Inside…

The IRM Quarterly

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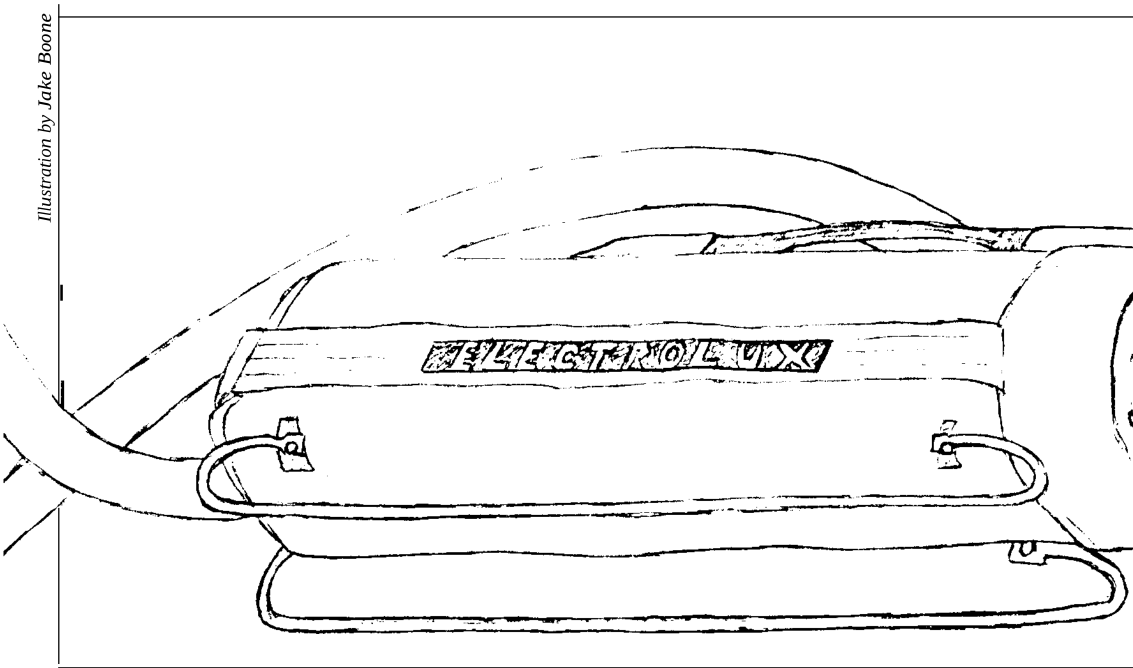


Illustration by Jake Boone

The IRM*'s latest equipment acquisition, which proved invaluable during recent instrument rearrangments: a flexible pre-owned Low-Vacuum Particulate-Matter Management System by Electrolux, donated by Shepherd Laboratories.*

Some Changes in Arrangements Improve Facility Utility

Chris Hunt
IRM

Several months ago, as we were ordering our latest piece of equipment, we realized that there was no obvious place to put the new Vibrating Sample Magnetometer in our existing facilities without disrupting people and instruments, or otherwise causing headaches. So, we took a long hard look at how we had made use of our laboratory space, realized that the existing distribution of machines was untenable, and accepted that something had to be done.

THE SPACE SHUFFLE

The number of machines at the *IRM* has grown considerably since our inception five years ago. In 1990, we had only two double rooms in Shepherd Laboratories, one of them housing the Superconducting Rock Magnetometer (SRM), the Spinner Magnetometer, the AF Demagnetizers, the Thermal Demagnetizer, the home-built AMS device (Roly-Poly), and the Bartington Susceptibility Bridge; and the other containing the Vibrating Sample Magnetometer (VSM), a couple of furnaces, and our meager sample-preparation equipment. Since then, we have added the MicroMag Alternating-Gradient Force Magnetometer, the MPMS Low-Temperature Susceptometer, the Mössbauer Spectrometer, the MOKE Microscope, the Magnetic Force Microscope (MFM), the Lake Shore Susceptometer, the Kappabridge Susceptometer, a battery of sectioning and polishing equipment, and a muffle furnace—not to mention a computer for each instrument plus a computer network to tie them all together. We had tried our best to grab additional lab rooms as they became available to keep up with the influx of goods. But, last spring, the new VSM order was the proverbial straw that broke the camel's back.

Unregulated Growth

Our physical expansion over the years has occurred naturally, that is to say, chaotically. We simply put each new instrument into whatever corner presented itself on delivery day. The results left the dust-sensitive MFM next to filth-spewing pneumatic rock press, and that's just one of many egregious mismatches. It had come to the point where rocks were being prepared by smashing them on the floor with a hammer right next to specimens being run on the vibration-sensitive MicroMag. In short, we were a mess! So, we took a collective deep breath and decided to reorganize everything along more sensible, or at least non-random, lines.

The Move

We spent the late spring and early summer, between visitors (and often even during their visits), ripping ourselves apart and reassembling the pieces into a new, more logical whole.

We elected to group instruments by type, more or less: The high-field machines (MPMS, MicroMag, and both VSMs) all moved to a double

Shuffle *continued on page 7…*

Visiting Fellows' Reports

Guests at the *IRM* this summer have included David Dunlop and Özden Özdemir on their annual trip from Toronto, who carried out several projects simultaneously as usual. Xixi Zhao came from California to evaluate his hydrothermal rocks. Finally, James Pickens arrived from Massachusetts to try to understand his reversal record from Chile. Below is a summary of their work at the *IRM*.

David Dunlop and Özden Özdemir
University of Toronto–Erindale

A Potpourri of Rock-Magnetic Experiments

David worked on three related projects:
(1) anomalously high unblocking temperatures of thermoviscous remagnetizations;
(2) paleointensity determination using multidomain magnetite;
(3) Thellier's laws of additivity and independence of partial thermal remanences (pTRMs).

(1) Thermoviscous overprints like viscous remanence (VRM) and pTRM can, in the case of single-domain (SD) grains, be erased by reheating to the original blocking temperature. However, in multidomain (MD) grains, part of the overprint survives up to the Curie point, making it difficult to separate primary and secondary paleomagnetic signals or to calibrate burial temperatures. The experiments done at the *IRM* showed that the effect is more severe in 135-μm magnetites than in 20-μm ones. Furthermore, prior low-temperature demagnetization (LTD) or 10-mT AF cleaning greatly sharpened the unblocking temperature (T_{UB}) spectrum.

(2) Paleointensity determination using multidomain magnetite gives a convex-down NRM-pTRM (Arai) plot. The experiments at the *IRM*, on 135-μm magnetite, showed that the curved Arai plots are reproducible: pTRM checks worked almost perfectly. Pre-cleaning the NRM and each successive pTRM using LTD was less successful. The Arai plots became less curved, but never approached the ideal SD straight line, largely because the NRM continued to decrease in successive LTD treatments, whereas each pTRM was LTD-treated only once.

(3) Experiments on pTRM(T_C,T) and pTRM(T,T_0) in 135-μm magnetite, with T = 400°C or 565°C, showed that these adjacent pTRMs are neither additive nor independent, as they would be in SD grains. Whether the pTRMs were studied individually or added orthogonally in a total TRM, there was about 20% overlap in T_{UB}s. Prior LTD was quite successful in eliminating overlapping T_{UB}s and restoring additivity.

Özden concentrated mainly on studying the low-temperature demagnetization of chemical remanences (CRMs) in natural and synthetic magnetites ranging from submicron to pseudo-single-domain (PSD) size. CRMs were induced in a water-cooled non-inductive resistance furnace located within Helmholtz coils inside a 6-layer mu-metal shield. The samples were partially oxidized by heating in air at 100°C, 150°C, and 200°C.

The results of AF demagnetization of CRM before and after low-temperature demagnetization showed that the CRM memory, which is the fraction of CRM surviving after LTD, decreased with increasing particle size, while the soft or erased fraction of CRM increased from 15% for the 0.2-μm magnetite to 35% for the 0.5-μm magnetite. AF demagnetization curves were soft before LTD but became harder after LTD.

Using the MPMS, the low-temperature saturation isothermal remanence (SIRM) was also studied during warming from 10 K to 300 K in order to understand the Verwey transition characteristics of the partially oxidized magnetites. The transitions were not sharp but were spread over a temperature interval of 40 K. The observed rapid decrease in remanence between 10 K and 50 K was due to very small crystallites, with nearly superparamagnetic behavior. These crystallites are probably partly responsible for the soft remanence component of CRM which was removed by LTD.

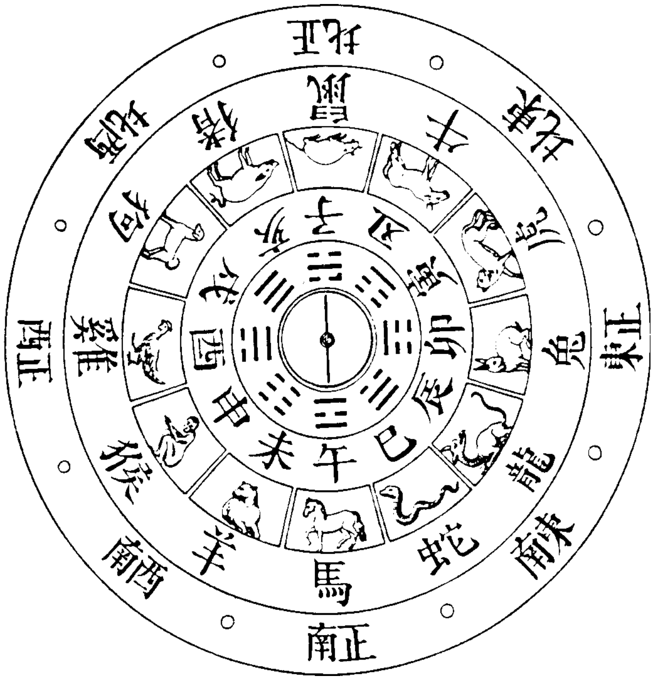
Özden also experimented with thermal and low-temperature demagnetization of SIRM and TRM of a 3-mm single crystal of magnetite. During thermal demagnetization, both SIRM and TRM decreased almost linearly with temperature up to 500°C. In the case of SIRM, the remaining one-third of the magnetization was lost in the range 500–525°C. For TRM, almost one-half was lost in the range 560–575°C. The TRM memory was thermally extremely stable; it could not be significantly demagnetized by 550°C step heating. The TRM memory disappeared at 575°C. The thermal demagnetization of SIRM memory showed similar behavior. The surprising result was that a 3-mm octahedral magnetite crystal preserves single-domain-like regions after low-temperature treatment.

Xixi Zhao
University of California–Santa Cruz

Rock Magnetism of Hydrothermal Sulfide Deposits from the Atlantic

Hydrothermal systems on slow-spreading, sediment-free mid-ocean ridges dominate global hydrothermal activity and, hence, are an important contributor to global mass and energy fluxes. Driven by heat from magmatic intrusion and emplacement of new crust, seawater circulates through the permeable portions of the crust and upper mantle, and discharges at the seafloor as both high-temperature (up to 400°C) focused and lower-temperature (< ~250°C) diffuse fluid flow. Ocean Drilling Program Leg 158 was designed to study the subsurface nature of such a site at the TAG (Trans-Atlantic Geotraverse) hydrothermal field on the slow-spreading (half-rate 1.2 cm a^{-1}) Mid-Atlantic Ridge near 26°N. The TAG site is composed of massive sulfides, probably in excess of 5 million tons, which is equivalent in size to some of the deposits in Cyprus, Oman, and other ophiolites on land. Because the interaction of circulating hydrothermal fluids with the oceanic basement not only gives rise to the development of seafloor mineral deposits, but also influences the physical properties and composition of the crust, it was hoped that detailed examination of the rock-magnetic properties would not only provide a definitive means of identifying the magnetic carriers in Leg

VF Reports *continued on page 6…*



Chinese "Magic Compass," reprinted in A. Schück, Der Kompass; Vorgänger des Kompasses*, Hamburg, 1888.*

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 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 2700 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

Stephenson, A., V. Florescu, and N. A. Booth
Field-impressed anisotropy of susceptibility in iron-terbium thin films, *J. Magn. Magn. Mater.*, *145*, 81–84, 1995.
Two thin films of $Fe_{1-x}Tb_x$ (x = 0.17 and 0.23) were shown to exhibit field-impressed anisotropy. After application of a direct field of 80 mT, which gave them an isothermal remanent magnetization (IRM) in their plane, the anisotropy of initial susceptibility differed from that measured after tumble-demagnetization. The effect of the direct field was to decrease the susceptibility measured along the applied field direction and to increase the susceptibility at right angles to this direction. The effect was almost certainly due to changes in domain alignment.

Biogeomagnetism

Corcoran, P. M.
A two-dipole model for electromagnetic interaction between power line harmonics and biogenic magnetite in cell tissue, *UPEC Conf. Proc.*, *2*, 704–707, 1994.
A two-dipole itinerant oscillator model was proposed to represent the interaction between biological tissue containing a very dilute suspension of magnetic dipoles and an external AC electromagnetic field. Theoretical calculations and experimental results have demonstrated far-infrared resonances in dielectric liquids. If similar resonances exist in magnetic dipoles in biological tissue, they are likely to occur at power-line frequencies.

Fassbinder, J. W. E., and H. Stanjek
Magnetic properties of biogenic soil greigite (Fe_3S_4), *Geophys. Res. Lett.*, *21*, 2349–2352, 1994.
Magnetic measurements were performed on soil samples which contained bacterial greigite. The greigite-containing soil horizon was characterized by SIRM/χ > 70 kA m^{-1} and by a G-factor > 5. That the greigite was single-domain was inferred from IRM, ARM, hysteresis, and susceptibility behavior. The magnetic parameters of soil greigite were compared with parameters of sedimentary greigite and of bacterial magnetite.

Moskowitz, B. M.
Biomineralization of magnetic minerals, *Rev. Geophys.*, *33*, *suppl. (IUGG Report)*, 123–128, 1995.
The field of biomineralization was reviewed, highlighting developments in the iron biomineralization of magnetic minerals by microorganisms and their impact on paleomagnetism, rock magnetism, and fine-particle magnetism. Four specific areas covered were magnetotactic bacteria, biomineralization, iron biominerals in sediments, and iron biominerals in relation to fine-particle magnetism.

Chemistry

Linderoth, S., S. Morup, and M. D. Bentzon
Oxidation of nanometer-sized iron particles, *J. Mater. Sci.*, *30*, 3142–3148, 1995.
The evolution of the oxidation of ultrafine (< 5 nm diameter) alpha-iron particles in ambient air has been studied using Mössbauer spectroscopy and electron microscopy. A 1–2-nm-thick oxide layer was found to appear almost immediately, whereafter the oxidation proceeded rather slowly. The oxide consisted of a mixture of Fe_3O_4 and γ-Fe_2O_3, but with the magnetic properties significantly modified due to the finite size of the oxide crystallites (the magnetic hyperfine fields were smaller than for the bulk materials, and very strong spin-canting occurred).

Zachariah, M. R., *et al.*
Formation of superparamagnetic nanocomposites from vapor phase condensation in a flame, *Nanostruct. Mater.*, *5*, 383–392, 1995.
In order to investigate interactions among small magnetic particles, nanocomposites were synthesized. Analysis of X-ray diffraction, electron microscopy, Mössbauer spectroscopy, and magnetization data revealed that (i) the nanometer-composite particles consisted of a 5–10-nm Fe_2O_3 core encased in a silica particle of diameter 30–100 nm, and (ii) the iron-oxide clusters were magnetically isolated and in some cases showed superparamagnetic behavior.

Climate Change

Bloemendal, J., X.-M. Liu, and T. C. Rolph
Correlation of the magnetic susceptibility stratigraphy of Chinese loess and the marine oxygen isotope record: chronological and palaeoclimatic implications, *Earth Planet. Sci. Lett.*, *131*, 371–380, 1995.
Spectral analysis of the magnetic-susceptibility timeseries showed that the 100-ka variance, which occurs in the marine oxygen-isotope record after about 1 Ma BP, also occurs in the magnetic-susceptibility record, reinforcing recent suggestions of a strong linkage between the high-latitude northern hemisphere and Asian climate. A significant improvement in the strength of the susceptibility–isotope correlation occurred after about 1.5 Ma BP, which corresponds to a significant increase in the rate of sediment accumulation across the Loess Plateau.

Fine, P., K. L. Verosub, and M. J. Singer
Pedogenic and lithogenic contributions to the magnetic susceptibility record of the Chinese loess/palaeosol sequence, *Geophys. J. Int.*, *122*, 97–107, 1995.
A study of the loess/paleosol sequence revealed that the magnetic susceptibility record arose primarily from a small amount of ferrimagnetic-phase iron. This iron consisted of nearly uniform amounts of a citrate-bicarbonate-dithionite (CBD)-resistant component (MD grains inherited from the parent loess material), and a CBD-soluble component (grains near the SP/SD boundary). *In situ* formation of the second component in the paleosols gave rise to the susceptibility enhancement of the loess column.

Hunt, C. P., *et al.*
Rock-magnetic proxies of climate change in the loess-palaeosol sequences of the western Loess Plateau of China, *Geophys. J. Int.*, *123*, in press, 1995.
A multiparameter approach confirmed that the susceptibility enhancement in paleosols was caused primarily by increased ultrafine magnetite and maghemite. Nevertheless, magnetic enhancement was due also to variations in concentration and mineralogy of the magnetic fraction. After the effects of concentration variations were removed through normalization of parameters, the resulting signal was ascribed more confidently to variations in magnetic grain size, which in turn was interpreted as a better proxy of pedogenesis than simple susceptibility.

Jelinowska, A., *et al.*
Mineral magnetic record of environment in Late Pleistocene and Holocene sediments, Lake Manas, Xinjiang, China, *Geophys. Res. Lett.*, *22*, 953–956, 1995.
Identification of magnetic minerals in a sedimentary sequence confirmed major changes in paleoenvironmental and paleohydrological conditions deduced from other methods and provided complementary information on changes in the lake system.

Tarduno, J. A.
Superparamagnetism and reduction diagenesis in pelagic sediments: enhancement or depletion?, *Geophys. Res. Lett.*, *22*, 1337–1240, 1995.
On the basis of new studies of pelagic sediments, it was proposed that reduction processes increased rather than depleted the ultrafine SP-grain population. At the modern Fe-redox boundary, enhanced SP grains coincided with a coarsening of remanence-carrying grains. SP grains also tracked proposed temporal changes in magnetite reduction caused by climatically-driven fluctuations in organic carbon. Hysteresis characteristics and changes in SP grains may help identify paleointensity artifacts caused by non-steady-state magnetic-mineral reduction.

Crustal Magnetization

Dyment, J., and J. Arkani-Hamed
Spreading-rate-dependent magnetization of the oceanic lithosphere inferred from the anomalous skewness of marine magnetic anomalies, *Geophys. J. Int.*, *121*, 789–804, 1995.
A new model, in which the magnetic structure of the oceanic lithosphere is dependent on spreading rate, provided a better fit with observations of anomalous skewness of marine magnetic anomalies than had previous models. Advances concerning accretionary processes at mid-ocean ridges suggested that the combined effect of variations with spreading rate of magma fractionation, alteration of layer 2A, and serpentinization of layer 3 and the uppermost mantle may account for the proposed variation.

Pilkington, M., and J. P. Todoeschuck
Scaling nature of crustal susceptibilities, *Geophys. Res. Lett.*, *22*, 779–782, 1995.
Scale-invariant or self-similar properties have been demonstrated for a wide range of geophysical processes and rock properties. Evidence from well logs and inferences from aeromagnetic-field power spectra suggested that crustal susceptibility also shows this behavior with a power spectrum proportional to the -4^{th} power of the spatial frequency. Examination of two large susceptibility data-sets supported the scaling hypothesis.

Ravat, D., *et al.*
Global vector and scalar MAGSAT magnetic anomaly maps, *J. Geophys. Res. B*, in press, 1995.
New empirical and analytical techniques for modeling ionospheric fields in MAGSAT data were developed which facilitated ionospheric field removal from uncorrected anomalies to obtain better estimates of regional lithospheric anomalies. Results suggested that implementation of the outlined processing scheme would lead to the mapping of the most robust lithospheric magnetic anomalies, vector components as well as scalar.

Data Manipulation

Gubbins, D., and P. Kelly
On the analysis of paleomagnetic secular variation, *J. Geophys. Res. B*, in press, 1995.
Modern methods of geomagnetic-field analysis can be applied to paleomagnetic data, provided that account is taken of the relatively sparse and inaccurate nature of paleomagnetic results. The field equations were simplified by linearizing the field about an axial dipole. The approximation is adequate for paleomagnetic data and can be used to show that the VGP scatter function is not an appropriate estimate of the non-axial-dipole field, even when averaged over longitude.

Geology

Opdyke, N. D.
Paleomagnetism, polar wandering, and the rejuvenation of crustal mobility, *J. Geophys. Res. B*, in press, 1995.
The decade from 1951–1961 witnessed the birth of a new geophysical subdiscipline, Paleomagnetism. Early studies in Europe, North America, and Australia led both to numerous conclusions about the ability of rocks to record past geomagnetic field directions and implications for polar wander curves and the movement of continents. These observations changed the mind-set of many Earth scientists and paved the way for seafloor spreading and plate tectonics.

Gordon, R. G.
Plate motions, crustal and lithospheric mobility, and paleomagnetism: prospective viewpoint, *J. Geophys. Res. B*, in press, 1995.
The shift in geoscience viewpoint, from a static to a mobilistic solid Earth, was brought about by paleomagnetism several decades ago. Five topics of current research on Earth's mobilistic surface are reviewed, and their future directions are discussed: the subdivision of Earth's surface into rigid plates and boundaries; the rigidity of plate interiors; plate velocities; hotspot velocities; and true polar wander.

Miscellaneous

Moskowitz, B. M.
Fundamental physical constants and conversion factors, in *A Handbook of Physical Constants, vol. 1*, edited by T.J. Ahrens, pp. 346–355, American Geophysical Union, Washington, DC, 1995.
Physical constants are presented, and relations between the SI and cgs unit systems are explained.

Models

Liu, Z.-Y.
The roles of steady and alternating fields playing in the anhysteretic process, *Geophys. J. Int.*, *121*, 354–358, 1995.
In a switching-field model of ARM acquisition, it was the total instantaneous field ($H_{ac} + H_{dc}$) that was responsible for imparting the ARM, and the coercivity of affected grains was determined accordingly. In order to perform a detailed analysis, cases of $H_{dc} = 0$, $d > 2H_{dc}$, $d = 2H_{dc}$, and $d < 2H_{dc}$ were examined (d is the amplitude decay per half-cycle of H_{ac}). The total residual remanence was dependent on H_{dc}, H_{ac}, and decay rate when $H_{dc} < d/2$, but was independent of H_{dc} when $H_{dc} \geq d/2$.

Physics

Jansen, R., V. A. M. Brabers, and H. van Kempen
One-dimensional reconstruction observed on Fe_3O_4 (110) by scanning tunneling microscopy, *Surface Science*, *328*, 237–247, 1995.
The (110) surface of Fe_3O_4 single crystals was studied by scanning tunneling microscopy (STM). A sputtering and annealing procedure resulted in a one-dimensional reconstruction consisting of rows running in the (110) direction. The row spacing was found to vary on different terraces; the most frequent row separation was 25 Å. Current-*vs.*-voltage curves displayed a transition from semiconducting to metallic character when the tip-sample distance was reduced.

Kawata, H., and K. Mori
X-ray magnetic Bragg scattering topography from Fe_3O_4, *Rev. Sci. Instr.*, *66*, 1407–1409, 1995.
The methodological success of X-ray magnetic Bragg scattering topography from a single crystal of Fe_3O_4 was described. The flipping ratio on the magnetic Bragg scattering intensity was enhanced by using a resonant effect at the Fe *K*-absorption edge. Domains, including the direction of spontaneous magnetization, were characterized from the topographic image.

Samiullah, M.
Verwey transition in magnetite: finite-temperature mean-field solution of the Cullen-Callen model, *Phys. Rev. B*, *51*, 10,352–10,356, 1995.
The Verwey transition in magnetite was studied by solving the Cullen-Callen spinless one-band model at finite temperatures. A complete phase diagram of the model exhibited three phases: a disordered phase, and two ordered phases—one multiply ordered and one singly ordered. Transitions from the disordered phase to the ordered phases were of the first-order type, and were entropy-driven. Near 120 K, the transition was from the disordered state to the multiply ordered state, and not to the singly ordered state.

Sasaki, S.
Fe^{2+} and Fe^{3+} ions distinguishable by X-ray anomalous scattering: method and its application to magnetite, *Rev. Sci. Instr.*, *66*, 1573–1576, 1995.
A chemical shift of about 5 eV was observed between ferrous and ferric ions in the XANES absorption spectra of FeO and Fe_2O_3, in which the Fe ions coordinate in regular octahedra; the spectrum of Fe_3O_4 (magnetite), in which the Fe ions are coordinated in two sublattices, lay between those of FeO and Fe_2O_3. A difference-Fourier technique promises the possibility of mapping valence differences for atoms of the same atomic species in a mixed-valence crystal.

Uhl, M., and B. Siberchicot
A first-principles study of exchange integrals in magnetite, *J. Phys. Condens. Matt.*, *7*, 4227–4237, 1995.
A method was presented to calculate *ab initio* exchange constants and spin-wave excitations of multi-sublattice magnetic structures on the basis of total-energy calculations of incommensurate magnetic structures. The exchange energies, dispersion curves, and Curie temperature for magnetite (Fe_3O_4) were obtained and compared with experimental results.

Reversals

Coe, R. S., M. Prévot, and P. Camps
New evidence for extraordinarily rapid change of the geomagnetic field during a reversal, *Nature*, *374*, 687–692, 1995.
Paleomagnetic results from lava flows that recorded a geomagnetic polarity reversal at Steens Mountain, Oregon, suggested the occurrence of brief episodes of astonishingly rapid field change (six degrees per day). The evidence consisted of large, systematic variations in the direction of remanent magnetization as a function of thermal-demagnetization temperature and of vertical position within a single flow. These variations are most simply explained by the hypothesis that the field was changing direction as the flow cooled.

Rock Magnetism

Hunt, C. P., B. M. Moskowitz, and S. K. Banerjee
Magnetic properties of rocks and minerals, in *A Handbook of Physical Constants*, *vol. 3*, edited by T.J. Ahrens, pp. 189–204, American Geophysical Union, Washington, DC, 1995.
A collation of magnetic parameters and their definitions for rocks and minerals is presented. Included are tables and graphs of susceptibility (grain-size-, composition-, and temperature-dependences), hysteresis parameters, natural and laboratory remanences, magnetostriction and magnetocrystalline-anisotropy constants, and Curie temperatures.

Tyson Smith, R., and K. L. Verosub
Thermoviscous remanent magnetism of Columbia River basalt blocks in the Cascade landslide, *Geophys. Res. Lett.*, *21*, 2661–1664, 1994.
A study of basalt samples from a landslide showed that a thermoviscous remanence (TVRM) had been acquired since the slide was emplaced about 800 years ago. The TVRM components with the lowest blocking temperatures were tightly clustered around the present field direction, while the NRM directions were consistent with a random distribution as expected for a landslide deposit.

Timescales

Baksi, A. K.
Fine tuning the radiometrically derived geomagnetic polarity time scale (GPTS) for 0–10 Ma, *Geophys. Res. Lett.*, *22*, 457–460, 1995.
New $^{40}Ar/^{39}Ar$ step-heating ages for geomagnetic field reversals at 3.2 and 4.5 Ma, along with previous data at approximately 1, 2, 10 and 16 Ma, were used to derive a geomagnetic polarity time scale for 0–10 Ma. The interpolated ages of chrons for 0–6 Ma were in good agreement with the astronomical time scale and differed considerably from earlier attempts, which were based in part on K-Ar dates. This time scale was estimated to be accurate to ±1% for 0–6 Ma; for 6–10 Ma, the lack of a tie-point limited the accuracy to about ±2%.

Cande, S. C., and D. V. Kent
Revised calibration of the geomagnetic polarity timescale for the Late Cretaceous and Cenozoic, *J. Geophys. Res. B*, *100*, 6093–6095, 1995.
Recently reported radioisotopic dates and magnetic anomaly spacings had made it evident that modification was required for the age calibrations of the geomagnetic polarity time scale of Cande and Kent (1992) at the Cretaceous/Paleogene boundary and in the Pliocene. The resulting adjusted geomagnetic reversal chronology for the Late Cretaceous and Cenozoic was consistent with astrochronology in the Pleistocene and Pliocene and with a new time scale for the Mesozoic.

Tectonics

Fruit, D., R. D. Elmore, and S. Halgedahl
Remagnetization of the folded Belden formation, northwest Colorado, *J. Geophys. Res. B*, in press, 1995.
Paleomagnetic and geochemical results were used to evaluate the origin of an apparent synfolding magnetization in Pennsylvanian limestones. It was not possible to unequivocally establish whether the characteristic magnetization was synfolding or prefolding, but synfolding magnetization caused by the syndeformational mineralizing fluids could be ruled out. Over-printing of a prefolding chemical magnetization by a postfolding viscous magnetization residing in multidomain grains was a likely explanation for the synfolding test result. ■

…VF Reports *continued from page 2*

158 samples, but would also shed some light on the origin and evolution of the sulfide deposits in the TAG hydrothermal mound. Since the *IRM* is uniquely equipped to perform various rock-magnetic experiments, the main objective of my visit here is to take advantage of the opportunity by performing rock-magnetic screening of my samples and, hence, putting this research project on a much sounder basis.

My two-week venture at the *IRM* was tremendously successful. After being given the usual "grand tour" by Chris Hunt, I was able to make MPMS measurements immediately, thanks to my supportive, kind-hearted colleagues at the *IRM*. The outdoor brown-bag group lunch the next day was very valuable (I was fortunate to be the first one to have such an informal meeting), and I received from it insightful input and many valuable suggestions from the wonderful, intelligent *IRM*ers. The results from measurements of thermal demagnetization of low-temperature (20 K) SIRM (done on the MPMS) indicate that grains of both magnetite and pyrrhotite (?) or chalcopyrite (?) are present in the sulfide cores as shown by the Verwey transition in the vicinity of 110 K and another transition at around 40 K. Measurements of magnetic susceptibility *vs.* temperature on the sulfide samples (using the Kappabridge with flowing gas) show almost no susceptibility breakdown during heating, but a significant peak of susceptibility at around 300°C during cooling, suggesting the possible presence of chalcopyrite. For the basalt samples recovered from near the edges of the sulfide mound, results from both the MPMS and the Kappabridge revealed the presence of titanomagnetite. These results are in good agreement with the room-temperature Mössbauer spectra which Pete Solheid kindly ran and explained for me. The results I obtained at the *IRM* provide definitive information on the magnetic carrier in these sulfides. In addition, a close inspection of the new rock-magnetic data reveals the relationship of magnetic properties to the nature of the hydrothermal alteration region: it appears that the pervasive hydrothermal alteration that has affected the entire TAG mound may have produced distinct zones where rocks have their own characteristic magnetic properties. The rock-magnetic results are also in excellent agreement with the preliminary shipboard identification of mineral assemblies and provide important constraints on the nature and extent of the mineral alteration and on the formation of the mound.

During my last two days at the *IRM*, I also measured ARM and pARM on selected samples, the results of which will be useful in understanding the grain-size distribution in these samples. I also had a chance to discuss my new rock-magnetic data with Bernie Housen, Bruce Moskowitz, and Subir Banerjee. I want to emphasize that these fruitful discussion meetings not only helped me understand the data better, but also led me to new research directions. These "last supper" meetings are deeply appreciated and certainly make one want to come back to the *IRM* as an annual pilgrimage! Further analysis of these new rock-magnetic data is still underway, and additional work including hysteresis measurements will be performed at my home institution.

James C. Pickens
University of Massachusetts–Amherst

Rock Magnetism of the Matuyama–Brunhes Reversal in Chilean Rocks

A comprehensive volcanic record of the Matuyama–Brunhes reversal has been collected from the Quebrada Turbia valley of the Tatara-San Pedro Volcanic Complex of southern Chile (36°S, 89°E). To provide a detailed transitional record, three sections within the canyon have been correlated through detailed paleomagnetic, geochemical, and geochronological sampling, and through photogrammetric analyses. Within these sections, the reversal in magnetic field polarity is recorded in 7 reversed, 26 transitional, and 4 normal flows (over 370 cores).

The rarity of such transitional records, and their importance with respect to modeling of the Earth's magnetic field, makes it vital to fully characterize these samples paleomagnetically and rock-magnetically. Further, it was hoped that the ferrimagnetic profiles of these cores, gained at the *IRM*, might provide an assessment of their suitability for paleointensity analyses.

The andesite flows recording the transitional field can be subdivided into two general groups based on XRF data and their alternating-field demagnetization behavior. A relatively strong viscous overprint that is slowly removed is found in the lowermost flows, but a coherent primary vector is not distinguished at fields up to 80 mT. XRF data suggest that the higher package is geochemically monotonous and that the flows were erupted relatively quickly. These data are supported by the demagnetization behavior of the cores, which are characterized by a weak viscous overprint and a well defined primary vector. One of the primary objectives of the study at the *IRM* was to investigate the ferrimagnetic differences between these two paleomagnetic behaviors.

At the *IRM*, the samples were analyzed using the MicroMag and the Kappabridge. Note that, given the strong NRM intensities of the cores, XRF powders instead of rock chips were used in these studies.

MicroMag hysteresis results place the entire reversal sequence within the pseudo-single-domain field. Variations in hysteresis properties, however, suggest that a range of grain sizes is present, complicating the interpretation of the data. Reflected-light microscopy studies are ongoing to quantify grain-size distributions.

Curie temperatures were obtained by using the Kappabridge to observe changes in low-field susceptibility with increasing temperature. The susceptibility plots generally mimicked the variations seen in associated XRF data, with the lower flows characterized by two dominant ferrimagnetic components and the higher ones by relatively uniform single-component behavior. The meaning of the curves from the lower flows is somewhat nebulous (at least to this author!), but indicate a low-temperature, low-susceptibility ferrimagnetic mineral coupled with titanomagnetite. Each mineral obviously carries a component of the TRM vector, possibly accounting for the variation in demagnetization behavior. The higher flows are more distinct and demonstrate characteristic titanomagnetite and magnetite curves. In all cases, a rise in susceptibility with temperature indicates that the cation-deficient nature of the magnetite component—an encouraging property with respect to paleointensity experiments. ■

Plan of portion of the second floor of Shepherd Laboratories, home of the IRM. *The new distribution of equipment groups similar or related instruments*.

…Shuffle *continued from page 1*

lab at the end of one of our halls; the low-field and remanence equipment (SRM, Spinner, AF and thermal demagnetizers, and Bartington) occupied another double lab at the other end. A third double lab in the middle, which had a fume hood, became the sample-preparation area, including presses, ovens, saws, polishers, chemicals, and hand tools. One of the single labs in our other hall re-emerged as the "clean" room for the two microscopes (MOKE and MFM). The Mössbauer stayed in its own single lab to meet radiation-safety requirements. And the three susceptometers (Kappabridge, Lake Shore, and Roly-Poly) made up the last single lab.

The greatest physical challenge was moving a large slab of granite—well, granodiorite really—down the hall to serve as the new base for the MFM. It still took six people to budge it after we got it up on wheels. [Units-conversion quiz: The slab measures 4 feet by 6 feet by 19 inches. If granodiorite has an average density of 2.73 g cm^{-3}, what was the mass of the thing? What were we, nuts?] The VSM's beefy electromagnet, which took only two people to move, was downright feathery by comparison.

Computer Network

Our old daisy-chain computer network had also grown too big and convoluted for its own good—some of the blossoms at its far end were wilting for lack of contact with the distant roots. What was the point of a computer network if one end could not reach the other? Simply shortening some of the most offensive sections did not do the trick. So, after Jim and Chris did some crawling around above the ceiling tiles to pull cables, a new hub-and-spoke network was completed. It started sending bits faster and more reliably than before, and with room to expand (at least a little). At last, everybody could talk to everybody else.

Visitors' Lounge

In the past, all Visiting Fellows and other informal visitors had been put at whatever desk was free at the time—sometimes in a lab, sometimes jammed in with a graduate student, sometimes just at a table-

Shuffle *continued on page 8…*

Meeting Update

IUGG

Boulder, July 1995
Subir Banerjee
Bruce Moskowitz
IRM

Both basic rock magnetism and its applications to a variety of Earth Science problems were emphasized at the Boulder, Colorado, Assembly of the International Union of Geodesy and Geophysics (IUGG) in July. In keeping with the theme of the assembly, "Geophysics in the Environment," there was an all-day session on "Magnetic Signatures of Environmental Change" on July 4. Roughly a quarter of the contributions dealt with the excellent rock-magnetic record of climate change in the 2.5-Ma-old Chinese loess columns. The rest dealt with new rock-magnetic proxies, their comparison with geochemical and pollen data, and applications to glacial/interglacial changes, anthropogenic records, and paleoproductivity variations of the marine realm.

Rock magnetism had a marathon day on a hot July 11. Magnetic domain observations and numerical micromagnetic models were main themes in the all-day session on "New Approaches in Rock Magnetism." Domain studies using Bitter, magneto-optic Kerr effect (MOKE), and magnetic-force microscopy (MFM) methods were presented describing domain states in small magnetite, domain features in hematite and titanomagnetite, micromagnetic features of domain walls, interactions of walls with surface defects, and domain observations at low (77K) and elevated (300–823 K) temperatures. Contributions describing numerical micromagnetic results included spin states in PSD grains, internal structures of domain walls, effects of magnetostriction, and blocking-temperature calculations. ■

More Visiting Fellows on the Way

Manditory use of our new Cover Sheet for Visiting Fellowship applications resulted in many well-written and well-thought-out proposals. For the period September 1995–February 1996, the new Fellows, with their affiliations and research interests, are listed below in alphabetical order.

N.B. The proposal deadline for visits next spring and summer will be in December, shortly after the AGU meeting. Look for announcements in the *IRM Quarterly*, *Eos*, and *GSA Today*.

Koji Fukuma
University of Toronto–Erindale
high-temperature hysteresis properties of oceanic basalts

Sergei Gadetsky
University of Arizona
domain-walls inTbFeCo films

Jonathon Glen
Univ. of California–Santa Cruz
iron magnetization (high T and P)

Chorng-Shern Horng
Academia Sinica
greigite alteration and remanence

Ellen Platzman
University College London
greenschist-grade dike rocks

Maureen Steiner
University of Wyoming
Jurassic Quiet Zone basalts

Joseph Stoner
University of Florida
magnetic properties of marine sediments

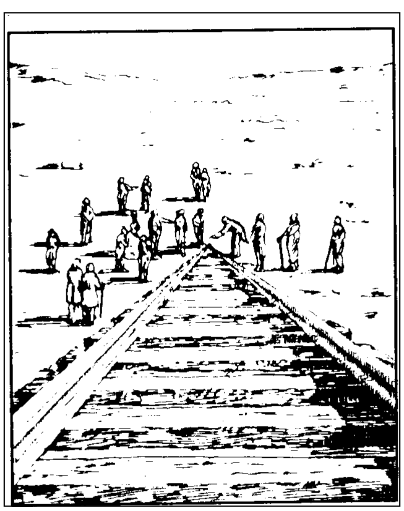
IRM Seeks New Manager

As some of you may know, Chris Hunt will be leaving the *IRM* this fall in order to pursue other interests in Vermont. Consequently, the position of *IRM* Facilities Manager will be vacant, and we are looking for someone to fill it.

The responsibilities of the Facilities Manager include initial training of student and faculty users on all of our equipment, running the Visiting Fellowship Program, production of the *IRM Quarterly* newsletter, and being the “oil” for the smooth day-to-day running of the *IRM*.

If you are interested in the Facilities Manager position, please contact Bruce Moskowitz [(612) 624-1547, bmosk@maroon.tc.umn.edu], or Subir Banerjee [(612) 624-5722)] immediately for further information.

Applications will be evaluated from September 1, 1995, until the position is filled.



David Macauley’s characters are experiencing a Great Moment in Architecture*: “Locating the vanishing point.”*
Editor’s note upon leaving the *IRM*: *Just as in this drawing, apparent end-points are often simply illusions, just artifacts of one’s point of view. Keeping that in mind, I say not “Good-bye,” but rather “See ya!”*

…Shuffle *continued from page 7*

top. This unsatisfactory arrangement placed undue burden both on the visitors (who nevertheless remained stoic throughout) and on their accidental office-mates. Furthermore, visitors sometimes had to wrestle with locals over the use of a computer for data-massage or even for e-mail. So, because there is a guest of some sort here nearly all of the time, we’ve created an office just for visitors that houses a desk, a DOS machine, a Mac, and perhaps our small refrigerator, coffee-maker, and radio. That’s the plan, anyway—we still have to finish convincing the current semi-occupant of the “*IRM* Lounge” to really and truly retire and move out already. [It should all actually happen this fall.]

Results

Our efforts seem to have paid off. Already the microscopes need less housekeeping attention, and now the images they produce make it through the network and down the hall to the printer regularly. Having all of the sample preparation equipment in one place has saved countless hours of running up and down the halls looking for that screwdriver or another gel-cap. Future visitors will no doubt enjoy an office of their very own. And the better ordered rearrangement appeals more to our sense of aesthetics. We’re confident that the changes we have made in our physical layout will provide an even better working environment for all *IRM* users.

WWWooops!

We made a wee mistake in the last issue by giving our new World Wide Web home-page address as: http://www.geo.umn.edu/docs/irm.html. At that address, you won’t see anything terribly interesting, but you will be directed to the correct address at which you will find all sorts of information about the *IRM* as promised: http://www.geo.umn.edu/orgs/irm/irm.html. Let us know what else you’d like to see there.

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, Assistant Professor/Associate Director; Jim Marvin, Senior Scientist; and Chris Hunt, Senior Scientist/Facilities Manager.

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The *IRM Quarterly* is published four times a year by the staff of the *IRM*, with editorial and layout assistance from Freddie Hart and Katie Levin. If you or someone you know would like to be on 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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