The IRM Quarterly

FALL 1997, VOL. 7, NO. 3 INSTITUTE FOR ROCK MAGNETISM

photo: Rukwa project

Sedidrill coring at Lake Massoko, in the Rungwe Mountains (Tanzania)

Postdoctoral Transitions III

David Williamson
IRM / CEREGE

One year in a beautiful vineyard

I found a beautiful vineyard in Minnesota. In 1995, I was invited by Subir Banerjee and Kerry Kelts at the Department of Geology and Geophysics of the University of Minnesota. I arrived at *IRM* as an associate research scientist from the French CNRS (my permanent employer) in September, 1996. With my colleagues from Aix-Marseille and Minneapolis, I focus my research on using rock-magnetic methods to identify climate-activated surface processes that have affected sediments, especially in tropical environments: eolianites from the Canary Islands, lakes from Ethiopia (Langano-Abjiata), Tanzania (Massoko, Rukwa), and Madagascar (Tritrivakely).

In these sites, the records of structure and composition-dependent magnetic properties point to a tremendous sensitivity of iron mineral assemblages to climate/environmental change (this is also obvious, in many cases, for concentration-dependent properties). However, the environmental processes by which a change in climate produces a corresponding change in magnetic properties need to be better understood. This is because:
i) magnetic properties of natural rocks, measured non-destructively at room temperature, do not uniquely constrain the characteristics of the magnetic mineral assemblage; further low- and high- temperature (low-T and high-T) experiments, as well as geochemical and mineralogical measurements, are essential to interpret room-T high-resolution records in more unique terms of grains size, mineralogy, or magnetic interactions.
ii) these properties are closely associated with changes in terrestrial and aquatic biological communities (pollen, diatom, organic carbon studies), illustrating the general association between iron and carbon cycles. However, environmental forcing of the iron dynamics (and feedback effects) is poorly understood (at least at the scale of 10 to 10^5 yr.).
At the *IRM*, and at the University of Minnesota, I have met many scientists dealing with these two questions, and shared their knowledge and ideas very simply and directly.

Dust deposition and pedogenesis in Canary Islands

I first worked on pilot samples taken from an eolianite-paleosol sequence from Lanzarote (fig.1). As in other sites, the paleosols, which developed during humid time-intervals from the last climatic cycle, are characterized by a relative enhancement in paramagnetic and SP contributions (mostly at the expense of PSD to MD contributions). This suggests a close relationship between rainfall and SP contributions in tropical soils. However, the magnetic concentration is sustained by local basaltic sources, which dominate during the deposition of coastal sands. Such sources show a contribution of Ti-magnetite, which was identified by low-T measurements of the low-field magnetic susceptibility (χ_{lf}), by Lowrie tests, and by the AC-field dependence of χ_{lf}, which varies with Ti-content in titanomagnetites.

Volcanic soils in the tropics

I have also analyzed several sets of soil samples from the volcanic catchments of Lakes Tritrivakely (Madagascar), Massoko (Tanzania), and from an altitudinal profile in Ethiopia. The magnetic concentration of topsoils is often very high (M_s>1Am^{2}kg^{-1}),

David Williamson

continued on page 6…

Visiting Fellows' Reports

The great El Nino of 1997-98 has extended the Minneapolis autumn into January, solstices and perihelions (perihelia?) notwithstanding. Our recent orbital arc included close encounters with: Rob Coe, who, attempting to understand discrepant records from Mono Lake, discovered a very interesting low-temperature puzzle; Weiming Zhou, who continued his detailed petrographic and magnetic investigations of ocean crust; and Luca Lanci, who probed the mysterious mineralogy of gleysoils and lacustrine records of rapid climate change.

Rob Coe
University of California-Santa Cruz
rcoe@earthsci.ucsc.edu

Fidelity of Magnetization of Mono Lake Sediments

We have been trying to understand why the first part of the Mono Lake Excursion (MLE) is not apparent in sections we have sampled at one locality in Mono Basin, even though it is clearly exhibited as a large swing in direction to westward declination and negative inclination in many sections at three other places around the lake (see Coe and Liddicoat, *Nature*, *367*, 57-59 for background). Records of the second part of the MLE, which is a swing to eastward declination and very steep inclination at apparently much higher relative field intensity than the first part, are almost identical at all localities. Detailed examination of the remanence suggests that, rather than not having been recorded at all, the first part of the MLE was overprinted by the higher intensity field of the second part. At the *IRM* I wanted to determine the magnetic mineral content and domain size distribution to see if they had any bearing on the discrepancy between the records.

Significant loss of NRM and susceptibility at 250°C during heating had suggested the possibility of greigite in our samples, as well as titanium-poor magnetite. This was a concern, even though the low-temperature phase is manifested identically in samples that did and did not record the MLE faithfully, because greigite is usually diagenetic rather than primary. Mössbauer analysis of magnetic concentrates at the *IRM* dispelled that worry, however, revealing maghemite as the low-blocking-temperature mineral along with magnetite (dominant), plus or minus accessory hematite. The maghemite was probably present at deposition in oxide grains eroded from nearby volcanic units, although it might also have grown later, but in any case its direction is generally indistinguishable from that residing in the higher-unblocking-temperature magnetite.

Thus we turned to low-temperature measurements in the MPMS (high-field) and Lakeshore (low-field) susceptometers to search for differences in magnetic grain-size distribution that might explain the discrepancy in recording of the MLE. We found none, although we did discover a puzzling phenomenon when carrying out field-cooled/zero-field-cooled (FC-ZFC) remanence measurements in the MPMS. The FC curve (demagnetization by warming from 20 K to 300 K of a TRM acquired by cooling in a field from 300 K to 20 K) lay below the ZFC curve until the Verwey transition temperature around 110 K, after which they nearly coincided. Because the ZFC curve is demagnetization of a SIRM produced at 20 K by the same field as produced the TRM of the FC case, it seems surprising that the SIRM should be greater than the TRM--my understanding is that the opposite is usually found. I'd be interested in hearing ideas for how to explain this phenomenon.

Having eliminated differences in magnetic mineralogy and grain size as prime culprits in the discrepant recording of the MLE, we carried out various tests back in Santa Cruz to determine properties of the bulk sediment (something any geologist probably would have told us to do first!). We discovered that the samples that fail to record well the first part of the MLE have a slightly smaller median grain size (4 as opposed to 6 microns), and--more significantly, we believe--a lower calcium carbonate content (6.5 as opposed to 11.8 wt %). Thus, it now seems to us that the most probable answer to our question is that initial remanence was protected from overprinting during the later part of the MLE at localities where carbonate cementation had already reduced void space enough to prevent rotation of most of the magnetic grains. If this is correct, it suggests that relatively minor variation in rate of cementation may spell the difference between sedimentary rocks that do and do not provide faithful records of geomagnetic polarity transitions and excursions.

Weiming Zhou
The University of Michigan
zhouw@umich.edu

Characterizing the Magnetic Minerals of Ocean-Floor Basalts

The purpose of my visit to the IRM was to obtain rock magnetic parameters of ocean-floor basalts and compare them with data from electron microscopic studies in order to determine how changes in the magnetic minerals contribute to changes in magnetization of the ocean floor. Our samples, including dredged and ODP/DSDP drilled samples, were collected from the Pacific Ocean and Atlantic Ocean with ages varying between 0 Ma and Jurassic. Our preliminary results indicate good agreement between the rock magnetic parameters and electron microscopic observations.

The most detailed electron microscopic studies have so far been carried out on very young ocean-floor basalts. In addition to larger titanomagnetite grains (1- 15 micrometer), abundant submicrometer titanomagnetite has been observed within an interstitial glass matrix. The thermal rock magnetic properties show that the unblocking temperature estimated from NRM demagnetization curves is higher than the Curie temperature from high-field experiments (Kent and Gee, *Science*, 1994; *Geology*, 1996). There are two explanations for the increased unblocking temperature: (1) the fine-grained titanomagnetite is preferentially maghemitized, or (2) the fine-grained titanomagnetite has lower Ti-contents. Electron microscopic studies show that the submicrometer titanomagnetite grains have a broad composition range (from uv0 to uv80), whereas the larger titanomagnetite grains have a narrow composition range around uv60. This variability in Ti-content provides a ready explanation for the thermal rock

VF Reports *continued on page 7…*

DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLA STUDIO DI PISA
E Filosofo, e Matematico primario del
SERENISSIMO
GR. DUCA DI TOSCANA
Doue ne i congressi di quattro giornate si discorre
sopra i due
MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO
MDCXXXII

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 4200 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

Borradaile, G. J., and B. Henry, 1997, Tectonic applications of magnetic susceptibility and its anisotropy: *Earth-Science Reviews, v. 42*, p. 49-93.

For magnetite, AMS primarily defines grain-shape anisotropy; for other minerals it expresses crystallographic control on magnetic properties. However not all AMS fabrics relate to crystallographic or grain alignment. Displacement fabrics generate AMS where an isotropic high-susceptibility matrix displaces unevenly-spaced low-susceptibility objects. AMS location fabrics occur when magnetite grains are close enough for their demagnetizing fields to interact. Inverse fabrics in single-domain magnetite may oppose the AMS contribution of parallel minerals.

Raposo, M. I. B., 1997, Magnetic fabric and its significance in the Florianopolis dyke swarm, southern Brazil: *Geophysical Journal International, v. 131*, no. 1, p. 159-70.

Anisotropy of magnetic susceptibility (AMS) in 62 mafic dykes shows two types of magnetic fabric. Type I is characterized by K1-K2 parallel to the dyke wall, representing magma flow within the dykes; type II has K1-K3 parallel to the dyke wall. Type I is found in 94 per cent of the dykes, and approximately 20 per cent of these have K1 inclinations of less than 30 degrees, suggesting horizontal or subhorizontal flow.

Instruments and Measurement Methods

Cowburn, R. P., Moulin, A. M., and Welland, M. E., 1997, High sensitivity measurement of magnetic fields using microcantilevers: *Applied Physics Letters, v. 71*, no. 15, p. 2202-4.

We have mounted magnetic γ-Fe_2O_3 particles on the end of a microcantilever in order to make a high sensitivity magnetic field sensor. An external magnetic field exerts a torque on the acicular oxide particles which in turn deflects the cantilever. The deflection is measured using a sensitive optical detection system. The sensor can resolve changes in applied field as small as 10^{-4} G (10 nT), and has good linearity over five orders of magnitude of applied field strength.

Uchiyama, T., Mohri, K., Shinkai, M., Ohshima, A., Honda, H., Kobayashi, T., Wakabayashi, T., and Yoshida, J., 1997, Position sensing of magnetite gel using MI sensor for brain tumor detection: *IEEE Transactions on Magnetics, v. 33*, no. 5, pt.2, p. 4266-8.

A brain tumor position sensing method using an MI (magneto impedance) micro-magnetic gradient sensor was investigated by measuring the spatial distributions of stray fields in gel samples, in which fine magnetic particles (FMP) were dispersed. Position sensing of the tumor tissue of a rat was also carried out. It was concluded that the proposed method would be useful for not only position sensing of the brain tumor but also 3D imaging of the tumor shape.

Magnetic Microscopy

Foss, S., Dahlberg, E. D., Proksch, R., and Moskowitz, B. M., 1997, Measurement of the effects of the localized field of a magnetic force microscope tip on a 180 degrees domain wall: *Journal of Applied Physics, v. 81*, no. 8, p. 5032-4.

Opposite polarity magnetic force microscope (MFM) profiles of domain walls (DWs) in magnetite were measured with a commercial MFM tip magnetized in opposite directions perpendicular to the sample surface. The influence of the tip field on a DW resulted in an overall more attractive interaction. The difference between opposite polarity DW profiles provided a qualitative measurement of the reversible changes in DW structure due to the localized field of the MFM tip. The rate of decay of the alteration with tip-sample separation varied across the DW and was much slower than expected from a simple model.

Moshkin, V. V., Ozhogin, V. I., Preobrazhensky, V. L., and Economov, N. A., 1997, Magneto-optical visualization of a sound-induced domain structure in hematite: *Journal of Magnetism and Magnetic Materials, v. 170*, no. 3, p. 285-8.

Non-uniform spin states (stripe domains) are induced by powerful pulse ultrasonic waves in a hematite (alpha -Fe_2O_3) single crystal. These states are visualized with the help of the Cotton-Mouton effect and quantitatively described in terms of an effective field proportional to the square of ultrasound amplitude.

Magnetic Petrology

Warner, R. D., and Wasilewski, P. J., 1997, Magnetic petrology of arc xenoliths from Japan and Aleutian Islands: *Journal of Geophysical Research, v. 102*, no. B9, p. 20225-43.

Arc xenoliths show 3 orders of magnitude range in natural remanent magnetization and saturation remanence and about 2 orders of magnitude range in magnetic susceptibility. Many possess induced magnetization 2 Am^{-1} and greater, with the expectation of additional magnetization due to viscous remanence at elevated temperature. The TiO_2 content of titanomagnetite, together with the presence of appreciable Al_2O_3 and MgO, result in Curie points

Abstracts *continued on page 4…*

continued from page 3

between 400 degrees and 550 degrees C. Each xenolith site groups distinctly on a plot of magnetic hysteresis ratios.

Magnetization Processes and Remanence

Borradaile, G. J., and Brann, M., 1997, Remagnetization dating of Roman and Mediaeval Masonry: *Journal of Archeological Science, v. 24*, p. 813-824.

Unblocking temperatures of the viscous remanence in masonry are related to the age of stabilization of archeological structures. For suitable rocks, calibration using historically dated structures permits us to estimate the age of more enigmatic structures by interpolation or modest extrapolation. Masonry from the Bishop's Palace (Lincoln, UK) has T_{UB}'s consistent with several major construction phases back to ca. AD 300.

Dunlop, D. J., and Argyle, K. S., 1997, Thermoremanence, anhysteretic remanence and susceptibility of submicron magnetites: Nonlinear field dependence and variation with grain size: *Journal of Geophysical Research, v. 102*, no. B9, p. 20199-210.

The authors have measured initial susceptibility χ_o and the dependence of ARM and TRM on applied field for seven samples of magnetite, with mean grain sizes from 40 to 540 nm. TRM acquisition is nonlinear in geomagnetically relevant weak fields. χ_o varies with particle shape but only weakly with particle size d, and can be used to correct for varying magnetite concentrations in sediment cores. ARM is strongly size dependent and is the best parameter for monitoring grain size variations in natural samples. ARM and TRM have similar variations, as d^{-1} for $d \leq 1$ μm, suggesting a common source for this pseudo-single-domain (PSD) dependence on grain size. However, TRM is 10-20 times more intense than ARM in grains around 0.2 μm in size. The authors propose that magnetite grains in the 0.1-0.5 μm size range can remain in metastable SD or two-domain states following acquisition of TRM but revert to a vortex ground state when field-cycled, for example, in ARM acquisition or alternating field demagnetization.

Fiorani, D., Dormann, J. L., Lucari, F., D'Orazio, F., Tronc, E., Prene, P., Jolivet, J. P., and Testa, A. M., 1997, Dynamic properties of interacting gamma -Fe_2O_3 particles: *Philosophical Magazine B, v. 76*, no. 4, p. 457-62.

The dynamic properties of a series of samples of γ-Fe_2O_3 particles with different aggregation states in a polymer mixture have been investigated by magnetization, ac susceptibility and Mössbauer spectroscopy measurements. The frequency dependence of the blocking temperature is satisfactorily described by a model based on a statistical calculation of the dipolar energy for a disordered assembly of particles with a volume distribution and easy axes in random directions.

Hayashi, M., Susa, M., and Nagata, K., 1997, Magnetic interaction between magnetite particles dispersed in calcium silicate glasses: *Journal of Magnetism and Magnetic Materials, v. 171*, no. 1-2, p. 170-8.

Inter-particle interaction has been investigated by measuring the superparamagnetic relaxation for magnetite particles dispersed in calcium silicate glasses using TRM, AC susceptibility and Mössbauer spectroscopy measurements: The temperature dependence of TRM can be explained by Néel's noninteracting theory. On the other hand, the relation between measurement time and blocking temperature in AC susceptibility measurements can be interpreted using Dormann's model in which the inter-particle interaction is taken into account.

Mahon, S. W., and Stephenson, A., 1997, Rotational remanent magnetization (RRM) and its high temporal and thermal stability: *Geophysical Journal International, v. 130*, no. 2, p. 383-9.

The time and temperature stability of various types of magnetic remanence has been measured in pottery samples containing magnetite and in a clay sample containing manganese ferrite. While the time decay of ARM and IRM is easily measurable at about 2 and 19 per cent per decade of time, respectively, the decay of RRM is too small to be measured, being less than about 0.1 per cent per decade of time. Thermal demagnetization of TRM, ARM and RRM indicates that RRM is also the most thermally stable. The implications of these experiments are that rocks which exhibit gyromagnetic effects such as RRM contain highly stable particles and therefore are likely to be most suitable for palaeomagnetism .

McConochie, S. R., Bissell, P. R., Parker, D. A., and Gotaas, J. A., 1997, Angular dependence of magnetization reversal in gamma - Fe_2O_3 single particles: An experimental and modelling study: *IEEE Transactions on Magnetics, v. 33*, no. 5, pt.1, p. 3043-5.

The switching field for isolated γ-Fe_2O_3 magnetic particles has been investigated as a function of the applied field angle both experimentally and numerically. At large applied field angles, the agreement between experimental results and micromagnetic simulations was poor. However, at the smaller applied field angles the simulations gave reasonable agreement with the experimental results.

Svedlindh, P., Jonsson, T., and Garcia-Palacios, J. L., 1997, Intra-potential-well contribution to the AC susceptibility of a noninteracting nano-sized magnetic particle system: *Journal of Magnetism and Magnetic Materials, v. 169*, no. 3, p. 323-34.

The model proposed by Shliomis and Stepanov to describe the low field magnetic response of a solid dispersion of noninteracting nano-sized particles has been used to calculate the temperature dependence of the AC susceptibility of a particle system with a known particle size distribution. A comparison with experimental AC susceptibility results shows the necessity of including both an inter-potential- and an intra-potential-well contribution to the magnetic response. Moreover, different relaxation times need to be assigned to the two contributions.

Modeling and Quantitative Interpretation

Fabian, K., and von Dobeneck, T., 1997, Isothermal magnetization of samples with stable Preisach function: a survey of hysteresis, remanence, and rock magnetic parameters: *Journal of Geophysical Research, v. 102*, no. B8, p. 17659-77.

Six elemental isothermal magnetization curves, derived from a general partition scheme of the Preisach diagram, can be easily obtained from common measurements. A physical rationale of the elemental curves reveals favorable properties for the investigation of interaction and domain state. The experimental applicability of these results is demonstrated for three (single-domain, pseudo-single-domain, multidomain) marine sediment samples. All presented methods can be applied without actually measuring Preisach functions.

Mössbauer, Kerr, Raman, and X-ray Spectroscopy

Fontijn, W. F. J., van der Zaag, P. J., Devillers, M. A. C., Brabers, V. A. M., and Metselaar, R., 1997, Optical and magneto -optical polar Kerr spectra of Fe_3O_4 and Mg^{2+}- or Al^{3+}-substituted Fe_3O_4: *Physical Review B, v. 56*, no. 9, p. 5432-42.

The diagonal elements of the dielectric tensor, between 0.5 and 5.0 eV, and the magneto -optical polar Kerr spectra, between 0.7 and 4.0 eV, have been determined for a synthetic crystal of magnetite, Fe_3O_4 with systematic Mg^{2+} and Al^{3+} substitutions. The off-diagonal elements of the dielectric tensor were calculated from these spectra. The observed trends in the major transitions upon substitution provide experimental evidence for intervalence charge transfer and intersublattice charge transfer transitions in

Fe_3O_4 .

Paleoclimate, Proxies, and Environmental Magnetism

Dearing, J. A., Bird, P. M., Dann, R. J. L., and Benjamin, S. F., 1997, Secondary ferrimagnetic minerals in Welsh soils: a comparison of mineral magnetic detection methods and implications for mineral formation: *Geophysical Journal International, v. 130*, p. 727-736.

The relative distributions of SP and stable SD grains are similar in 9 of 10 representative soil samples, approximately 20-30% SSD and 70-80% SP. Multidomain (MD) grains were not detected in the samples studied. There is evidence that some soils contain significant numbers of ultrafine SP grains <0.010 µm that are not detected by low-temperature remanence measurements at 20 K. The positively skewed grain-size distributions strongly suggest weathering and fermentation as controlling processes of SFM formation, rather than the degradation of SSD bacterial magnetosomes and primary minerals.

Dekkers, M. J., 1997, Environmental magnetism: an introduction: *Geologie en Mijnbouw, v. 76*, p. 163-182.

This paper presents a review of these environmental magnetic applications: analysis of paleoclimate variation in loess and other sediments; untangling of sedimentary features in piston cores; and anthropogenic impact on the environment, in archeological studies and in studies of present-day pollution. The pathways between the provenance area and the depositional site has a crucial impact on magnetic properties.

Paleomagnetism and Tectonics

Borradaile, G. J., 1997, Deformation and paleomagnetism: *Surveys in Geophysics, v. 18*, p. 405-435.

Tectonic deformation affects paleomagnetic vectors by a variety of mechanisms, including rotation of fold limbs, strain reorientation (both intra- and inter-granular), and stress demagnetization/ remagnetization. The predeformational orientation can be recovered only when the noncommutattive sequence of events in the natural strain history are correctly reversed.

Kirschvink, J. L., Ripperdan, R. L., and Evans, D. A., 1997, Evidence for a large-scale reorganization of Early Cambrian continental masses by inertial interchange true polar wander: *Science, v. 277*, no. 5325, p. 541-5.

Analysis of Vendian to Cambrian paleomagnetic data shows anomalously fast rotations and latitudinal drift for all of the major continents. These motions are consistent with an Early to Middle Cambrian inertial interchange true polar wander event, during which Earth's lithosphere and mantle rotated about 90 degrees in response to an unstable distribution of the planet's moment of inertia. The proposed event produces a longitudinally constrained Cambrian paleogeography and accounts for rapid rates of continental motion during that time.

Properties of Magnetic Minerals

Bercoff, P. G., and Bertorello, H. R., 1997, Exchange constants and transfer integrals of spinel ferrites: *Journal of Magnetism and Magnetic Materials, v. 169*, no. 3, p. 314-22.

We have studied Fe_3O_4, $CoFe_2O_4$, $NiFe_2O_4$ and $CuFe_2O_4$ considering Néel's two-sublattice collinear model and superexchange theory. We have found that, for this theory to be valid, the interaction between ions in tetrahedral sites should be very weak, and we have proposed a model to find the constants J_{AB} and J_{BB} with the assumption that $J_{AA}=0$.

Clark, T. M., and Evans, B. J., 1997, Influence of chemical composition on the crystalline morphologies of magnetite: *IEEE Transactions on Magnetics, v. 33*, no. 5, pt.2, p. 4257-9.

Cubic and octahedral magnetite specimens from a variety of localities have been examined to ascertain the influence of chemical composition on their morphology. The presence of cations which favor occupancy of the A site in the magnetite spinel structure is shown to be significant in the formation of cubic magnetite at concentrations of x=0.02 in $Zn_xFe_{3-x}O_4$, with unusual order-disorder phenomena accompanying this change in habit.

Hou, D. L., Nie, X. F., Shao, S. X., Lu, P., and Luo, H. L., 1997, Studies on the magnetic anisotropy and the coercivity of granular gamma - Fe_2O_3 powders: *Physica Status Solidi A, v. 161*, no. 2, p. 459-68.

By the law of approach to saturation, the effective magnetic anisotropy constants K_E of granular γ-Fe_2O_3 powders at different temperatures are obtained. The variation of K_E with temperature is about the same as that of the shape magnetic anisotropy K_{sh}, and the magnetization reversal process of granular γ-Fe_2O_3 is close to uniform rotation at different temperatures.

Okudera, H., 1997, Single crystal X-ray studies of cation-deficient magnetite: *Zeitschrift fur Kristallographie, v. 212*, no. 6, p. 458-61.

X-ray diffraction studies of synthetic single-crystal magnetite specimens show that cation vacancies are selectively formed at the octahedral sites. The effects of cation deficiency are an increase of atomic mean square displacements and a decrease of anisotropy in thermal motions of the octahedral site cations.

Özdemir, Ö., and Dunlop, D. J., 1997, Effect of crystal defects and internal stress on the domain structure and magnetic properties of magnetite: *Journal of Geophysical Research, v. 102*, no. B9, p. 20211-24.

The Bitter colloid technique shows spike and closure domains around nonmagnetic inclusions, chemically altered regions, and grain boundaries in a natural single crystal of magnetite. Coercivity Hc varies with T as $\lambda_{111}\omega^{0.5}/Ms$, in agreement with theoretical predictions of impedance of a wall of width ω by dislocation stress fields. These observations support the idea that the stability of remanence in multidomain magnetite is mainly due to pinning of domain walls by crystal defects.

Ranganathan, S., Prince, A. A. M., Raghavan, P. S., Gopalan, R., Srinivasan, M. P., and Narasimhan, S. V., 1997, Kinetics of dissolution of magnetite in PDCA based formulations: *Journal of Nuclear Science and Technology, v. 34*, no. 8, p. 810-16.

Magnetite is one of the important corrosion products of pressurised heavy water reactors. The rate of dissolution of synthetically prepared magnetite was studied in low concentrations of PDCA containing acidic formulations. The effect of addition of ascorbic acid, citric acid, Fe^{2+}-PDCA complex was also studied, and the effects of pH and the temperature on the dissolution rate were determined.

Snowball, I. F., 1997, The detection of single-domain greigite (Fe_3S_4) using rotational remanent magnetization (RRM) and the effective gyro field (B_g): mineral magnetic and palaeomagnetic applications: *Geophysical Journal International, v. 130*, no. 3, p. 704-16.

The intensity of rotational remanent magnetization (RRM) acquired by single-domain greigite was combined with measurements of ARM to calculate the effective biasing field (B_g) that produced the RRM. Samples of single-domain greigite had B_g and MDFRRM values that differ significantly from values for a suite of natural and synthetic ferrimagnetic iron oxide samples. Measurements of B_g and MDFRRM were used to detect the presence of greigite in a 4 m long Late Weichselian sediment core. Variations in the natural remanent magnetization (NRM) correlate with changes in magnetic mineralogy.

■

continued from page 1

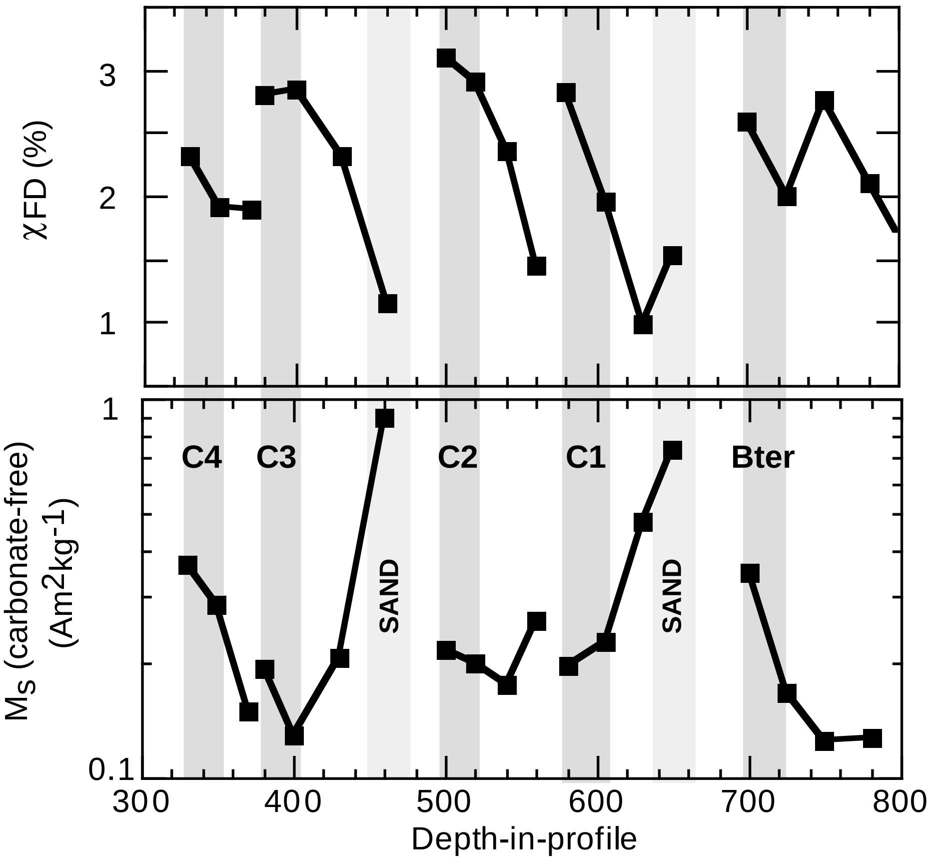

Figure 1: M_s and χ_{FD} profiles of the eolianite-paleosol sequence from La Mala quarry (Lanzarote, Canary Islands). Due to the local basaltic source, coastal sands present the higher magnetization. The five paleosols (Bter to C4) show significantly higher χ_{FD} values, illustrating the presence of an SP component which exists in loess and sand end-members, but dominates in (top)soils.

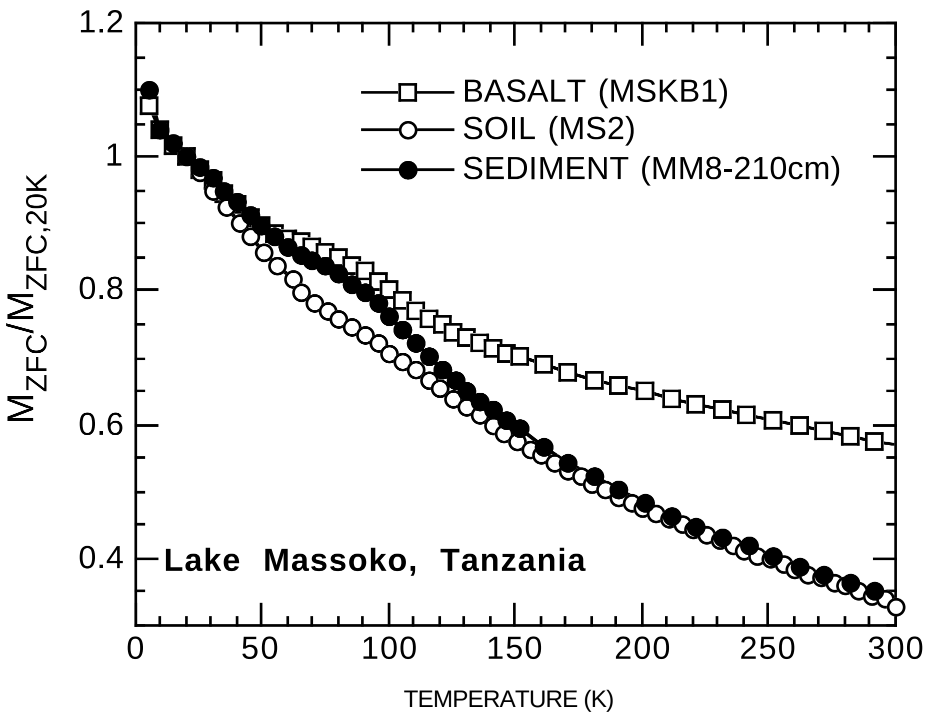

Figure 2: Thermal IRM demagnetization curves of the basaltic catchment, the topsoil, and a holocene sediment, from the Lake Massoko crater (Tanzania). The IRM was acquired at 5K in a 2.5T dc field after cooling in zero-field. The basalt and the sediment show a drop in magnetization near the Verwey transition of magnetite, between 95 and 120K. The general decrease of IRM between 5 and 300K in the topsoil and in the sediment reflect a strong SP component in these rocks. The possible magnetic mixture of topsoil and basaltic sources in the sediment is under improvement.

leading to magnetic interactions which I have tried to identify using dilution experiments. The low-T behavior of these soils and their Mössbauer spectra suggest that the processes which constrain the magnetic mineralogy of soils are i) the neoformation of (ultra)fine iron oxides, and ii) the differential weathering of volcanic glass and "primary" iron minerals.

Magnetic variability in lakes during the Late Quaternary and the Holocene

This is the most important part of my work here, for both the IRM and the Limnological Research Center (LRC) have a strong interest in sedimentary magnetic records and lacustrine environments, from intertropical to subpolar areas.

At Lake Tritrivakely, a basaltic maar lake from Madagascar, the hematite contribution from highly weathered soils is observed during arid periods, with oxic lake-bottom conditions. In contrast, the contributions of magnetically "hard" iron oxides disappear when the lake-bottom becomes anoxic. The dissolution of iron oxides in anoxic conditions is associated with the presence of important amounts (up to 60% of the coarse fraction) of siderite (iron carbonate) and vivianite (iron phosphate). These two minerals are observed in many maar-lake, and/or iron-rich terrigenous sediments (e.g., Lake Barombi Mbo in Cameroon, Lac du Bouchet, Holzmaar or Lac St Front in Europe, Lake of the Clouds in Northern Minnesota). Erosional processes thus result in strong biogeochemical changes in aquatic ecosystems, associated with methane production.

At Lake Massoko, a 40 kyr maar from Tanzania, the 35m long cores (EEC Rukwa project) recorded almost all the story of this young crater. Comparison of the sediments with present-day soils and the basaltic catchment suggests that soil magnetic enhancement occurred during relatively humid periods, at least at the precessional scale. In contrast, the highest frequency changes in magnetic concentration-, structure- and grainsize-dependent magnetic proxies, which seem to result from erosional events, are closely associated with changes in the lacustrine ecosystem, as inferred from diatom and organic matter assemblages. Again, the Fe and C cycles in such lakes exhibit a similar sensitivity to climate change, here on time-scales less than 100 yr. I am now trying to detail such relationships by improving the iron mineralogy in these sedimentary environments.

Exchange

These very great times would not exist without the help of the NATO scientific program, which sponsored my stay in 96-97, the CNRS, and the scientific exchange between "magnetic exchange" people from

...David Williamson

continued from page 6

the IRM and "global change" people from University of Minnesota. Many thanks and "slunges" to Subir Banerjee, Mike Jackson, Gideon N'Gobi, Jim Marvin, Bruce Moskowitz, Peat Solheid, Stefanie Brachfeld, Bernie Housen, Taras Pokhil, Chris Geiss, Rick Oches, Pieter Vlag and B.J. Wanamaker at IRM, and to Kerry Kelts, Herb Wright, Andy Breckenridge, Dawn Graber, Emi Ito, Bill Seyfried, Margaret Davis and the RTG people at "U of M".

...VF Reports

continued from page 2

magnetic properties. On the other hand, the magnetic susceptibility vs. temperature curve obtained with a Geofyzika Kappa Bridge at the *IRM* is fully reversible, indicating that preferential maghemitization is unlikely. The observed reversible drop between 550 and 600 degree C on the curve indicates the existence of low-Ti magnetite.

It is commonly observed that the glass, interstitial as well as near the pillow rims, has been altered to clay minerals in the older ocean-floor basalts. However, the glass in the older basalts has been preserved occasionally at some sites. Interestingly, we find that the submicrometer titanomagnetite within the interstitial glass at these sites appears to have a much lower oxidation state than the large-grained titanomagnetite in some cases in the older basalts. A set of our samples from DSDP556 (30 Ma), kindly provided by Thomas Pick, reveals that a lot of glass has been preserved. Electron microscopic studies indicate that the large titanomagnetite grains have been fully oxidized to titanomaghemite, which is supported by the observation of superlattices and by lattice parameter measurements of the individual titanomagnetite grains using TEM. However, some interstitial glass is still preserved and the submicrometer titanomagnetite grains within the interstitial glass show no superlattices. Moreover, the measurements of lattice parameters indicate very low or no oxidation. In contrast to the young ocean-floor basalt, the unblocking temperature estimated from the NRM demagnetization curve (using both 2G cryogenic magnetometer and MicroMag) is about 100 degree C below the Curie temperature from both Js(T) curves (MicroVSM) and susceptibility (T) curves (Kappa Bridge). Our studies indicate that the fine-grained titanomagnetite can be shielded from oxidation by a glass matrix, which supports our conclusions about the young ocean-floor basalts. These findings are of great importance for paleointensity studies of submarine basaltic glass.

Luca Lanci
E.T.H. Hoenggerberg
lanci@geo.phys.ethz.ch

Magnetic Properties of Soils and Lake Sediments

When I applied to visit the *IRM* Laboratory our main goal was to investigate in detail the magnetic properties of hydromorphic soils (gleysols) that we were studying in Switzerland. Later on I was involved in a study of paleoclimate in lake sediments which gave very good results and soon became my main interest. So I took both the soil and the lake samples to the *IRM*.

The lake samples come from a core drilled in a high Alpine lake. The study is part of the SNF-project AQUAREAL, which was set up to study rapid climate changes in the Alps, and we were quite excited when we found a clear relationship between magnetics and climatic proxies. A major change in magnetic mineralogy and in the superparamagnetic contribution corresponds to the climatic warming after the Younger Dryas. High-coercivity magnetic minerals that characterize the Pleistocene disappear in the Holocene and the concentration of ferrimagnetic minerals increases.

We already knew that the rock-magnetic properties of the gleysols were distinguishable for the pedogenic horizons. Our previous results also suggested that susceptibility was dominated by paramagnetic minerals and showed that low and high coercivity minerals are present throughout the profile. The contribution of the low coercivity mineral to the IRM decreases with depth while that of the high coercivity phase increases. The presence of superparamagnetic grain sizes was suggested by the frequency dependent susceptibility and isothermal remanence acquired at liquid nitrogen temperature. Other information on iron contents in soils was available from chemical analysis as pyrophosphate, oxalate and citrate-bicarbonate-dithionite (CBD) extractions.

We were interested in investigating in detail the magnetic mineralogy of the high and low coercivity phases of both sets of samples . Our goal was also to estimate the grain size distribution in the SP range and to measure high field (paramagnetic) susceptibility. Moreover in the soil samples we wanted to try to verify the presence of ferrihydrite that

Ampère, André-Marie

b. Jan 22, 1775, Lyon
d. Jun 10, 1836, Marseille

It is said that within a week after hearing the news of Ørsted's discovery in 1820 (of the effects of filamentary electric currents on a compass needle), Ampère had developed the theoretical foundations of electromagnetism (which he named "electrodynamics"). It is thus fitting that the SI units for both electric current (A) and magnetic moment (Am^2) bear Ampère's name. *Ampère's Law* mathematically describes the magnetic force between two currents. He built the first galvanometer, and in 1827 published his *Memoir on the Mathematical Theory of Electrodynamic Phenomena, Uniquely Deduced from Experience*.

Santa Fe 4 Conference in the Works

Mark your calendar! We are planning to hold the Fourth Santa Fe Conference on Rock Magnetism during the last weekend in June (Thursday afternoon/evening, June 25 - Sunday noon, June 28) at St John's College (site of the previous three Santa Fe meetings). Contingent upon funding from NSF, we anticipate providing partial reimbursement of travel expenses, as for past meetings.

The results of a preliminary interest survey indicated a wide variety of preferences for focus areas. Those most frequently mentioned included: paleoclimate and environmental magnetism; high-resolution paleofield records; and quantitative interpretation of rock-magnetic data, proxies, and "tests". If you are interested in participating or obtaining more information, please contact Mike Jackson at *IRM* to get on the mailing list.

…Visiting Fellow Reports

continued from page 7

was suggested by oxalate extraction, thus we took a couple of samples of synthetic ferrihydrate to compare the magnetic properties.

The high field (paramagnetic) susceptibility was computed from the hysteresis loop measured at the *IRM* laboratory. Measurements were made with the AGFM on a large number of samples, which confirmed that room temperature susceptibility is mainly controlled by paramagnetic minerals. Moreover the hysteresis properties provided quantitative information on the ferromagnetic mineralogy as a function of depth. While in the laboratory I could also have a taste of the new Micro-VSM and I had the impression that this instrument is almost as sensitive as the AGFM without its fragile sample holder, and has several additional advantages (larger samples, anisotropy measurements, temperature range from 20° to 800°C).

We planned to take advantage of the information that could be provided by the Mössbauer spectrometer to reveal the magnetic mineralogy of these rocks, which can be very complicated. We hoped that the Mössbauer could give us a more quantitative result compared to the traditional rock-magnetic methods based on coercivity and unblocking temperature. Unfortunately it turned out that the concentration of ferromagnetic minerals in our extracts was too low to get good Mössbauer results. Perhaps the mistake was that we used too strong a magnet during the extraction, which attracted all sort of paramagnetic minerals.

Although this experiment was not very successful we did get a lot of information from another beautiful instrument, the Quantum Design MPMS. The first set of experiments on the MPMS was designed to obtain information on remanent and induced magnetization at different fields and temperatures. A second set of experiments, the thermal demagnetization of a low temperature IRM, was used to detect phase transitions (e.g. Verwey) and to estimate the grain size distribution in the SP range.

The first experiment was successful in measuring the high and low field susceptibility at different temperatures. The second experiment was able to detect the Verwey in the lake samples (thus identifying the magnetic mineral as magnetite) while in the soils we noticed that the decay of magnetization for temperatures below 30K was very similar to that obtained for the synthetic ferrihydrate. We also noticed that in the lake samples the grain-size distribution in the SP range was different in warm and cold samples. We could use this results to obtain another rock-magnetic parameter useful to discriminate climatic factors.

The experiments I did at the *IRM* led to several interesting results. Although these beautiful data, measured with very high precision, cannot yet be interpreted in an equally quantitative way, they have helped us to better understand in a qualitative way the magnetic properties of our samples.

Collectors Series #7.

From "Revue generale de l'electricité," Nov. 1922, Paris

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.

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*. 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:

Mike Jackson
Institute for Rock Magnetism
University of Minnesota
291 Shepherd Laboratories
100 Union Street S. E.
Minneapolis, MN 55455–0128
phone: (612) 624-5274
fax: (612) 625-7502
e-mail: irm@geolab.geo.umn.edu
web: http://www.geo.umn.edu/orgs/irm/irm.html

Institute for Rock Magnetism