Marvin, Bruce Moskowitz, Scott Rubin, Mitra Sahu, Peat Solheid, Weiwei Sun
IRM

In order to plan visits to the IRM, *many people have asked what is entailed in making given measurements. The answer consists of a series of short lab notes by the people who most often do the work. This last of three installments on real-world data-gathering at the* IRM *deals with, among other things, thermal techniques, paleointensity, and imaging.*

Thermal Techniques

TRM

A thermal remanent magnetization (TRM) can be imparted to a sample in a controlled-field, controlled-atmosphere furnace. The field can be set from 0 μT to 100 μT, and the environment in the furnace can be air, nitrogen, carbon monoxide, or carbon dioxide. Samples should be small enough to fit in a standard quartz boat (about an inch in diameter). A heating cycle up to 600°C and back takes roughly an hour and a half. TRMs can then be measured in less than a minute on the superconducting rock magnetometer (SRM).

Thermal demagnetization

Demagnetization in the thermal demagnetizer takes from 45 minutes to an hour per step, depending on the maximum temperature. Between heating steps, remanence measurements are again made in less than a minute on the SRM. To speed up measurements, you can run up to eight standard cores at a time, but plan to spend most of a day on one set of six-step thermal demagnetizations.

Paleointensity

Thellier

The Thellier method—involving thermal demagnetizations of natural remanent magnetization (NRM) and TRM—is the most time-consuming of the paleointensity techniques. Double heating steps take about three hours in the controlled-field furnace, although magnetizations are measured on the SRM in only a matter of minutes. Plan on several days per set of three samples to do a complete Thellier paleointensity determination.

Shaw

The Shaw paleointensity method—involving alternating-field (AF) demagnetizations of NRM, TRM, and anhysteretic remanent magnetization (ARM)—goes a bit faster since there is only one heating, and since AF demagnetization is done in mere minutes per step. An entire Shaw experiment takes about 4 hours.

Relative

A determination of relative paleointensity—involving AF demagnetizations of NRM and ARM only—is the quickest (and dirtiest!) of the procedures. A typical experiment using three-axis NRM measurements, one-axis ARM measurements, and six AF demagnetization steps for each was clocked at 40 minutes per sample, or 45 minutes for doing two samples in tandem.

Miscellaneous

CBD

Citrate-bicarbonate-dithionite (CBD) treatment is a wet chemistry technique which dissolves very fine-grained iron-oxide minerals. Preparing the needed solutions from re-

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Visiting Fellows' Reports

Despite the cold temperatures this winter (down to –30°F, not to mention the dreaded wind chill), our Visitors were undaunted. **Peter Jaumann** came up from Iowa City to characterize his Pleistocene paleoclimate sediments. **Tia Bijaksana** came down from St. John's to investigate inclination shallowing in deep-sea sediments. Finally, **Suzanne McEnroe** came over from Amherst to investigate all sorts of igneous and metamorphic iron oxides. Below is a summary of the work done by the Fellows at the *IRM*:

Peter J. Jaumann
University of Iowa

Mineral Magnetic Properties of Lake Sediments as a Last Glacial Maximum Paleoclimate Proxy

My objectives for this project were (1) to obtain common room-temperature magnetic granulometry data, (2) to measure typical hysteresis parameter ratios, and (3) to attempt to quantify estimates of erosion and watershed surface runoff. I came with two well-^{14}C-dated lacustrine sequences from the central Mississippi River valley. Both records span the time around the last glacial maximum (LGM) from about 21 ka to 16 ka. The focus was on the Jamestown Quarry (JTQ), a lacustrine upland sequence with varying lithologies. In contrast, Lomax is an alluvial lowland record.

Prior to my visit to the *IRM*, we analyzed the JTQ section for several paleoclimate proxies such as pollen, lake levels, ostracodes, and clay mineralogy. We are planning to measure δ^{18}O, δ^{13}C, and trace metals on the ostracode shells. The JTQ profile includes three prominent (flood) clay layers which might be related to meltwater pulses stemming from aperiodic fluctuations of the Michigan ice lobe to the north. With the mineral magnetic record I wanted to derive semi-quantitative estimates of erosion and runoff from the clay layers. Such estimates can then be used as input to local and regional models of soil-water balance or lake-level change. Ultimately, I plan to use the different LGM paleoclimatic proxies (*i.e.*, geologic observations) both (1) to validate output from General Circulation Models such as GENESIS for the Midwestern region, and (2) as lower boundary condition model input parameters (*e.g.*, land-surface albedo and effective soil moisture).

Altogether, I conducted more than 700 measurements. Parameters obtained included laboratory magnetic susceptibility (χ), dual-frequency susceptibility (χ_{fd}, at 470 and 4700 Hz), ARM, SIRM (at 1000 mT), and hysteresis loops ($J_{\mathrm{rs}}/J_{\mathrm{s}}$ and $H_{\mathrm{cr}}/H_{\mathrm{c}}$ ratios). To analyze more data, I opted to use the MicroMag for hysteresis loops. The bridges were used for measuring χ, and the AF demagnetizers and cryogenic magnetometer were used to determine ARM.

Preliminary results indicate that the flood clays are magnetically very weak, resulting in very small hysteresis loops that have large diamagnetic components. Hence, it will prove difficult to extract semi-quantitative runoff estimates using mineral magnetic properties. The distribution of χ and ARM along the sequence reproduces significant lithologic variations very well. Excluding the flood clays, hysteresis loop ratios ($J_{\mathrm{rs}}/J_{\mathrm{s}}$ vs. $H_{\mathrm{cr}}/H_{\mathrm{c}}$) seem to indicate the presence of mostly pseudo-single-domain (PSD) and multi-domain (MD) grains, possibly some superparamagnetic (SP) grains, and barely any single-domain (SD) grains. PSD grains are associated with lacustrine silts derived from the Peoria loess, which contain abundant lightly-colored organic (*Chara*) laminae as well as ostracode and mollusk shells. MD grains can be found mainly in very organic-rich silts, and SD grains occur preferentially in clayey silts with thin organic laminae. A biogenic origin for some of the grains can not be excluded. Plotting and interpreting various magnetic variables and ratios will definitely reveal further insights as well as produce more puzzles. Future work might include using the VSM to estimate grain size, and conducting low-temperature remanence experiments with the MPMS to better define total magnetic and fractional grain-size distributions.

I spent a very productive and enjoyable week at the *IRM* and would like to thank **Chris Hunt**, **Subir Banerjee**, **Peat Solheid**, **Jim Marvin**, and **Gin Kletetschka** for discussions and/or help. Special thanks to **Peat Solheid** who shared his office space and Mississippi valley loess data with me. I am particularly grateful to **Chris Hunt** for organizing the trip to Minneapolis, answering all my questions, and for running back and forth between the VSM and MicroMag to change the famous delicate glass sample holder on the MicroMag.

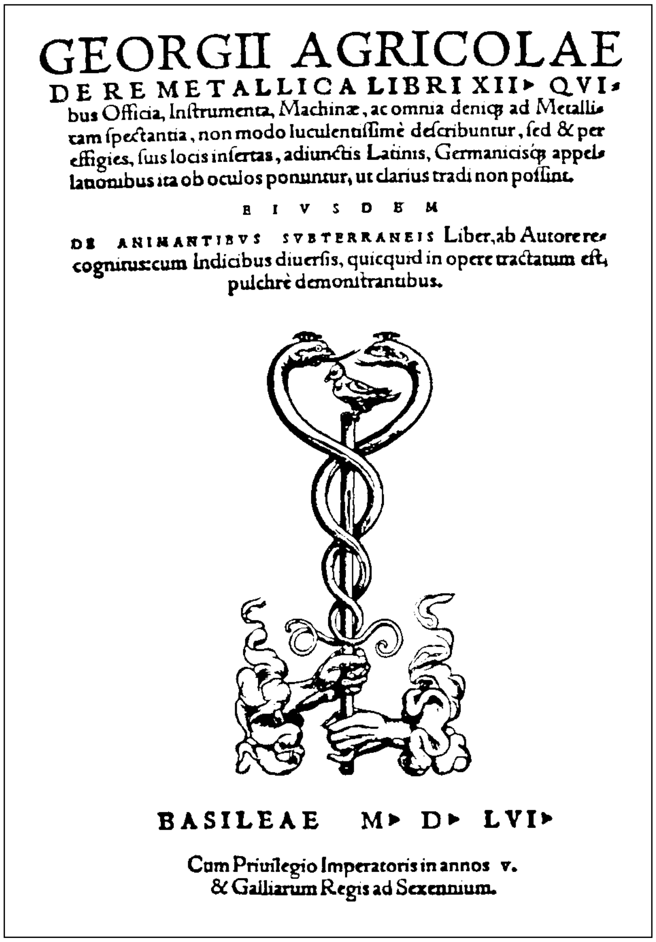
Satria Bijaksana
Memorial University of Newfoundland

Rock-Magnetic Study of Magnetic Inclination Shallowing in Sediments

My supervisor and I have shown (Hodych and Bijaksana, *J. Geophys. Res.*, *98B*, 22,429-22,441, 1993) [see last summer's *IRM Quarterly* for an abstract] that anisotropy of anhysteretic remanence (AAR) can improve the accuracy of the magnetic inclination record in Cretaceous deep-sea sediments from the Pacific plate. AAR, which presumably reflects the preferred orientation of the magnetic particles within the sample, correlates nicely with the observed inclination shallowing. Currently, I am trying to use the same principle for recent (soft) clay-rich and carbonate-rich deep-sea sediments from both the Pacific (DSDP site 578) and the Atlantic (DSDP site 606). The results will be compared with the existing theory. To do this, I need to know the predominant ferrimagnetic mineral and its domain state in my samples.

The purpose of my visit to the *IRM* was to measure low-temperature remanence (using the MPMS) and hysteresis loops (using the MicroMag) for my samples. The temperature dependence of low-temperature remanence will help me to distinguish hematite from magnetite, and to determine its contribution to

VF Reports continued on page 5…



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ita ob oculos ponuntur, ut clarius tradi non poſſint.

EIVSDEM

DE ANIMANTIBVS SVBTERRANEIS Liber, ab Autore recognitus:
cum Indicibus diuerſis, quicquid in opere tractatum eſt,
pulchrè demonſtrantibus.

BASILEAE M▸ D▸ LVI▸

Cum Priuilegio Imperatoris in annos v.
& Galliarum Regis ad Sexennium.

Title page from Georgius Agricola's De Re Metallica, *1556.*

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 edited for the* IRM Quarterly. *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 2100 references, is available free of charge. Your contributions both to the list and to the Abstracts section of the* IRM Quarterly *are always welcome.*

AMS

Lu, G., and C. McCabe
Magnetic fabric determined from ARM and IRM anisotropies in Paleozoic carbonates, southern Appalachian basin, *Geophys. Res. Lett., 20,* 1099-1102, 1993.
Because anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM) are carried by different grain-size fractions of magnetite, the ARM anisotropy ellipsoids of Paleozoic carbonates differed markedly from the IRM anisotropy ellipsoids. The former appeared to reflect a pre-deformation depositional magnetic fabric; conversely, the latter was compatible with a tectonic fabric due to Alleghenian deformation.

Yan, G., and S. Hu
The correction of TRM deviation induced by AMS and its application, *J. Geomagn. Geoelectr., 45,* 495-502, 1993.
Using the theory that the anisotropy eigenvalue ratios of thermal remanent magnetization (TRM) are the square of the principal susceptibility ratios in anisotropic multidomain magnetic assemblages, a formula was derived to correct the deviation of TRM directions away from the ambient field direction that was caused by the anisotropy of magnetic susceptibility (AMS).

Crustal Magnetization

Gee, J., *et al.*
Magnetization of the La Palma seamount series: implications for seamount paleopoles, *J. Geophys. Res., 98B,* 11,743-11,767, 1993.
The natural remanent magnetization (NRM) of samples from a section through an exposed seamount proved to be a poor indicator of the original magnetization direction because hydrothermal alteration had changed the magnetic mineralogy and degraded the signal through remagnetization. It was concluded that viscous and induced magnetization probably account for 15–25% of the total magnetization of seamounts.

Masalu, D. C. P., K. Tamaki, and K. Kobayashi
Paleomagnetism of the Joban seamount chain, northwestern Pacific, *J. Geomagn. Geoelectr., 45,* 503-534, 1993.
A 3-D magnetic inversion was applied to bathymetric and magnetic total-force data from five seamounts in the Joban chain. The three northern seamounts showed relatively complex magnetization structures; the two southern seamounts had simple ones. Collectively, the seamounts showed the presence of at least two groups of inclinations, suggesting that the origin of this chain was not the passage of the Pacific plate over a single stationary hotspot.

Pariso, J., and H. P. Johnson
Do lower crustal rocks record reversals of the Earth's magnetic field? Magnetic petrology of oceanic gabbros from Ocean Drilling Program hole 735B, *J. Geophys. Res., 98B,* 16,013-16,032, 1993.
Results of a magnetic and petrographic study of oceanic gabbros suggested that their primary magnetization was a thermal remanent magnetization, or a very high-temperature chemical remanent magnetization acquired near the ridge crest. Hysteresis loop parameters indicated that all of the studied samples were capable of carrying significant, stable remanent magnetization, so that layer 3 crustal rocks are capable of recording reversals of the Earth's magnetic field.

Pariso, J., and H. P. Johnson
Do layer 3 rocks make a significant contribution to marine magnetic anomalies? In situ magnetization of gabbros at Ocean Drilling Program hole 735B, *J. Geophys. Res., 98B,* 16,033-16,052, 1993.
To predict the magnitude of a typical layer-3 anomaly as observed at the sea surface, the average effective magnetization of olivine gabbros was used in a 2-D forward model. The results indicated that deep-crustal sections would contribute from 25% to 75% of the overlying marine magnetic anomalies at the sea surface, assuming near-vertical polarity boundaries within oceanic layer 3.

Imaging

Baruchel, J.
X-ray and neutron topographical studies of magnetic materials, *Physica B, 192,* 79-93, 1993.
Using neutron and synchrotron topography, which allowed the simultaneous observation of crystalline and magnetic defects, investigations were made of the relationships among domain size, sample purity, domain shape, and magnetic history of a crystal. Observations were also made of domain shapes, movements, and interactions with crystalline defects as a function of temperature or applied field.

Models

Hollerbach, R., and C. A. Jones
Influence of the Earth's inner core on geomagnetic fluctuations and reversals, *Nature, 365,* 541-543, 1993.
In a time-dependent model in which the field in a conducting inner core was electromagnetically coupled to that in the outer core, the inner-core field did not adjust instantaneously to the outer core, but responded over a few thousand years. Large, rapid fluctuations in the outer core were thus damped out by the inner core to produce a relatively stable external dipole field, so that only particularly large, long-lasting fluctuations lead to reversals.

Paleointensity

Mankinen, E. A., and D. E. Champion
Latest Pleistocene and Holocene geomagnetic paleointensity on Hawaii, *Science*, *262*, 412-416, 1993.
An analysis was made of geomagnetic paleointensity determinations from Hawaiian lava flows, radiocarbon-dated to from between 45,000 and 10,000 years ago. The results, combined with others worldwide, indicated that the intensity of the geomagnetic field was about 35% lower than that of the Holocene average. A long-term reduction of this magnitude is compatible with reported increases in the production rate of cosmogenic nuclides during the same interval.

Pick, T., and L. Tauxe
Geomagnetic palaeointensities during the Cretaceous normal superchron measured using submarine basaltic glass, *Nature*, *366*, 238-242, 1993.
High-quality Thellier-Thellier paleointensity data obtained from Recent submarine basaltic glasses yielded today's geomagnetic intensity at the sampling site, and Cretaceous normal superchron samples gave paleointensities that were 25–45% of today's value. The data thus extended what is known as the "Mesozoic dipole low" into the Cretaceous superchron, and confirmed that submarine basaltic glass is an excellent material for paleointensity studies.

Schneider, D. A.
An estimate of late Pleistocene geomagnetic intensity variation from Sulu Sea sediments, *Earth Planet. Sci. Lett.*, *120*, 301-310, 1993.
Using only continuous shipboard measurements of remanence and susceptibility, the relative variation in the geomagnetic field strength was estimated. Calibration of the resultant relative paleointensity record against estimates of absolute paleointensity yielded an estimate of the virtual dipole moment since 100 ka. The record obtained compared favorably with Mediterranean Basin sediment records.

Valet, J.-P., and L. Meynadier
Geomagnetic field intensity and reversals during the past four million years, *Nature*, *366*, 234-238, 1993.
A long and continuous record of geomagnetic field intensity showed that intensity variations were dominated by two modes. Major episodes of field regeneration prevailed on timescales of a few thousand years immediately after most reversals, while stable polarity states were characterized by a slow (0.5 Ma) relaxation process. Reversals were seen as the consequence of a progressive degradation of the dipole field.

Physics

Belov, K. P.
Electronic processes in magnetite (or, "Enigmas of magnetite"), *Phys.-Uspekhi* (transl. of *Uspeki Fiz. Nauk*), *36* (*163* in orig.), 380-391 (53-66 in orig.), 1993.
A new model for the low-temperature transformation at T_t = 100–120 K in magnetite is presented, which is based on the behavior of spontaneous magnetization, magnetoresistance, the magnetocaloric effect, magnetic anisotropy, and magnetostriction in the T_t region. This magnetic-electronic model of the transition is consistent with experimental facts that do not fit into the Verwey model of a structural-electronic transition.

Reversals

Prévot, M., and P. Camps
Absence of preferred longitude sectors for poles from volcanic records of geomagnetic reversals, *Nature*, *366*, 53-57, 1993.
A compilation of intermediate poles from volcanic records of excursions and reversals did not confirm previous inferences, and reinforced doubts about the ability of sediments to record a rapidly varying field. These VGPs were uniformly distributed in longitude, indicating that the reversing field was statistically axisymmetrical. Thus, there was no evidence for control of transitional fields by the temperature distribution in the lower mantle.

Rock Magnetism

Moskowitz, B. M., R. Frankel, and D. Bazylinski
Rock magnetic characterization of biogenic magnetite, *Earth Planet. Sci. Lett.*, *120*, 283-300, 1993.
Results of a study of magnetic properties of magnetites produced by magnetotactic and dissimilatory iron-reducing bacteria suggested that a combination of room-temperature coercivity analysis and low-temperature remanence measurements provided a characteristic magnetic signature for intact chains of single-domain (SD) particles of biogenic magnetite.

Oldfield, F.
Towards the discrimination of fine grained ferrimagnets in lake and nearshore sediments by magnetic measurements, *J. Geophys. Res.*, *in press*, 1994.
Natural soil and sediment samples were grouped according to χ_{ARM}, χ, and χ_{fd} characteristics. The origin of one set was detrital; the other probably bacterial. Magnetic measurements alone cannot yet discriminate between bacterial and fine-grained detrital ferrimagnets, but they might do so, provided that the distinctions proposed are substantiated by TEM.

Secular Variation

Verhoef, J., and C. A. Williams
A method for isolating secular geomagnetic variation from shipboard total field measurements: a test case in the NE Atlantic, *Geophys. J. Int.*, *115*, 471-481, 1993.
From shipboard data obtained between 1956 and 1988, some 29,000 secular variation values were calculated at cross-over points. These results were compared with those obtained from the International Geomagnetic Reference Fields (IGRF). Statistical analysis revealed that the shipboard values were able to match or even to improve the IGRF values.

Sediments

Lu, R., and S. K. Banerjee
Magnetite dissolution in deep sediments and its hydrologic implication: a further study of sediments from Site 808, Leg 131, *J. Geophys. Res.*, *in press*, 1994.
Results of a rock-magnetic and geochemical study of deep-sea sediments revealed that decomposition of organic matter at great depth caused catagenesis which mobilized iron and manganese. This, rather than early shallow diagenesis or variation in sediment source, was responsible for magnetite dissolution and hence for the low NRM intensity zones found at depth.

Morden, S. J.
Magnetic analysis of K/T boundary layer clay from Stevns Klint, Denmark, *Meteoritics*, *28*, 595-599, 1993.
The magnetic mineralogy of samples of Cretaceous/Tertiary boundary-layer clay was found to consist of single-domain magnetite, fine-grained pyrrhotite (Fe_7S_8), and other sulfides which altered to magnetite upon heating. A magnetic separate from the coarse fraction was found to contain low-Ni Fe (T_C = 750–770°C) in trace quantities, which was interpreted as debris from the vaporization of a K/T impactor.

Nagy, E. A., and K. E. Sieh
The use of paleomagnetic analysis to assess nonbrittle deformation within the San Andreas fault zone, *J. Geophys. Res.*, *98B*, 17,965-17,979, 1993.
DRM declination directions (used to measure rotational, nonbrittle deformation of sediment samples taken from unconsolidated strata exposed across the San Andreas fault zone) were so variable that the results of paleomagnetic calculations were not precise enough to discern reasonable (< 20°) amounts of rotation. These results put into question a similar soft-sediment study which claims to have successfully detected less than 20° in rotational deformation.

…*VF Reports continued from page 2*

remanence. The hysteresis loops will help me determine the domain state of the magnetic grains in my samples.

Unfortunately, the MPMS died just a few days before my visit [but see page 7 for an update.] However, **Chris** and **Jim** managed to set up the "new toy on the block"—the LakeShore susceptometer—for me to use. The LakeShore gives susceptibility, instead of remanence, as a function of temperature. After hours of figuring out how to run the sample smoothly, we managed to measure a few clay-rich samples. One of the samples shows an interesting peak around 120 K, which is presumably due to the Verwey transition. The other samples do not show this peak, but show paramagnetic behavior. My luck was better with the MicroMag. The hysteresis loops indicate that my clay-rich samples are pseudo-single domain (PSD). The values of M_{rs}/M_s vs. H_{cr}/H_c tend to cluster in the PSD region. On the contrary, for my carbonate-rich samples these values tend to scatter. Some of them even fall in the SD region.

I cannot say much about these results (yet) because I still have to finish the bulk of my measurements (AAR, compaction experiments, and so on) this summer. By then I hope to get a better picture of the problem.

My stay at *IRM* was enjoyable. I express my appreciation to **Subir Banerjee**, **Bruce Moskowitz**, and **Weiwei Sun** for discussions and advice. **Chris Hunt** and **Jim Marvin** helped me in using the instruments. I thank both of them for their time and patience. I also thank the entire staff and students for their hospitality. (By the way, as I write this, I was promised the best dumplings in town, courtesy of **Weiwei Sun**!)

Suzanne McEnroe
University of Massachusetts

Magnetic Properties of Intrusive Igneous Rocks from New England

In my 1993 Ph.D. thesis at the University of Massachusetts, I studied the paleomagnetism of Triassic and Jurassic diabases in Massachusetts and Rhode Island, and larger Cretaceous intrusions, ranging from gabbro through syenite, in Vermont, New Hampshire, and Maine. In these studies many of the rocks were quite coarse-grained, but with extremely stable remanence, and I wanted to seek a quantitative explanation for these properties.

This led me to my recent (and first) visit to the *IRM*—a visit which I viewed as a training period where I would have an opportunity to discover what was available, learn how to run the equipment, and acquire some pertinent data. I brought a large collection of Mesozoic intrusive igneous rocks from New England. The diabases ranged in composition from tholeiitic, transitional alkalic to alkalic. The titanomagnetite grains ranged from ultra-fine magnetite dust to fine skeletal crystals, large coarse-grained magnetites, and small exsolutions in silicates. I had previously characterized the magnetic mineralogy in the samples by reflected-light microscopy as to mineralogy, oxidation state morphology, textures, and amount and type of alteration, if any. The samples had different magnetic behaviors which I had been trying to associate with the reflected-light observations. Prior to my trip to the *IRM* I had done detailed alternating-field and thermal demagnetization, and SIRM measurements on many samples. Obtaining magnetic grain-size information from the hysteresis ratios (J_{rs}/J_s and H_{cr}/H_c) was a primary aim of the visit, as was trying to correlate this information with the petrographic information.

I measured hysteresis properties, Curie temperatures, ARMs, SIRMs, and susceptibility. Hysteresis properties were measured to get a better handle on the grain-sizes of the magnetic carriers. The VSM was used to measure 59 paleomagnetic cores which had been cut in half perpendicular to the base of the core. From the other half of the cores either polished thin sections or polished cores had been made. Powders remaining from paleomagnetic diabase samples that had been crushed for geochemical analysis were also brought along. I was able to run 25 hysteresis loops and SIRMs on these samples on the MicroMag. Based on the J_{rs}/J_s and H_{cr}/H_c ratios, samples fell in all three domain categories (single domain, pseudo-single domain, and multi-domain), though the majority plotted in the field of pseudo-single domain. In some cases, results were predictable and easily correlated with the observed magnetic mineralogy. In other instances, the results were surprising.

Though the Curie temperature measurements were time-consuming, I was able to obtain 30 good Curie points on the VSM. After preparing a pellet of powder, I would painstakingly load it into the glass sample holder (which was very easy to break), then gently pack it in with fiberfrax, and hope it would hold tightly in position for the duration of the run. The Curie measurements took about an hour to run, so during this time I would measure ARMs, demagnetize ARMs, or measure susceptibilities.

Frequency dependence of susceptibility, both at room temperature and at low temperature, was measured on the LakeShore susceptometer on five selected samples. The room-temperature analysis showed little or no paramagnetic components. The low-temperature measurements all beautifully displayed low-temperature transitions for magnetite and for ilmenite.

Bruce Moskowitz kindly showed me how to observe Bitter patterns on polished cores. We also tried to observe the domain walls moving on the MOKE.

Now I can start to interpret and correlate the mass of data I acquired at the *IRM*. During my next visit to the *IRM* I am sure I will be just as hungry for data, but I will plan to spend more time on domain imaging. As a paleomagnetist and not a rock magnetist, I was slightly intimidated by the thought of visiting the *IRM*, but found it a wonderful place. Technical assistance was always available, but more important, my basic questions about rock magnetism were answered in a helpful and friendly manner. My sincere thanks to **Subir Banerjee**, **Chris Hunt**, **Jim Marvin**, and **Bruce Moskowitz** for their help, hospitality, and thought-provoking conversations. ■

Visiting Fellowship Application Form

This form is to be photocopied for use as part of a Visiting Fellowship application. Each of the equipment descriptions includes: its name, manufacturer, and specifications; the approximate time needed to make a measurement; and a typical sample size. In the blank space next to the appropriate entry, write in your estimate of how much time you will need, how many samples you have, or other relevant comments.

Name: ______________________

Fellowship Category: Graduate Student ________ Post-Ph.D. ________

Preferred Dates: ______________________

Institution: ______________________

Phone: ______________ Fax: ______________

E-mail: ______________________

SUSCEPTIBILITY EQUIPMENT

Estimates:

Susceptibility Bridges [Bartington Instruments]
sensitivity 1.2×10^{-5} SI; frequencies 470 Hz and 4700 Hz [~10 sec/sample (8 cm^3)]

Susceptibility Anisotropy Bridge [in-house]
sensitivity 1.2×10^{-6} SI; frequency 680 Hz [~2 min/sample (8 cm^3)]

High-Temperature Susceptometer [Kappa]
sensitivity 4×10^{-8} SI; frequency 720 Hz; temperatures from ambient to 1100 K [several hours/sample (≤ 200 mg chip or powder)]

Low-Temperature AC Susceptometer [Lake-Shore Cryotronics]
sensitivity 2×10^{-8} SI; frequencies 1 Hz to 10,000 Hz, real and imaginary components plus harmonics; temperatures 15 K to 325 K [several hours/sample (≤ 200 mg chip or powder)]

PALEOMAGNETIC EQUIPMENT

Spinner Magnetometer [Schonstedt]
sensitivity 1×10^{-10} A·m^2 [~3 min/sample (8 cm^3)]

Superconducting Rock Magnetometer (SRM) [2G Corporation]
sensitivity 2×10^{-11} A·m^2 [~1 min/sample (8 cm^3)]

Alternating Field (AF) Demagnetizers [Schonstedt]
peak applied fields from 0 to 100 mT; biasing fields from 0 mT to 0.2 mT; ARM and partial ARM capability [~1 min/demagnetization step or ARM (8 cm^3)]

Thermal Demagnetizer [Schonstedt]
temperatures from ambient to 1100 K; optional applied fields from 0 mT to 0.2 mT [~1 hour/demagnetization step or TRM (8 cm^3, 8 samples per batch)]

ROCK-MAGNETIC EQUIPMENT

Estimates:

Superconducting Susceptometer (MPMS) [Quantum Design]
sensitivity 1×10^{-11} A·m^2; applied fields from 0 T to 5 T; temperatures from 2 K to 400 K [~1 hour/sample minimum depending on measurement program (≤ 200 mg chip or powder)]

Vibrating Sample Magnetometer (VSM) [Princeton Applied Research]
sensitivity 2×10^{-8} A·m^2; applied fields from 0 T to 1.7 T; temperatures from 77 K to 1200 K [~30 min/sample for hysteresis loops (8 cm^3) and ~2 hours/sample for Curie points (≤ 200 mg chip or powder)]

Alternating Gradient Force Magnetometer (MicroMag) [Princeton Measurements]
sensitivity 1×10^{-11} A·m^2 [~5 min/sample for hysteresis loops (≤ 100 mg chip or powder)]

SPECIALTY EQUIPMENT

Magneto-Optic Kerr Effect (MOKE) System [Leitz, Hamamatsu, Sony, and Buehler]
applied fields from 0 T to 0.1 T; image manipulating software; sample preparation facilities [~4 hours/sample (5 cm^2 polished grains or thin sections)]

Magnetic Force Microscope (MFM) [Digital Instruments]
magnetic and topographic resolution ~20 nm [several hours/sample (1 cm^2 polished single grains, thin sections, or thin films)]

Mössbauer Spectrometer [Ranger Scientific]
temperatures from 2 K to ambient; zero applied field (external field up to 5 T not yet available) [several hours/sample (≤ 200 mg chip or powder)]

Errant SQUID Responsible for MPMS Upgrade

It's all in a day's work for Jim Marvin!

Despite the efforts of **Jim Marvin** (a.k.a. he-who-can-fix-anything), the *IRM*'s SQUID simply got away. That is, the super-conducting quantum interference device (SQUID) sensor, which is at the heart of Quantum Design's Magnetic Property Measurement System (MPMS), failed. But our loss was also our gain, since its necessary repair could be readily combined with a long-planned upgrade: In the past, a "zero field" in the MPMS was achieved by turning off and quenching the magnet, resulting in a field of about 300 µT. The upgrade—a new high-uniformity 5-T magnet and active field-cancellation capability—will provide a "zero field" of less than 5 µT. This will greatly improve confidence in zero-field, low-temperature measurements. The MPMS should be back on-line in late April. ■

…Tasks continued from page 1

agent powders takes about 15 minutes. Mixing the various components, heating the brew, and stirring the concoction to dissolve the iron oxides takes a total of about 40 minutes. A final 5 minutes are needed for rinsing the sample. All together, one CBD step takes about an hour. Rates of dissolution—and therefore the number of steps needed—depend on the specific mineral involved: small goethites go quickly, in one step; large magnetites stay around forever.

Glass ceramic synthesis

Magnetite- or titanomagnetite-bearing glass ceramic samples can easily be fashioned at the *IRM*. First, powdered calcium, silicon, and titanium oxides are mixed with potassium carbonate, sodium carbonate, and ferrous oxalate. The resulting powder is sintered at 1400°C for an hour and then quenched to make glass. Finally, the glass can be annealed in a controlled atmosphere at up to 1000°C. The entire process (including 24 hours for annealing) takes about 30 hours.

Magnetic extraction

Magnetic extracts of varying quality can be made by putting a manually ground bulk sample into suspension in water or alcohol. A hand magnet grabs the biggest grains in a matter of minutes; for a more thorough extraction, a sample can be run overnight through a closed-loop circulation system featuring a high-gradient magnetic finger. However, neither method is very efficient, so whole samples should be used whenever possible.

IMAGING

MOKE

Images of magnetic domains at the surface of a sample are obtained on the Magneto-Optic Kerr Effect (MOKE) microscope. First, the sample must be cut and either embedded in resin or glued to a glass slide; then, it must be well polished. (The width of the assembly must not exceed 2.5 cm so that it can fit between the pole pieces of the magnet.) This preparation can take up to 10–12 hours, depending on the sample. After a couple of hours have been devoted to learning to use the reflected-light microscope, the magnetic field, and the image manipulation system, getting a good magnetic contrast can take from 15 minutes to a couple of hours more depending on the sample. Finally, image data-file manipulation can take considerable time, too. In other words, expect to spend several hours on each sample after its preparation.

MFM

Simultaneous topographic and magnetic images of sample surfaces are made with the Magnetic Force Microscope (MFM). Sample preparation is similar to that for the MOKE, but the size of the sample can be no more than 1 cm^2, and the topographical variations should be less than a couple of microns. Loading the prepared sample and mounting the cantilever requires approximately 10 minutes; finding the appropriate parameter settings for imaging requires about 15 more; obtaining one 30×30-µm image of any sample typically takes 20 minutes. At this point, the amount of time needed for MFM measurements varies considerably. For a complete picture of a sample which is fairly uniform topographically and magnetically, a good hour is required to make a few images of various sizes; to study a non-uniform sample, particularly one that has never been examined before, extra time will be needed to find and verify magnetic features, and to make several sequences of images. Once more, expect to spend several hours on each sample after its preparation.

Tasks continued on page 8…

Santa Fe II Conference Planned for This Summer

The *IRM* is organizing a second conference at St. John's College in Santa Fe, NM on June 23–26, 1994. The focus of the workshop, entitled "Remagnetization and Environmental Rock Magnetism: Clues to Records of Past Geodynamics and Global Change," will consist of three interrelated topics: (1) Fundamental studies on the effects of low- or moderate-temperature (300–900 K) geochemical change on the magnetic structure and remanent magnetization of primarily iron oxides; (2) the effects of such changes on the direction and intensity of the paleomagnetic vector, recorded in crystalline rocks; and (3) the effects of the same processes on the field-reversal and climate-change records in sediments. Approximately twenty-five post-Ph.D. researchers, twenty-five senior graduate students, and four guest speakers will participate. An NSF grant may provide some travel funds on a competitive basis. For more information, get in touch with **Chris Hunt** at the *IRM*, who is serving as the conference coordinator. ■

. . . Tasks continued from page 7

OTHER

Mössbauer

Mössbauer spectra are produced with a Ranger system. Only samples that contain at least 0.02 gm of iron atoms will yield good spectra. After samples are placed in 1×13-mm plastic cells, Mössbauer experiments take about a day to run, including a set-up time of about 15 minutes for room-temperature spectra, and a few hours for low-temperature spectra. The interpretation process has recently been greatly improved, thanks to new data-massaging software by **Tom Kent** at WEB Research Co. in Minneapolis, but it is still not exactly child's play: a minimum of 3 hours is necessary for each sample. The best rule of thumb: Bring very few (3 to 5) samples for Mössbauer spectra, even if you are familiar with the interpretation process.

IN CONCLUSION…

The last three issues have included features about doing lab work at the *IRM*. We hope that they have been helpful in giving you a realistic idea of how much time to budget when planning research trips to Minnesota—please refer to these summaries when writing Visiting Fellowship proposals. A brief synopsis of most *IRM* equipment can be found on the Visiting Fellow Application Form on page 6.

The next issue will contain a wealth of information about the *IRM*'s affectionately dubbed "Susceptibility Hall," which houses the "Roly-Poly" magnetic-anisotropy susceptometer, the new LakeShore low-temperature AC susceptometer, and the ordered-but-yet-to-be-delivered Kappa Bridge high-temperature susceptometer. ▬

IRM Graduate Student Gets a "Best Paper" Award

At the Fall AGU meeting in San Francisco, the *IRM*'s **Sherry Foss** received one of the GP-Section's "Best Student Paper" awards for her talk entitled "Magnetic force microscopy (MFM) of single crystal magnetite." **Sherry**, who is pursuing her Ph.D. in Physics, has been instrumental [pun intended!] in getting the *IRM*'s MFM in working order—see the article about our MFM in the Winter 1992–93 *IRM Quarterly*. ▬

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 1–3-week period during the following half year. Shorter, less formal visits are arranged on an individual basis through the laboratory manager.

The *IRM* staff consists of **Subir Banerjee**, Director; **Bruce Moskowitz**, Associate Director; **Jim Marvin**, Senior Scientist; and **Chris Hunt**, Scientist and Lab Manager.

Funding for the *IRM* is provided by the **W. M. Keck Foundation**, the **National Science Foundation**, and the UNIVERSITY OF MINNESOTA.

The *IRM Quarterly* is published four times a year by the staff of the *IRM* with editorial and layout assistance from **Freddie Hart**. If you or someone you know would like to be on [or off] our mailing list, if you have something you would like to contribute (*e.g.*, titles plus abstracts of papers in press), or if you have any suggestions to improve the newsletter, please notify the editor:

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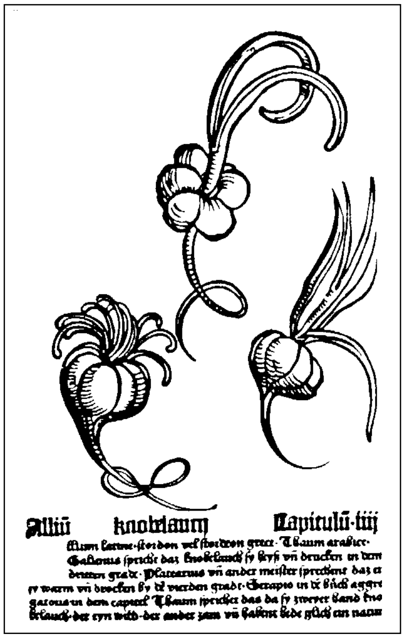
I R M
Institute for Rock Magnetism

The New Visiting Fellows

Our latest crop of Visiting Fellows is a bit larger than usual. For the period March–August 1994, the Fellows, with their affiliations and research interests, are listed below in alphabetical order. Watch for their reports in upcoming issues.

N.B. The proposal deadline for visits during the period September 1994–February 1995 will be in May, shortly after the AGU meeting—save this issue and use a copy of the form on page 6 when applying. Look for announcements in the spring issue of the *IRM Quarterly*, as well as in *Eos* and in *GSA Today*.

"'. . . garlic weakens and overcomes the strength of a magnet. For a magnet smeared with garlic juice cannot attract iron. . . .'" So said proponents of the use of divining rods to locate ore veins, who were quoted and then lambasted by Georgius Agricola (1494–1555) in his De Re Metallica *(1556), which, by the way, was translated in 1912 by none other than L. H. and H. C. Hoover. [Yes, that's the then-future President, who probably should have stuck with translating!]*



Knoblauch, or Garlic (Allium sativum L.) from Hortus sanitatis*, Mainz, 1485*

Bob Butler
University of Arizona
Remagnetization of carbonates from Alaska

David Dunlop, **Özden Özdemir**, and **Song Xu**
University of Toronto
Domain patterns/Low-T demagnetization/Goethite/VRM/pTRM

Kaushik Katari
Franklin and Marshall College
Archaeomagnetism of hearths

Mike McWilliams and **Hagai Ron**
Stanford University
Records of the Laschamp Event in the Lisan formation, Israel

Chris Orme and **Elizabeth Schuler**
University of Michigan
Multilayers on the MOKE/MFM

Carl Richter
Ocean Drilling Program
Deep-sea terrigenous sediments

Pavel Sroubek
Michigan Technological University
Paleoenvironment from cave sediments

Joe Stoner and **Jim Channell**
Université de Québec and University of Florida
Paleoclimate from deep-sea sediments

Jeff TenPas
University of California–Davis
Low-T oxidation of magnetite in Chinese loess

Weixin Xu
University of Michigan
Rock-magnetism of maghemite in oceanic pillow basalts ▬