ISSN: 2152-1972

The IRM
Quarterly
Fall 2015, Vol. 25 No.3

Inside...

Visiting Fellows' Reports 2
Current Articles 6
... and more throughout!

The IRM at 25: A Quarter Century of Community-Based Research and Education

Bruce Moskowitz, Subir Banerjee, Joshua Feinberg, Mike Jackson, Peat Sølheid, Dario Bilardello
Institute for Rock Magnetism

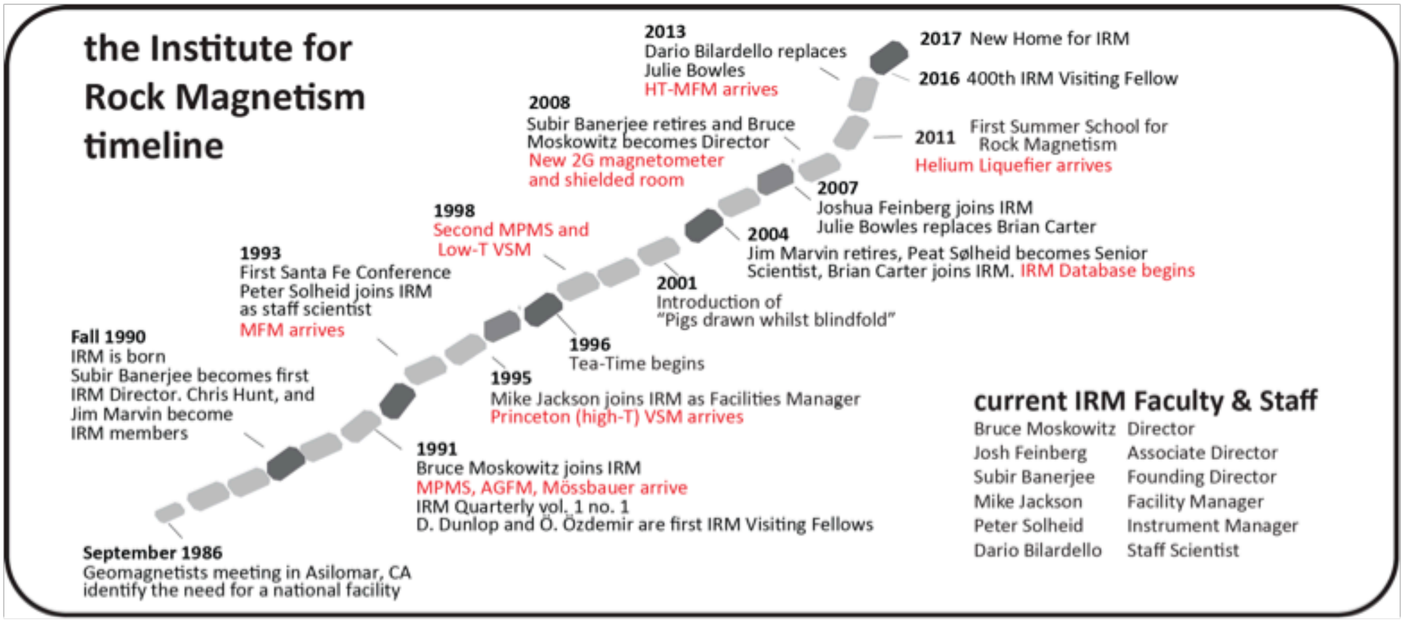


Fig 1. 30-year chronology of IRM development, schematically represented by a chain of bacterial magnetosomes.

IRM Origins and Development

In 1986, at an Asilomar meeting on the future of paleo- and rock magnetism organized chiefly by Subir Banerjee, 28 researchers began discussing an idea for a center where researchers in earth science and allied fields in the physical sciences could share ideas and have access to advanced instrumentation for magnetic material characterization and experimentation. Sensitive magnetic measurements would make it possible to determine the compositions, concentrations, particle sizes and orientation distributions of the trace magnetic phases in terrestrial and extraterrestrial materials. This in turn would improve our understanding of the origins and significance of the natural remanence carried by them, as well as providing valuable information on the physical and chemical processes involved in their formation and subsequent alteration.

The first attempt to fund such a center (originally called the National Center for Rock Magnetism) was in 1988 through a new initiative at NSF called the Science and Technology Centers (STC) program. The proposal was reviewed favorably and it actually made it into the final round of competition, and when the review panel came for a site evaluation they were told by the governor of Minnesota that "we must have more rock magnetism." However the proposal was not funded in the end. Two Earth Science related STCs that did get funded in those early days of the program were by our colleagues in mineral physics (Center for High-Pressure Research at Stony Brook, NY) and seismology (Southern California Earthquake Center at USC, CA). A proposal for a more modest facility (now called the Institute for Rock Magnetism) proved to be much more successful in 1990, funded by the Instrumentation and Facilities program in the Division of Earth Sciences at NSF, the W. M. Keck Foundation, and the University of Minnesota. In hindsight it was probably lucky that we did not get the STC funding back in 1988 because the lifetime STC funding for individual centers was limited to 11 years total.

cont'd. on pg. 9...

Visiting Fellow Report

Anisotropy of magnetic susceptibility and remanence in layered intrusions – Reinfjord Ultramafic Complex and Bjerkreim Sokndal Layered Intrusion

Andrea R. Biedermann
Norwegian University of Science and Technology, Trondheim, Norway
andrea.biedermann@ntnu.no

Introduction

Magnetic fabrics are important proxies for rock textures (Borradaile and Jackson, 2010). Magnetic anisotropy also deflects magnetization and influences magnetic anomalies or paleomagnetic data (Clark, 1997; Fuller, 1963). We are interested in characterizing and understanding magnetic fabrics in two layered intrusions: the Reinfjord Ultramafic Complex in the Seiland Igneous Province, Northern Norway, and the Bjerkreim Sokndal intrusion, Rogaland, Southern Norway.

The Reinfjord Ultramafic Complex (RUC) consists of > 25 000 km3 ultramafic material, emplaced at 25-30 km depth (Roberts et al., 2006). It is currently not understood how this large amount of ultramafic melt could have been emplaced in the crust. Anisotropy of magnetic susceptibility (AMS) is used to better understand the rock fabric, and assist the geological interpretation. It is thus essential to separate paramagnetic and ferromagnetic fabrics, which are carried by olivine and pyroxene, and by magnetite (±sulfides), respectively.

The Bjerkreim Sokndal Layered Intrusion (BKSK) consists of plagioclase pyroxene cumulates, and the layering in the intrusion is associated with distinct magnetic anomalies. A strong negative anomaly, reducing the surface field by about half, is associated with one of the layers, MCU IVe' (McEnroe et al., 2001). This layer contains hemo-ilmenite and magnetite in addition to the paramagnetic minerals. The natural remanent magnetization (NRM) causing the negative anomaly is carried by hemo-ilmenite, which is expected to have a preferential orientation. We are interested in how the changing mineral fabric along the fold affects the observed anomaly at the surface.

Low-field AMS in both intrusions is strong (P = k1/k3 up to 1.45 in RUC, and up to 2.13 in BKSK) and the principal susceptibility directions appear to be related to geologic features. In the RUC, the maximum susceptibility direction is parallel to the main geological dip direction, and in the BSKK, the minimum susceptibility is normal to the trend of the layering, which corresponds to the trend of the negative anomaly. For a full interpretation of AMS data, it is however essential to know which minerals carry the AMS.

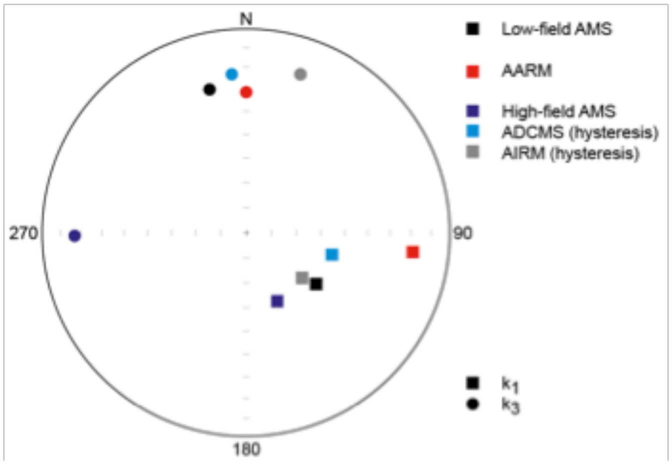


Figure 1. Maximum and minimum principal susceptibility and remanence directions of a representative sample from the RUC.

Methods

A series of experiments were conducted to isolate individual components of the magnetic fabric: High-field anisotropy measurements based on hysteresis loops, anisotropy of anhysteretic remanent magnetization (AARM), anisotropy of isothermal remanent magnetization (AIRM) and anisotropy of thermal remanent magnetization (ATRM). These measurements were complemented with rock magnetic experiments, i.e. acquisition of isothermal remanence up to 9 T, and field-cooled/zero-field-cooled remanence.

Results

High-field AMS and anisotropy of remanence have been measured on the Seiland samples (Fig. 1). The anisotropy of remanence and low-field AMS have similar orientations of maximum and minimum susceptibility axes, whereas the minimum axis of the high-field paramagnetic AMS is perpendicular to the minimum susceptibility of the low-field AMS.

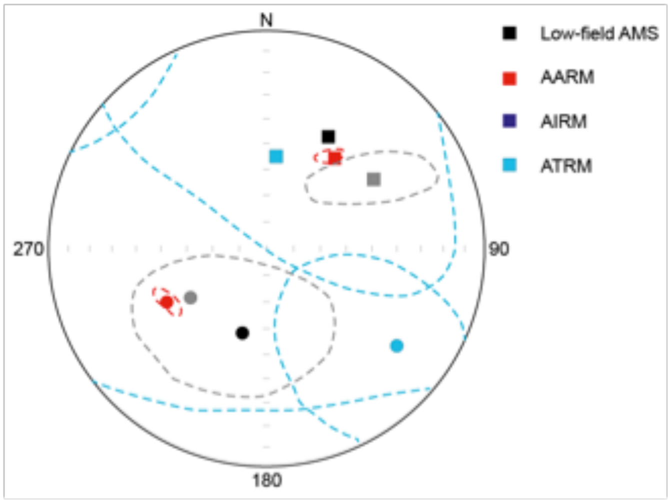


Figure 2. Maximum and minimum principal susceptibility and remanence directions of a representative sample from the Bjerkreim Sokndal layered intrusion. Dashed lines indicate confidence ellipses.

The samples from Bjerkreim-Sokndal were too magnetic for high-field AMS measurements. AARM is strong and in most samples coaxial with low-field AMS (Fig. 2). AIRM and ATRM were hardly significant or not significant. This indicates that a low-coercivity mineral such as magnetite contributes a large part to the low-field AMS. The high-coercivity ilmenite was either not magnetized in the 1 T field used for AIRM, or does not show any anisotropy.

Acknowledgments:

Dario Bilardello, Mike Jackson and Peat Solheid are thanked for helpful discussions and assistance with experiments at the IRM. This study is financed by the Swiss National Science Foundation, project P2EZP2-155517, and an IRM Visiting Fellowship.

References

Borradaile, G.J. and Jackson, M., 2010. Structural geology, petrofabrics and magnetic fabrics (AMS, AARM, AIRM). Journal of Structural Geology, 32(10): 1519-1551.

Clark, D.A., 1997. Magnetic petrophysics and magnetic petrology: aids to geological interpretation of magnetic surveys. Journal of Australian Geology and Geophysics, 17: 83-103.

Fuller, M.D., 1963. Magnetic anisotropy and paleomagnetism. Journal of Geophysical Research, 68(1): 293-309.

McEnroe, S.A., Robinson, P. and Panish, P.T., 2001. Aeromagnetic anomalies, magnetic petrology, and rock magnetism of hemo-ilmenite- and magnetite-rich cumulate rocks from the Sokndal Region, South Rogaland, Norway. American Mineralogist, 86: 1447-1468.

Roberts, R.J., Corfu, F., Torsvik, T.H., Ashwal, L.D. and Ramsay, D.M., 2006. Short-lived mafic magmatism at 560–570 Ma in the northern Norwegian Caledonides: U–Pb zircon ages from the Seiland Igneous Province. Geological Magazine, 143(6): 887-903.

Report from the 2015 Visiting Fellowship at the IRM

Ran Issachar
Department of Geosciences,
Tel Aviv University
ranissachar@gmail.com

Chalk rocks within the Dead-Sea-Fault plate boundary exhibit well defined magnetic fabrics. The rocks show both AMS and AARM fabrics (Figure 1), however those two differ in characteristics. The AARM fabric is held only by remanence and thus suggest preferred orientation of ferromagnetic grains.

In order to correctly interpret the magnetic fabrics, knowledge of the magnetic mineralogy is required. Therefore, the main goal for the IRM visit was to determine the magnetic mineralogy within the samples. For that, 15 samples were examined by: AF demagnetization curves, VSM hysteresis loops, thermal IRM demagnetization, high temperature susceptibility measurements and MPMS experiments.

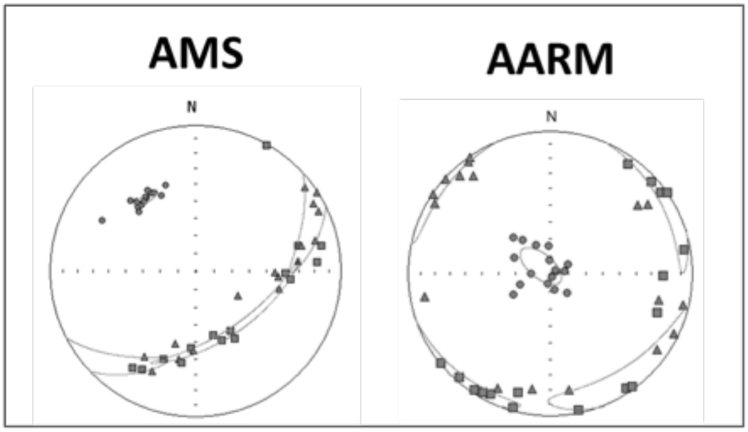


Figure 1. AMS and AARM fabrics of chalk within the Dead-Sea-Fault plate boundary.

The challenge was that the content of magnetic minerals is very low, and is masked by large contents of paramagnetic and diamagnetic minerals. For that, all the experiments and sample handling had to be very careful and precise. For example, to increase the accuracy, the VSM runs were set for high averaging time and 8 repetitions, and the sample holder was separately measured and then subtracted.

The main results are presented in Figure 2. The AF demagnetization curves indicates soft minerals, as most of the moment is lost between 10-35 mT (Figure 2a). The shape of the curve suggest sub-micron grain size (Figure 2a). The raw data of the VSM (Figure 2b) indicates the dominancy of paramagnetic minerals as ferromagnetic component is negligible. The slope corrected curve (Figure 2c) however, reveals the existence of very low corecivity ferromagnetic phase. The shape of the loop is consistent with super-paramagnetic grains (Figure 2c).

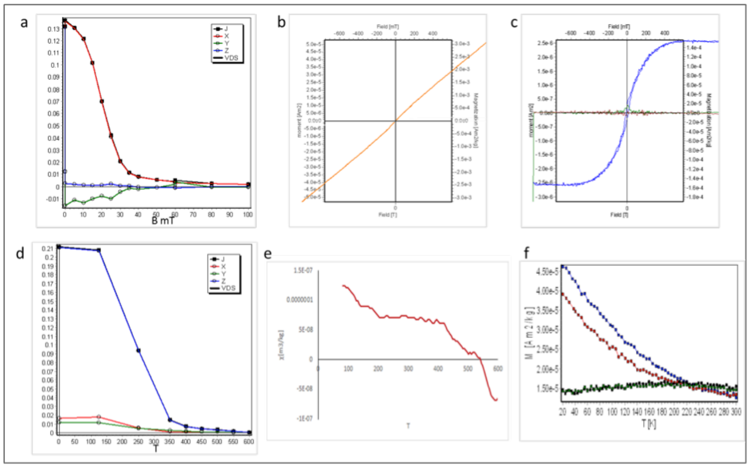


Figure 2. Main results of the experiment conducted at the IRM. a) AF demagnetization curves. b) Raw data of VSM loops. c) Slop corrected VSM loops. d) Thermal IRM demagnetization, the IRM was first acquired 1T along x, 300mT along y and then 100mT along z. e) High temperature susceptibility measurements. f) MPMS experiments.

Thermal demagnetization (Figure 2d) indicates that most of the initial magnetization is along z axis, also suggesting soft minerals (the IRM was first acquired 1T along x, 300 mT along y and then 100 mT along z). Most of the moment loss is between 125º-350º as typical for sulfides. The remaining magnetization is lost after 500º as typical for magnetite-maghemite. High temperature susceptibility (Figure 2e) shows two drops during heating, at 100º-200º and 400º-600º. After ~550º the susceptibility in negative, indicates diamagnetic component.

The MPMS (Figure 2f) experiment shows no phase transitions at cooling, suggest the absence of magnetite or pyrrhotite. The curve indicates very little change at cooling, monotonic loss of moment on warming and reversibility during cooling warming cycle.

Examination of the whole results suggest that magnetic minerals are fine grained, probably super-paramagnetics, with very low corecivity. The most likelihood mineralogy emerges is a combination of greigite and oxidized magnetite.

Particle size dependent microbial oxidation and reduction of magnetite

James M. Byrne & Andreas Kappler
Geomicrobiology, Center for Applied Geosciences, University of Tuebingen, Germany
james.byrne@uni-tuebingen.de

Iron (Fe) minerals are ubiquitous in the environment and commonly exist in combination with a number of different Fe-metabolizing bacteria including both Fe(II)-oxidizing and Fe(III)-reducing bacteria [1]. The formation of magnetite by magnetotactic bacteria [2] or dissimilatory iron(III)-reducing bacteria (e.g. Geobacter sulfurreducens) [3] has been known for several decades. However, the potential for bacteria to further interact with the magnetic mineral once formed is relatively unknown despite the fact that microbial-mineral interactions play a crucial role in the mobility of metals and nutrients, and for establishing certain redox conditions in the environment. We recently showed that Fe-metabolizing bacteria can use magnetite nanoparticles as an electron sink or source depending upon the redox conditions present, and likened the magnetite to a natural battery (biogeochemical battery) [4]. In that study, we incubated magnetite nanoparticles in the light with the phototrophic Fe(II)-oxidizing bacteria Rhodopseudomonas palustris TIE-1 [5] followed by incubation in the dark with Fe(III)-reducing bacteria Geobacter sulfurreducens. We used several techniques including magnetic susceptibility, x-ray diffraction (XRD) and Mössbauer spectroscopy to observe changes to the redox state of the mineral. This process of light/dark incubation was repeated, showing that the process of microbial oxidation and reduction of magnetite could be cycled. Many open questions emerged as a result of this research, notably the potential effect that particle size would have on the microbe-mineral interaction. Furthermore, we wanted to know if these changes, which were detectable through several mineralogical methods, could be observed using low temperature magnetic measurements. This led to our application to carry out measurements at the Institute for Rock Magnetism (IRM).

Two different types of magnetite were synthesized, denoted nano-ctrl (d~12 nm) [6] and micro-ctrl (d~200-300 nm) [7] (Figure 1). These magnetite samples were incubated in the presence of either Fe(II)-oxidizing bacteria Rhodopseudomonas palustris TIE-1 (denoted nano-ox or micro-ox), or the Fe(III)-reducing bacteria Geobacter sulfurreducens (denoted nano-red or micro-red). After several days of incubation, the magnetite was dried for the magnetic measurements. Low temperature measurements were performed using a Quantum Design MPMS-2 superconducting quantum interface device (SQUID) magnetometer. Field cooled-zero field cooled saturation isothermal remanent magnetisation (FC-ZFC-SIRM) curves were obtained together with room temperature SIRM (RTSIRM) protocols. The data collected has been submitted for publication.

FC-ZFC-SIRM measurements of nano-ctrl showed a relatively steep decrease in magnetization during warming from 20 K to ~110 K followed by a more gradual decrease as temperature increased to 295 K. Micro-ctrl showed much more characteristic behaviour of bulk magnetite with a gradual decrease in magnetization on warming until above 100 K at which point the magnetization sharply decreased before plateauing above ~120 K. The rapid change in the slope of magnetization for both nano-magnetite and micro-magnetite samples can be attributed to the Verwey transition (Tv) [8]. Tv is commonly described to occur at ~120 K, and any changes in the transition temperature can be thought of as being due to oxidation (maghemitization) of magnetite. It was seen in the data that Tv decreased by ~5 K for nano-ox in comparison to nano-ctrl, confirming that the sample was partially oxidized by the bacteria. No such decrease in Tv could be observed for micro-ox compared to micro-ctrl which suggests oxidation did not occur. Changes in the RTSIRM curves were most apparent for the nano-magnetite series of samples. Whilst the cooling curves for nano-ctrl, nano-ox and nano-red share similar characteristics, the warming curve for nano-ox shows a much more dramatic drop in magnetization above ~220 K and continue to fall to 80% of the initial magnetisation before cooling and is thought to be an effect of microbial Fe(II) oxidation. These results confirm that nano-magnetite was more susceptible to oxidation than micro-magnetite. This behaviour was expected due to the increased surface area to volume ratio of nano-magnetite enabling a larger portion of the Fe to be available to the Fe(II)-oxidizing bacteria. The measurements were, however, unable to confirm such a particle size based effect for the Fe(III)-reducing bacteria as the nano-red and micro-red samples showed similar characteristics to the nano-ctrl and micro-ctrl samples respectively.

In summary, these magnetic-based approaches have helped to further develop an understanding of how Fe-metabolizing bacteria can utilize magnetite for growth and respiration. This has several important consequences in terms of using magnetic measurements to search for

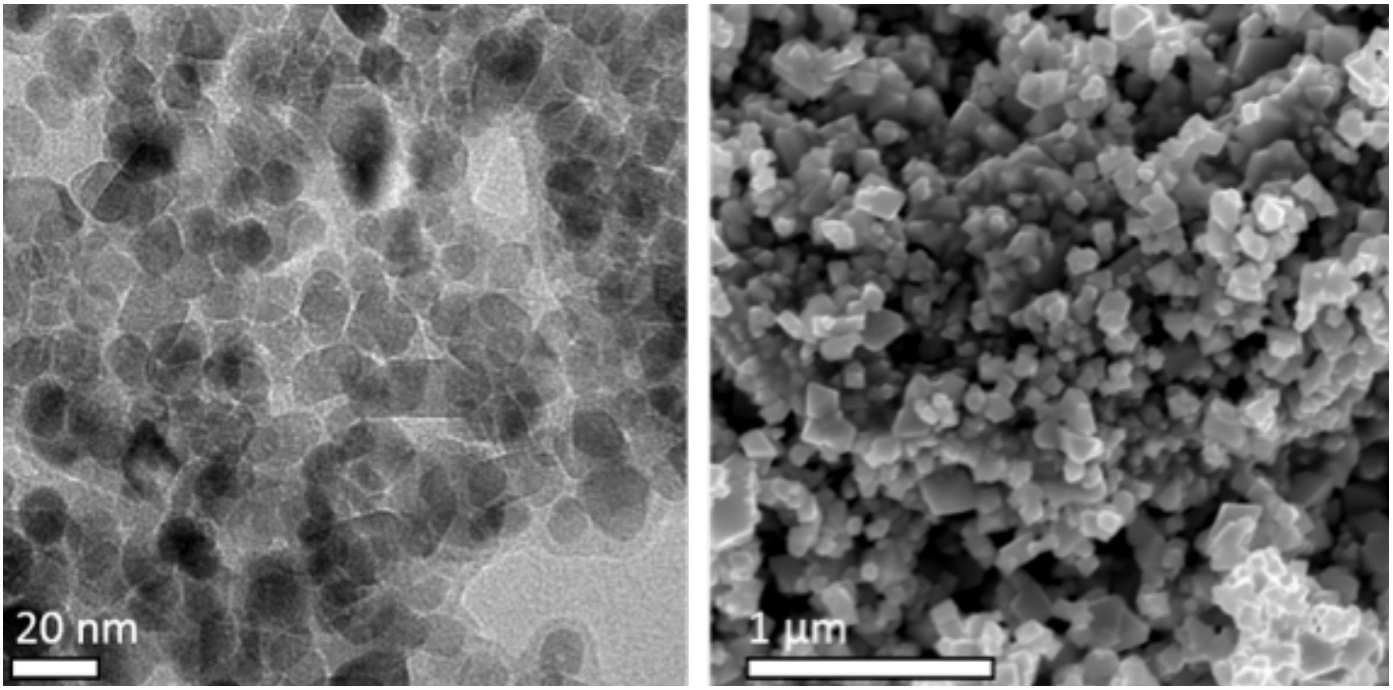


Figure 1. Electron micrographs of (a) nano-magnetite and (b) micro-magnetite.

signatures of current or past microbial activity in soils, sediments and potentially even the rock record. For example, increases or decreases in magnetization of environmental samples could suggest microbial Fe(III) reduction or Fe(II) oxidation respectively rather than simply being due to increases or decreases in the overall magnetic content of a sample. These type of measurements could also potentially be used as evidence of previous changes in redox conditions which favour either type of Fe-metabolizing bacteria.

Acknowledgements

We are grateful to the IRM for supporting the Visiting Research Fellowship of J. Byrne who was also supported with a Deutsche Forschungsgemeinschaft (DFG) Individual Research Grant (KA 1736/31-1). We would also like to acknowledge the M. Jackson and J. Feinberg for their help and assistance with data interpretation.

References

1. Melton, E. D., et al., 2014, The interplay of microbially mediated and abiotic reactions in the biogeochemical Fe cycle. Nat Rev Micro 12, 797-808.
2. Blakemore, R., 1975, Magnetotactic bacteria. Science 190, 377-379.
3. Lovley, D. R., et al., 1987, Anaerobic production of magnetite by a dissimilatory iron-reducing microorganism. Nature 330, 252-254.
4. Byrne, J. M., et al., 2015, Redox cycling of Fe(II) and Fe(III) in magnetite by Fe-metabolizing bacteria. Science 347, 1473-1476.
5. Jiao, Y., et al., 2005, Isolation and Characterization of a Genetically Tractable Photoautotrophic Fe(II)-Oxidizing Bacterium, Rhodopseudomonas palustris Strain TIE-1. Appl. Environ. Microbiol. 71, 4487-4496.
6. Pearce, C. I., et al., 2012, Synthesis and properties of titanomagnetite (Fe3−xTixO4) nanoparticles: A tunable solid-state Fe(II/III) redox system. Journal of Colloid and Interface Science 387, 24-38.
7. Schwertmann, U., et al., Iron oxides in the laboratory. John Wiley & Sons: 2000.
8. Özdemir, Ö., et al., 1993, The effect of oxidation on the Verwey transition in magnetite. Geophysical Research Letters 20, 1671-1674.

Registration for the upcoming Summer School in Rock Magnetism is now open!
Please register at:
http://learning.umn.edu/search/publicCourseSearchDetails.do?method=load&courseId=4235593

Please share your thougths on holding the 2017 Conference on Rock Magnetism in Australia!
https://docs.google.com/forms/d/1UCCrXfsRh0CmLSKFilI1gLAt-AjY8fcguuO2aethO6Q/viewform

The next **Visiting Fellow Application Deadline** is April 30th! Find details at https://irm.umn.edu

Current Articles

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 are taken from ISI Web of Knowledge, after which they are subjected to Procrustean culling 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 10,000 references, is available free of charge. Your contributions both to the list and to the Current Articles section of the IRM Quarterly are always welcome.

Archeomagnetism

Donadini, F., V. Serneels, L. Kapper, and A. El Kateb (2015), Directional changes of the geomagnetic field in West Africa: Insights from the metallurgical site of Korsimoro, Earth and Planetary Science Letters, 430, 349-355.

Ech-Chakrouni, S., J. Hu, and J.-P. Marchal (2015), Comparison of archaeomagnetic and 14C datings of ovens in a cremation necropolis of funerary urns in Belgium, Studia Geophysica Et Geodaetica, 59(4), 578-593.

Saigyo, H., et al. (2015), Magnetic properties of Hagi ware, Journal of the Ceramic Society of Japan, 123(1440), 649-655.

Biomagnetism

Shaw, J., A. Boyd, M. House, R. Woodward, F. Mathes, G. Cowin, M. Saunders, and B. Baer (2015), Magnetic particle-mediated magnetoreception, Journal of the Royal Society Interface, 12(110).

Wang, Y. Z., W. Lin, J. H. Li, T. W. Zhang, Y. Li, J. S. Tian, L. X. Gu, Y. V. Heyden, and Y. X. Pan (2015), Characterizing and optimizing magnetosome production of Magnetospirillum sp XM-1 isolated from Xi'an City Moat, China, Fems Microbiology Letters, 362(21).

Environmental magnetism and Climate

Anderson, P., P. Minyuk, A. Lozhkin, M. Cherepanova, V. Borkhodoev, and B. Finney (2015), A multiproxy record of Holocene environmental changes from the northern Kuril Islands (Russian Far East), Journal of Paleolimnology, 54(4), 379-393.

Bertini, A., F. Toti, M. Marino, and N. Ciaranfi (2015), Vegetation and climate across the Early-Middle Pleistocene transition at Montalbano Jonico, southern Italy, Quaternary International, 383, 74-88.

Bitinas, A., V. Katinas, P. L. Gibbard, S. Saarmann, A. Damusyte, E. Rudnickaite, V. Baltrunas, and J. Satkunas (2015), The problem of the lower boundary of the Pleistocene in Eastern Lithuania, Quaternary International, 386, 89-101.

Bower, D. M., D. R. Hummer, A. Steele, and A. Kyono (2015), The co-evolution of fe-oxides, ti-oxides, and other microbially induced mineral precipitates in sandy sediments: understanding the role of cyanobacteria in weathering and early diagenesis, Journal of Sedimentary Research, 85(10), 1213-1227.

Cao, L. W., E. Appel, S. Y. Hu, G. Yin, H. Lin, and W. Rosler (2015), Magnetic response to air pollution recorded by soil and dust-loaded leaves in a changing industrial environment, Atmospheric Environment, 119, 304-313.

Capraro, L., P. Macri, D. Scarponi, and D. Rio (2015), The lower to Middle Pleistocene Valle di Manche section (Calabria, Southern Italy): State of the art and current advances, Quaternary International, 383, 36-46.

Carson, T., C. M. Bachmann, and C. Salvaggio (2015), Soil signature simulation of complex mixtures and particle size distributions, Optical Engineering, 54(9).

de Carvalho, A., A. V. Inda, J. R. Fink, and N. Curi (2015), Iron oxides in soils of different lithological origins in Ferriferous Quadrilateral (Minas Gerais, Brazil), Applied Clay Science, 118, 1-7.

Dorfman, J. M., J. S. Stoner, M. S. Finkenbinder, M. B. Abbott, C. Xuan, and G. St-Onge (2015), A 37,000-year environmental magnetic record of aeolian dust deposition from Burial Lake, Arctic Alaska, Quaternary Science Reviews, 128, 81-97.

Hansel, C. M., C. J. Lentini, Y. Z. Tang, D. T. Johnston, S. D. Wankel, and P. M. Jardine (2015), Dominance of sulfur-fueled iron oxide reduction in low-sulfate freshwater sediments, Isme Journal, 9(11), 2400-2412.

Hauselmann, P., A. Mihevc, P. Pruner, I. Horacek, S. Cermak, H. Hercman, D. Sahy, M. Fiebig, N. Z. Hajna, and P. Bosak (2015), Snezna jama (Slovenia): Interdisciplinary dating of cave sediments and implication for landscape evolution, Geomorphology, 247, 10-24.

Hayashida, A., R. Nakano, A. Nagashima, K. Seto, K. Yamada, and H. Yonenobu (2015), Magnetic properties of surficial sediments in Lake Ogawara on the Pacific coast of northeastern Japan: spatial variability and correlation with brackish water stratification, Earth Planets and Space, 67.

Henrique-Pinto, R., V. A. Janasi, C. C. G. Tassinari, B. B. Carvalho, C. R. Cioffi, and N. M. Strikis (2015), Provenance and sedimentary environments of the Proterozoic Sao Roque Group, SE-Brazil: Contributions from petrography, geochemistry and Sm-Nd isotopic systematics of metasedimentary rocks, Journal of South American Earth Sciences, 63, 191-207.

Kader, M. A., A. Z. M. Moslehuddin, A. M. Kamal, and Y. Mori (2015), Mineralogical Composition of Some Selected Paddy Soils of Bangladesh, Journal of the Faculty of Agriculture Kyushu University, 60(2), 463-470.

Kazaoka, O., et al. (2015), Stratigraphy of the Kazusa Group, Boso Peninsula: An expanded and highly-resolved marine sedimentary record from the Lower and Middle Pleistocene of central Japan, Quaternary International, 383, 116-135.

Kissel, C., C. Laj, A. Rodriguez-Gonzalez, F. Perez-Torrado, J. C. Carracedo, and C. Wandres (2015), Holocene geomagnetic field intensity variations: Contribution from the low latitude Canary Islands site, Earth and Planetary Science Letters, 430, 178-190.

Kokinou, E. (2015), Magnetic properties of soils in a designated Natura area (GR4310010, Giouchtas Mountain), Interpretation-a Journal of Subsurface Characterization, 3(4), SAB33-SAB42.

Lascu, I., B. Wohlfarth, B. P. Onac, S. Bjorck, and B. Kromer (2015), A Late Glacial paleolake record from an up-dammed river valley in northern Transylvania, Romania, Quaternary International, 388, 87-96.

Liu, Q. S., C. S. Jin, P. X. Hu, Z. X. Jiang, K. P. Ge, and A. P. Roberts (2015), Magnetostratigraphy of Chinese loess-paleosol sequences, Earth-Science Reviews, 150, 139-167.

Ma, M. M., S. Y. Hu, L. W. Cao, E. Appel, and L. S. Wang (2015), Atmospheric pollution history at Linfen (China) uncovered by magnetic and chemical parameters of sediments from a water reservoir, Environmental Pollution, 204, 161-172.

Marino, M., et al. (2015), Paleoenvironmental and climatostratigraphic insights for Marine Isotope Stage 19 (Pleistocene) at the Montalbano Jonico succession, South Italy, Quaternary International, 383, 104-115.

Mouraviev, F. A., M. P. Arefiev, V. V. Silantiev, N. M. Khasanova, N. M. Nizamutdinov, and A. A. Trifonov (2015), Red paleosols in the key sections of the Middle and Upper Permian of the Kazan Volga region and their paleoclimatic significance, Paleontological Journal, 49(10), 1150-1159.

Negri, A., et al. (2015), A potential global boundary stratotype section and point (GSSP) for the Tarentian Stage, Upper Pleistocene, from the Taranto area (Italy): Results and future perspectives, Quaternary International, 383, 145-157.

Nordt, L., S. Atchley, and S. Dworkin (2015), Collapse of the Late Triassic megamonsoon in western equatorial Pangea, present-day American Southwest, Geological Society of America Bulletin, 127(11-12), 1798-1815.

Ojha, G., E. Appel, M. Wawer, and T. Magiera (2015), Monitoring-based discrimination of pathways of traffic-derived pollutants, Studia Geophysica Et Geodaetica, 59(4), 594-613.

Prajith, A., V. P. Rao, and P. M. Kessarkar (2015), Magnetic properties of sediments in cores from the Mandovi estuary, western India: Inferences on provenance and pollution, Marine Pollution Bulletin, 99(1-2), 338-345.

Pulley, S., and K. Rowntree (2016), The use of an ordinary colour scanner to fingerprint sediment sources in the South African Karoo, Journal of Environmental Management, 165, 253-262.

Pulley, S., K. Rowntree, and I. Foster (2015), Conservatism of mineral magnetic signatures in farm dam sediments in the South African Karoo: the potential effects of particle size and post-depositional diagenesis, Journal of Soils and Sediments, 15(12), 2387-2397.

Schrank, A. B. S., and L. F. De Ros (2015), Diagenetic processes in cretaceous sandstones from occidental Brazilian Equatorial Margin, Journal of South American Earth Sciences, 63, 1-19.

Skaberne, D., I. Turk, and J. Turk (2015), The Pleistocene clastic sediments in the Divje babe I cave, Slovenia. Geochemical characterisation and provenance (Part 2), Palaeogeography Palaeoclimatology Palaeoecology, 438, 379-394.

Su, Y. L., G. Q. Chu, Q. S. Liu, Z. X. Jiang, X. Gao, and T. Haberzettl (2015), A 1400 year environmental magnetic record from varved sediments of Lake Xiaolongwan (Northeast China) reflecting natural and anthropogenic soil erosion, Geochemistry Geophysics Geosystems, 16(9), 3053-3060.

van der Bilt, W. G. M., J. Bakke, K. Vasskog, W. J. D'Andrea, R. S. Bradley, and S. Olafsdottir (2015), Reconstruction of glacier variability from lake sediments reveals dynamic Holocene climate in Svalbard, Quaternary Science Reviews, 126, 201-218.

van der Waal, B., K. Rowntree, and S. Pulley (2015), Flood bench chronology and sediment source tracing in the upper Thina catchment, South Africa: the role of transformed landscape connectivity, Journal of Soils and Sediments, 15(12), 2398-2411.

Wang, H. P., J. Wang, Y. C. K. Chen-Wiegart, and D. V. Kent (2015), Quantified abundance of magnetofossils at the Paleocene-Eocene boundary from synchrotron-based transmission X-ray microscopy, Proceedings of the National Academy of Sciences of the United States of America, 112(41), 12598-12603.

Wang, L. S., S. Y. Hu, G. Yu, M. M. Ma, and M. N. Liao (2015), Paleoenvironmental reconstruction of the radial sand ridge field in the South Yellow Sea (east China) since 45 ka using the sediment magnetic properties and granulometry, Journal of Applied Geophysics, 122, 1-10.

Williams, J. J., K. K. McLauchlan, J. R. Mueller, E. M. Mellicant, A. E. Myrbo, and I. Lascu (2015), Ecosystem development following deglaciation: A new sedimentary record from Devils Lake, Wisconsin, USA, Quaternary Science Reviews, 125, 131-143.

Xu, C. Y., K. Y. Deng, J. Y. Li, and R. K. Xu (2015), Impact of environmental conditions on aggregation kinetics of hematite and goethite nanoparticles, Journal of Nanoparticle Research, 17(10).

Zan, J. B., X. M. Fang, M. D. Yan, Z. G. Zhang, and D. W. Zhang (2015), Regional variations in magnetic properties of surface sediments in the Qaidam Basin and their paleoenvironmental implications, Journal of Applied Geophysics, 122, 86-93.

Zhou, H. Y., X. S. Wang, and A. Q. Shan (2015), Discriminating soil-contamination sources using combination of magnetic parameters, Environmental Earth Sciences, 74(7), 5805-5811.

Extraterrestiram and Planetary Magnetism

Brachfeld, S., D. Shah, E. First, J. Hammer, and J. Bowles (2015), Influence of redox conditions on the intensity of Mars crustal magnetic anomalies, Meteoritics & Planetary Science, 50(10), 1703-1717.

Buz, J., B. P. Weiss, S. M. Tikoo, D. L. Shuster, J. Gattacceca, and T. L. Grove (2015), Magnetism of a very young lunar glass, Journal of Geophysical Research-Planets, 120(10), 1720-1735.

Erokhin, Y. V., V. A. Koroteev, V. V. Khiller, E. V. Burlakov, K. S. Ivanov, and D. A. Kleimenov (2015), The Kunashak meteorite: New data on mineralogy, Doklady Earth Sciences, 464(2), 1058-1061.

Plattner, A., and F. J. Simons (2015), High-resolution local magnetic field models for the Martian South Pole from Mars Global Surveyor data, Journal of Geophysical Research-Planets, 120(9), 1543-1566.

Rochette, P., J. Gattacceca, B. Devouard, F. Moustard, N.S. Bezaeva, C. Cournède, B. Scaillet (2015) Magnetic properties of tektites and other related impact glasses, Earth and Planetary Science Letters, 432, 381-390, doi:10.1016/j.epsl.2015.10.030

Sharp, T. G., Z. D. Xie, P. S. de Carli, and J. P. Hu (2015), A large shock vein in L chondrite Roosevelt County 106: Evidence for a long-duration shock pulse on the L chondrite parent body, Meteoritics & Planetary Science, 50(11), 1941-1953.

Fundamental Rock and Mineral Magnetism

Abrajevitch, A., E. Font, F. Florindo, and A. P. Roberts (2015), Asteroid impact vs. Deccan eruptions: The origin of low magnetic susceptibility beds below the Cretaceous-Paleogene boundary revisited, Earth and Planetary Science Letters, 430, 209-223.

Almeida, T. P., A. R. Muxworthy, T. Kasama, W. Williams, C. Damsgaard, C. Frandsen, T. J. Pennycook, and R. E. Dunin-Borkowski (2015), Effect of maghemization on the magnetic properties of nonstoichiometric pseudo-single-domain magnetite particles, Geochemistry Geophysics Geosystems, 16(9), 2969-2979.

Bezaeva, N.S., F. Demory, P. Rochette, R.A. Sadykov, J. Gattacceca, T. Gabriel, and Y. Quesnel (2015), The effect of hydrostatic pressure up to 1.61 GPa on the Morin transition of hematite-bearing rocks: Implications for planetary crustal magnetization, Geophysical Research Letters, 42 (23), 10,188-10,196, doi: 10.1002/2015GL066306.

Bruvera, I. J., P. M. Zelis, M. P. Calatayud, G. F. Goya, and F. H. Sanchez (2015), Determination of the blocking temperature of magnetic nanoparticles: The good, the bad, and the ugly, Journal of Applied Physics, 118(18).

Heslop, D. (2015), Numerical strategies for magnetic mineral unmixing, Earth-Science Reviews, 150, 256-284.

Kamnev, Y. K., N. O. Kozhevnikov, A. Y. Kazansky, and S. M. Stefanenko (2015), Impulse response of viscous remanent magnetization: laboratory measurements by a pulse induction system, Russian Geology and Geophysics, 56(11), 1642-1651.

Lascu, I., R. J. Harrison, Y. T. Li, J. R. Muraszko, J. E. T. Channell, A. M. Piotrowski, and D. A. Hodell (2015), Magnetic unmixing of first-order reversal curve diagrams using principal component analysis, Geochemistry Geophysics Geosystems, 16(9), 2900-2915.

Muxworthy, A. R. (2015), Investigation of magnetic particulate matter inside animals' lung tissue: preliminary results, Studia Geophysica Et Geodaetica, 59(4), 628-634.

Tikoo, S. M., J. Gattacceca, N. L. Swanson-Hysell, B. P. Weiss, C. Suavet, and C. Cournede (2015), Preservation and detectability of shock-induced magnetization, Journal of Geophysical Research-Planets, 120(9), 1461-1475.

Magnetic Fabrics and Anisotropy

Almqvist, B. S. G., A. R. Biedermann, I. Klonowska, and S. Misra (2015), Petrofabric development during experimental partial melting and recrystallization of a mica-schist analog, Geochemistry Geophysics Geosystems, 16(10), 3472-3483.

Biedermann, A.,R., T. Pettke, R.J. Angel, and A.M. Hirt (2016), Anisotropy of magnetic susceptibility in alkali feldspar and plagioclase, ?Geophysical Journal International,?doi: 10.1093/gji/ggw042

Dubey, A. K. (2014), Anisotropy of Magnetic Susceptibility, in Understanding an Orogenic Belt: Structural Evolution of the Himalaya, edited, pp. 17-34.

Gastal, M. D., F. J. F. Ferreira, J. U. da Cunha, C. Esmeris, E. Koester, M. I. B. Raposo, and M. D. M. Rossetti (2015), Lavras granite emplacement and gold mineralization during the development of the post-collisional volcanoplutonic center, west of the Sul-riograndense Shield: Geophysical and structural data, Brazilian Journal of Geology, 45(2), 217-241.

Ibraimo, D. L., and R. B. Larsen (2015), Geological setting, emplacement mechanism and igneous evolution of the Atchiza mafic-ultramafic layered suite in north-west Mozambique, Journal of African Earth Sciences, 111, 421-433.

Issachar, R., T. Levi, S. Marco, and R. Weinberger (2015), Anisotropy of magnetic susceptibility in diamagnetic limestones reveals deflection of the strain field near the Dead Sea Fault, northern Israel, Tectonophysics, 656, 175-189.

Pensa, A., G. Giordano, R. A. F. Cas, and M. Porreca (2015), Thermal state and implications for eruptive styles of the intra-Plinian and climactic ignimbrites of the 4.6 ka Fogo A eruption sequence, Sao Miguel, Azores, Bulletin of Volcanology, 77(11).

Tamaki, M., K. Suzuki, and T. Fujii (2015), Paleocurrent analysis of Pleistocene turbidite sediments in the forearc basin inferred from anisotropy of magnetic susceptibility and paleomagnetic data at the gas hydrate production test site in the eastern Nankai Trough, Marine and Petroleum Geology, 66, 404-417.

Mineral Physics

Agruzov, P. M., I. V. Pleshakov, E. E. Bibik, S. I. Stepanov, and A. V. Shamrai (2015), Transient magneto-optic effects in ferrofluid-filled microstructured fibers in pulsed magnetic field, Epl, 111(5).

Andersson, M. S., R. Mathieu, S. S. Lee, P. S. Normile, G. Singh, P. Nordblad, and J. A. De Toro (2015), Size-dependent surface effects in maghemite nanoparticles and its impact on interparticle interactions in dense assemblies, Nanotechnology, 26(47).

Bliem, R., et al. (2015), Adsorption and incorporation of transition metals at the magnetite Fe3O4(001) surface, Physical Review B, 92(7).

Firdous, T., D. Vick, M. Belov, F. F. Sani, A. McDermott, J. E. Losby, D. A. Bazylinski, T. Prozorov, D. K. Potter, and M. R. Freeman (2015), Nanomechanical torque magnetometry of an individual aggregate of similar to 350 nanoparticles, Canadian Journal of Physics, 93(11), 1252-1256.

Gandhi, A. C., P. M. Reddy, T. S. Chan, Y. P. Hod, and S. Y. Wu (2015), Memory effect in weakly-interacting Fe3O4 nanoparticles, Rsc Advances, 5(103), 84782-84789.

Ibragimov, S. Z. (2015), Titanomagnetites with Magnetite-Ulvospinel breakdown structures. Coercive properties: modeling and experiment, Izvestiya-Physics of the Solid Earth, 51(6), 885-896.

Mirza, I. M., K. Ali, A. K. Sarfraz, A. Ali, and A. ul Haq (2015), A study of dielectric, optical and magnetic characteristics of maghemite nanocrystallites, Materials Chemistry and Physics, 164, 183-187.

Pedrosa, J., B. F. O. Costa, A. Portugal, and L. Duraes (2015), Controlled phase formation of nanocrystalline iron oxides/hydroxides in solution - An insight on the phase transformation mechanisms, Materials Chemistry and Physics, 163, 88-98.

Zhang, Y. F., C. Wang, Y. Wu, W. L. Liu, and Z. M. Jin (2015), Experimental constraints on formation of hematite in olivine at high pressures and temperatures, Physics and Chemistry of Minerals, 42(9), 761-771.

Paleointensity and records of the Geomagnetic Field

Biggin, A. J., E. J. Piispa, L. J. Pesonen, R. Holme, G. A. Paterson, T. Veikkolainen, and L. Tauxe (2015), Palaeomagnetic field intensity variations suggest Mesoproterozoic inner-core nucleation, Nature, 526(7572), 245.

Buffett, B. (2015), Dipole fluctuations and the duration of geomagnetic polarity transitions, Geophysical Research Letters, 42(18), 7444-7451.

Kilifarska, N., R. Nedialkov, and T. Velichkova (2015), Geomagnetic field variations due to active tectonic processes during periods of lower solar and magnetospheric activity, Comptes Rendus De L Academie Bulgare Des Sciences, 68(9), 1145-1152.

Mandea, M., C. Narteau, I. Panet, and J. L. Le Mouel (2015), Gravimetric and magnetic anomalies produced by dissolution-crystallization at the core-mantle boundary, Journal of Geophysical Research-Solid Earth, 120(9), 5983-6000.

Pavlov, V., F. Fluteau, R. Veselovskiy, A. Fetisova, A. Latyshev, L. T. Elkins-Tanton, A. V. Sobolev, and N. A. Krivolutskaya (2015), Volcanic pulses in the Siberian Traps as inferred from Permo-Triassic geomagnetic secular variations, Volcanism and Global Environmental Change, 63-78.

Puetz, S. J., and G. Borchardt (2015), Quasi-periodic fractal patterns in geomagnetic reversals, geological activity, and astronomical events, Chaos Solitons & Fractals, 81, 246-270.

Tema, E., P. Camps, E. Ferrara, and T. J. Poidras (2015), Directional results and absolute archaeointensity determination by the classical Thellier and the multi-specimen DSC protocols for two kilns excavated at Osterietta, Italy, Studia Geophysica Et Geodaetica, 59(4), 554-577.

Turner, G. M., J. D. Howarth, G. de Gelder, and S. J. Fitzsimons (2015), A new high-resolution record of Holocene geomagnetic secular variation from New Zealand, Earth and Planetary Science Letters, 430, 296-307.

Wang, H. P., D. V. Kent, and P. Rochette (2015), Weaker axially dipolar time-averaged paleomagnetic field based on multidomain-corrected paleointensities from Galapagos lavas, Proceedings of the National Academy of Sciences of the United States of America, 112(49), 15036-15041.

Weiss, B. P., et al. (2015), Pervasive remagnetization of detrital zircon host rocks in the Jack Hills, Western Australia and implications for records of the early geodynamo, Earth and Planetary Science Letters, 430, 115-128.

Paleomagnetism

Branellec, M., J. P. Callot, C. Aubourg, B. Niviere, and J. C. Ringenbach (2015), Matrix deformation in a basement-involved fold-and-thrust-belt: A case study in the central Andes, Malargue (Argentina), Tectonophysics, 658, 186-

205.

Burton-Johnson, A., and T. R. Riley (2015), Autochthonous v. accreted terrane development of continental margins: a revised in situ tectonic history of the Antarctic Peninsula, Journal of the Geological Society, 172(6), 822-835.

Clauzon, G., et al. (2015), The Roussillon Basin (S. France): A case-study to distinguish local and regional events between 6 and 3 Ma, Marine and Petroleum Geology, 66, 18-40.

Courtillot, V., F. Fluteau, and J. Besse (2015), Evidence for volcanism triggering extinctions: a short history of IPGP contributions with emphasis on paleomagnetism, Volcanism and Global Environmental Change, 228-243.

Duarte, A. V., H. Bohnel, and V. Yutsis (2015), Paleomagnetism of the Miocene Jantetelco Granodiorites and Tepexco Volcanic Group and inferences for crustal block rotations in central Mexico - Reevaluation, Tectonophysics, 658, 117-127.

Font, E., S. Fernandes, M. Neres, C. Carvallo, L. Martins, J. Madeira, and N. Youbi (2015), Paleomagnetism of the Central Atlantic Magmatic Province in the Algarve basin, Portugal: First insights, Tectonophysics, 663, 364-377.

Halls, H. C. (2015), Paleomagnetic evidence for similar to 4000 km of crustal shortening across the 1 Ga Grenville orogen of North America, Geology, 43(12), 1051-1054.

Holdgate, G. R., M. W. Wallace, and S. Forbes (2015), Pre-Cenozoic geology of the Latrobe Valley Area-onshore Gippsland Basin, SE Australia, Australian Journal of Earth Sciences, 62(6), 695-716.

Ichihashi, R. J., H. Zaman, Y. Wada, Y. Sugamori, Y. Kajikawa, H. S. Ahn, K. Uno, P. S. Zimin, V. G. Sakhno, and Y. Otofuji (2015), Paleomagnetic evidence for post-Early Cretaceous tectonic rotation of the Sikhote-Alin Superterrane, Far East Russia, Journal of Asian Earth Sciences, 111, 88-99.

Jing, X. Q., Z. Y. Yang, Y. B. Tong, and Z. R. Han (2015), A revised paleomagnetic pole from the mid-Neoproterozoic Liantuo Formation in the Yangtze block and its paleogeographic implications, Precambrian Research, 268, 194-211.

Karetnikov, A. S. (2015), Age of Chad ultramafite Massif (Khabarovsk Region) estimated from paleomagnetic evidence, Russian Journal of Pacific Geology, 9(6), 467-482.

Kudymov, A. V., I. P. Voinova, A. I. Tikhomirova, and A. N. Didenko (2015), Geology, Geochemistry, and Paleomagnetism of Rocks of the Utitsa Formation, North Sikhote Alin, Russian Journal of Pacific Geology, 9(5), 323-337.

Lagabrielle, Y., J. Bourgois, J. Dyment, and B. Pelletier (2015), Lower plate deformation at the Chile Triple Junction from the paleomagnetic record (45 degrees 30 ' S-46 degrees S), Tectonics, 34(8), 1646-1660.

Lahtinen, R., M. Sayab, and F. Karell (2015), Near-orthogonal deformation successions in the poly-deformed Paleoproterozoic Martimo belt: Implications for the tectonic evolution of Northern Fennoscandia, Precambrian Research, 270, 22-38.

Mazaud, A., J. E. T. Channell, and J. S. Stoner (2015), The paleomagnetic record at IODP Site U1307 back to 2.2 Ma (Eirik Drift, off south Greenland), Earth and Planetary Science Letters, 429, 82-89.

Michelena, M. D., and R. Kilian (2015), Magnetic signatures of the orogenic crust of the Patagonian Andes with implication for planetary exploration, Physics of the Earth and Planetary Interiors, 248, 35-54.

Mints, M. V., I. B. Philippova, P. S. Babayants, Y. I. Blokh, and A. A. Trusov (2015), Middle Paleoproterozoic Bryansk-Kursk-Voronezh intracontinental collisional orogen, East European Craton: Early Precambrian History and 3d Models of Deep Crustal Structure, 510, 156-170.

Mints, M. V., I. B. Philippova, P. S. Babayants, Y. I. Blokh, and A. A. Trusov (2015), Neoarchean Volgo-Uralia continent, East European Craton: Early Precambrian History and 3d Models of Deep Crustal Structure, 510, 131-153.

Mitchell, N. C., H. L. Simmons, and C. H. Lear (2015), Modern and ancient hiatuses in the pelagic caps of Pacific guyots and seamounts and internal tides, Geosphere, 11(5), 1590-1606.

Musgrave, R. J. (2015), Oroclines in the Tasmanides, Journal of Structural Geology, 80, 72-98.

Nemkin, S. R., E. Fitz-Diaz, B. van der Pluijm, and R. van der Voo (2015), Dating synfolding remagnetization: Approach and field application (central Sierra Madre Oriental, Mexico), Geosphere, 11(5), 1617-1628.

Otofuji, Y., H. Zaman, G. Shogaki, H. Seki, V. F. Polin, D. Miura, H. S. Ahn, Y. Ivanov, P. Minyuk, and P. Zimin (2015), Paleomagnetism of the Late Cretaceous ignimbrite from the Okhotsk-Chukotka Volcanic Belt, Kolyma-Omolon Composite Terrane: Tectonic implications, Journal of Geodynamics, 91, 1-12.

Ozden, S., E. Gundogdu, and T. Bekler (2015), Interactions between Eurasian/African and Arabian plates: Eskisehir Fault, NW Turkey, Journal of African Earth Sciences, 111, 349-362.

Palcu, D. V., M. Tulbure, M. Bartol, T. J. Kouwenhoven, and W. Krijgsman (2015), The Badenian-Sarmatian Extinction Event in the Carpathian foredeep basin of Romania: Paleogeographic changes in the Paratethys domain, Global and Planetary Change, 133, 346-358.

Pilipenko, O. V., and V. M. Trubikhin (2015), Paleomagnetic studies of upper Neopleistocene rocks from the El'tigen cross section, Kerch Peninsula, Geomagnetism and Aeronomy, 55(6), 821-829.

Plan, L., A. Schober, D. Scholz, C. Spotl, P. Pruner, and P. Bosak (2015), Speleogenesis of the Hermannshohle cave system (Austria): Constraints from Th-230/U-dating and palaeomagnetic analysis, International Journal of Speleology, 44(3), 315-326.

Sancar, T., C. Zabci, H. S. Akyuz, G. Sunal, and I. M. Villa (2015), Distributed transpressive continental deformation: The Varto Fault Zone, eastern Turkey, Tectonophysics, 661, 99-111.

Symons, D. T. A., F. Tornos, K. Kawasaki, F. Velasco, and I. Rosales (2015), Genetic constraints from paleomagnetic dating for the Aliva zinc-lead deposit, Picos de Europa Unit, northern Spain, Mineralium Deposita, 50(8), 953-966.

Tong, Y. B., Z. Y. Yang, H. Wang, L. Gao, C. Z. An, X. D. Zhang, and Y. C. Xu (2015), The Cenozoic rotational extrusion of the Chuan Dian Fragment: New paleomagnetic results from Paleogene red-beds on the southeastern edge of the Tibetan Plateau, Tectonophysics, 658, 46-60.

Uehara, D., R. A. F. Cas, C. Folkes, S. Takarada, H. Oda, and M. Porreca (2015), Using thermal remanent magnetisation (TRM) to distinguish block and ash flow and debris flow deposits, and to estimate their emplacement temperature: 1991-1995 lava dome eruption at Mt. Unzen Volcano, Japan, Journal of Volcanology and Geothermal Research, 303, 92-111.

Uno, K., D. Yamashita, T. Onoue, and D. Uehara (2015), Paleomagnetism of Triassic bedded chert from Japan for determining the age of an impact ejecta layer deposited on pen-equatorial latitudes of the paleo-Pacific Ocean: A preliminary analysis, Physics of the Earth and Planetary Interiors, 249, 59-67.

Yonkee, W. A., and A. B. Weil (2015), Tectonic evolution of the Sevier and Laramide belts within the North American Cordillera orogenic system, Earth-Science Reviews, 150, 531-593.

Zhao, J., B. C. Huang, Y. G. Yan, and D. H. Zhang (2015), Late Triassic paleomagnetic result from the Baoshan Terrane, West Yunnan of China: Implication for orientation of the East Paleotethys suture zone and timing of the Sibumasu-Indochina collision, Journal of Asian Earth Sciences, 111, 350-364.

Prospecting and Surveying

Curto, J. B., T. Diniz, R. M. Vidotti, R. J. Blakely, and R. A. Fuck (2015), Optimizing depth estimates from magnetic anomalies using spatial analysis tools, Computers & Geosciences, 84, 1-9.

de Souza, J. P. G., M. H. Leao-Santos, C. D. Freitas, F. M. V. Matos, and D. L. O. de Carvalho (2015), Applicability of standard Euler deconvolution, modeling, and amplitude magnetic data inversion in Greenfield programs: The Leite target case study, Carajas Mineral Province, Brazil, Interpretation-a Journal of Subsurface Characterization, 3(3), T131-T143.

Finn, C. A., P. A. Bedrosian, J. C. Cole, T. D. Khoza, and S. J. Webb (2015), Mapping the 3D extent of the Northern Lobe of the Bushveld layered mafic intrusion from geophysical data, Precambrian Research, 268, 279-294.

Kamm, J., I. A. Lundin, M. Bastani, M. Sadeghi, and L. B. Pedersen (2015), Joint inversion of gravity, magnetic, and petrophysical data - A case study from a gabbro intrusion in Boden, Sweden, Geophysics, 80(5), B131-B152.

Mansouri, E., F. Feizi, and A. A. K. Ramezanali (2015), Identification of magnetic anomalies based on ground magnetic data analysis using multifractal modelling: a case study in Qoja-Kandi, East Azerbaijan Province, Iran, Nonlinear Processes in Geophysics, 22(5), 579-587.

Martinez, C., and Y. G. Li (2015), Lithologic characterization using airborne gravity gradient and aeromagnetic data for mineral exploration: A case study in the Quadrilatero Ferrifero, Brazil, Interpretation-a Journal of Subsurface Characterization, 3(2), SL1-SL13.

Ogunmola, J. K., E. N. Gajere, E. A. Ayolabi, S. B. Olobaniyi, D. N. Jeb, and I. J. Agene (2015), Structural study of Wamba and Environs, north-central Nigeria using aeromagnetic data and NigeriaSat-X image, Journal of African Earth Sciences, 111, 307-321.

Olaniyan, O., R. S. Smith, and B. Lafrance (2015), Regional 3D geophysical investigation of the Sudbury Structure, Interpretation-a Journal of Subsurface Characterization, 3(2), SL63-SL81.

Persson, L., and M. Erlstrom (2015), Geophysical imaging of Silurian carbonates by use of ground and airborne electromagnetic and radiometric methods on the island of Gotland, Sweden, Interpretation-a Journal of Subsurface Characterization, 3(3), SY1-SY11.

Petrovic, D., V. Cvetkov, I. Vasiljevic, and V. Cvetkovic (2015), A new geophysical model of the Serbian part of the East Vardar ophiolite: Implications for its geodynamic evolution, Journal of Geodynamics, 90, 1-13.

Ruotoistenmaki, T. (2015), Ore potential trends in Finland: Indications from geochemical, geophysical and lineament data, Journal of Geochemical Exploration, 159, 278-289.

Solon, F. F., S. L. Fontes, and M. A. Meju (2015), Magnetotelluric imaging integrated with seismic, gravity, magnetic and well-log data for basement and carbonate reservoir mapping in the Sao Francisco Basin, Brazil, Petroleum Geoscience, 21(4), 285-299.

Tschirhart, V., J. A. Percival, and C. W. Jefferson (2015), Geophysical models of the Montresor metasedimentary belt and its environs, central Nunavut, Canada, Canadian Journal of Earth Sciences, 52(10), 833-845.

van den Hove, J. C., L. Ailleres, P. G. Betts, and R. A. F. Cas (2015), Subsurface structure of a large basaltic maar volcano examined using geologically constrained potential field modelling, Lake Purrumbete Maar, Newer Volcanics Province, southeastern Australia, Journal of Volcanology and Geothermal Research, 304, 142-159.

Vuji?, E., and M. Brki? (2015), Data reduction of Croatian geomagnetic repeat stations surveys by using the spherical elementary current systems method Studia Geophysica Et Geodaetica, 59(4), 635-646.

Xuan, C., and H. Oda (2015), UDECON: deconvolution optimization software for restoring high-resolution records from pass-through paleomagnetic measurements, Earth Planets and Space, 67.

Spectroscopy, Microscopy and Instrumentation

Bathgate, E. J., H. E. Maynard-Casely, G. Caprarelli, L. D. Xiao, B. Stuart, K. T. Smith, and R. Pogson (2015), Raman, FTIR and XRD study of Icelandic tephra minerals: implications for Mars, Journal of Raman Spectroscopy, 46(10), 846-855.

Joos, A., C. Rumenapp, F. E. Wagner, and B. Gleich (2016), Characterisation of iron oxide nanoparticles by Mossbauer spectroscopy at ambient temperature, Journal of Magnetism and Magnetic Materials, 399, 123-129.

Oshtrakh, M. I., M. V. Ushakov, V. Sepelak, V. A. Semionkin, and P. C. Morais (2016), Study of Iron oxide nanoparticles using Mossbauer spectroscopy with a high velocity resolution, Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy, 152, 666-679.

Quintana, P., V. Tiesler, M. Conde, R. Trejo-Tzab, C. Bolio, J. J. Alvarado-Gil, and D. Aguilar (2015), Spectrochemical Characterization of Red Pigments Used in Classic Period Maya Funerary Practices, Archaeometry, 57(6), 1045-1059.

Rousaki, A., C. Bellelli, M. C. Calatayud, V. Aldazabal, G. Custo, L. Moens, P. Vandenabeele, and C. Vazquez (2015), Micro-Raman analysis of pigments from hunter-gatherer archaeological sites of North Patagonia (Argentina), Journal of Raman Spectroscopy, 46(10), 1016-1024.

Sato, T., Y. Sawaki, H. Asanuma, W. Fujisaki, Y. Okada, S. Maruyama, Y. Isozaki, K. Shozugawa, M. Matsuo, and B. F. Windley (2015), Redox condition of the late Neoproterozoic pelagic deep ocean: Fe-57 Mossbauer analyses of pelagic mudstones in the Ediacaran accretionary complex, Wales, UK, Tectonophysics, 662, 472-480.

Stratigraphy

Chang, H., L. Y. Li, X. K. Qiang, C. N. Garzione, A. Pullen, and Z. S. An (2015), Magnetostratigraphy of Cenozoic deposits in the western Qaidam Basin and its implication for the surface uplift of the northeastern margin of the Tibetan Plateau, Earth and Planetary Science Letters, 430, 271-283.

Corral, J. C., E. L. Pueyo, A. Berreteaga, A. Rodriguez-Pinto, E. Sanchez, and X. Pereda-Suberbiola (2016), Magnetostratigraphy and lithostratigraphy of the Lano vertebrate-site: Implications in the uppermost Cretaceous chronostratigraphy of the Basque-Cantabrian Region, Cretaceous Research, 57, 473-489.

Gnibidenko, Z. N., N. K. Lebedeva, and A. V. Levicheva (2015), Magnetostratigraphy of the Campanian-Maastrichtian Bakchar Basin (southeastern West Siberia), Russian Geology and Geophysics, 56(11), 1652-1661.

Kodama, K. P., and L. A. Hinnov (2015), Rock Magnetic Cyclostratigraphy, 1-165 pp.

Rybkina, A. I., A. K. Kern, and Y. V. Rostovtseva (2015), New evidence of the age of the lower Maeotian substage of the Eastern Paratethys based on astronomical cycles, Sedimentary Geology, 330, 122-131.

Spagnuolo, C. M., S. M. Georgieff, and A. E. Rapalini (2015), Magnetostratigraphy of the Miocene Las Arcas Formation, Santa Maria Valley, northwestern Argentina, Journal of South American Earth Sciences, 63, 101-113.

Tang, Z. H., X. X. Dong, X. Wang, and Z. L. Ding (2015), Oligocene-Miocene magnetostratigraphy and magnetic anisotropy of the Baxbulak section from the Pamir-Tian Shan convergence zone, Geochemistry Geophysics Geosystems, 16(10), 3575-3592.

Tohver, E., L. Lanci, A. Wilson, J. Hansma, and S. Flint (2015), Magnetostratigraphic constraints on the age of the lower Beaufort Group, western Karoo basin, South Africa, and a critical analysis of existing U-Pb geochronological data, Geochemistry Geophysics Geosystems, 16(10), 3649-3665.

Wu, Y., T. P. Ouyang, S. F. Qiu, Z. G. Rao, and Z. Y. Zhu (2015), A sedimentary paleomagnetic record of the upper Jaramillo transition from the Lantian Basin in China, Earth Planets and Space, 67, 1-12.

Zhang, Z. L., Z. Y. Shen, J. M. Sun, X. Wang, Z. H. Tian, X. Q. Pan, and L. Q. Shi (2015), Magnetostratigraphy of the Kelasu section in the Baicheng depression, Southern Tian Shan, northwestern China, Journal of Asian Earth Sciences, 111, 492-504.

Synthesis

Hao, H. Y., D. D. Sun, Y. Y. Xu, P. Liu, G. Y. Zhang, Y. Q. Sun, and D. Z. Gao (2016), Hematite nanoplates: Controllable synthesis, gas sensing, photocatalytic and magnetic properties, Journal of Colloid and Interface Science, 462, 315-324.

Kozakova, Z., I. Kuritka, N. E. Kazantseva, V. Babayan, M. Pastorek, M. Machovsky, P. Bazant, and P. Saha (2015), The formation mechanism of iron oxide nanoparticles within the microwave-assisted solvothermal synthesis and its correlation with the structural and magnetic properties, Dalton Transactions, 44(48), 21099-21108.

Long, N. V., Y. Yang, T. Teranishi, C. M. Thi, Y. Q. Cao, and M. Nogami (2015), Synthesis and magnetism of hierarchical iron oxide particles, Materials & Design, 86, 797-808.

Melnyczuk, J. M., and S. Palchoudhury (2014), Synthesis and Characterization of Iron Oxide Nanoparticles, in Handbook of Research on Nanoscience, Nanotechnology, and Advanced Materials, edited, pp. 89-107.

cont'd. from pg. 1...

Subir (left) and Bruce (right) ca 1989.

The idea hatched four years earlier at Asilomar became reality in 1990, when the Institute for Rock Magnetism (IRM) was established as a shared resource for the GPE and broader research communities, providing instruments to study the magnetism of rocks, sediments, biological materials and synthetic analogs. This is accomplished with a suite of instruments that measure magnetization from 2-1000 K, in DC fields up to 5 T and AC fields up to 10 kHz, and a low-temperature probe (20-300 K) for vector remanence measurements. These magnetometric capabilities are complemented by Mössbauer spectrometers (4.2-300K, 0-6.5T) and a high-temperature magnetic force microscope (Tmax~ 673 K). A unique aspect of the IRM was that it allowed for routine measurements below 300 K and provided new ways of "seeing" magnetism. This has enabled researchers to study magnetic behavior through magnetic ordering temperatures, crystal phase transitions, and blocking temperatures, providing new insights into mineral magnetism as well as developing new methods to interpret the magnetism of natural materials.

IRM Oversight and Planning

From the beginning the IRM has operated under the joint guidance of its local leadership (Fig 1) and an external Review and Advisory Committee (RAC), an international panel of leading researchers in paleomagnetism, rock magnetism and related fields (Table 1). To date, 38 of our esteemed colleagues have contributed their time, efforts and strategic vision to the RAC, helping to keep the IRM's instrumental capabilities aligned with the needs of the research community, and evaluating all Visiting Fellowship applications. Members currently serve 4-year terms, during which they typically review about 100 Visiting Fellow proposals, and participate in two full-day meetings at the IRM as well as additional shorter sessions held in conjunction with Santa Fe and AGU conferences. The active participation of these distinguished colleagues has been an essential ingredient in maintaining the IRM as an effective resource for the GP research community.

Visiting Fellows

The main access to the IRM by the research community is through the Visiting Fellowship (VF) program. To date, 388 Fellowships have been awarded to students, post-docs and senior researchers representing 157 institutions in the US and 30 other countries. Nearly half of these Fellowships have been awarded to researchers from universities with strong programs in paleomagnetism and rock magnetism (Toronto-Erindale 26; Michigan 14; UC-Santa Cruz 13; LMU München 12; Wisconsin-Madison 9; IPGP 8; Lehigh 8; ODP 8; NGU Trondheim 7; Michigan Tech 7; SIU Carbondale 7; Massachusetts–Amherst 7; New Mexico 7; Rochester 7; ETH Zürich 6; Imperial College London 6; UC-Berkeley 6; UNAM 6; Florida 6; Oklahoma 6; Yale University 6). Nearly 50% of Visiting Fellows have been students.

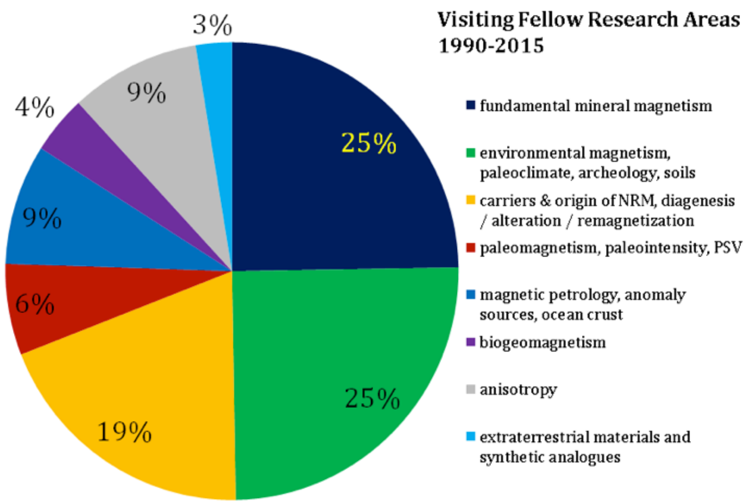


Fig 2. General breakdown of research areas investigated by Visiting Fellows at the IRM over the past 25 years.

Visiting Fellow research projects have covered a remarkably broad range of scientific fields, problems, geologic settings and materials (Fig. 2). Pseudotachylites, horse-spleen ferritin, the Chelyabinsk meteorite, Armenian obsidian, Chinese loess, Pittsburgh tree leaves, Brazilian termite nests, Middle Eastern archeological copper slags, Martian meteorites, the Vredefort impact structure, Antarctic shelf sediments, Pangean redbeds, cultured and wild magnetotactic bacteria, oil sands, Paleocene-Eocene boundary sediments, blood diamonds, "snowball Earth" sediments and cap carbonates… well, you get the idea. The variety of scientific problems addressed is just as great as the variety of materials, including the origins and evolution of the magnetic fields of the terrestrial planets; tectonic plate motions and mantle dynamics; changing environmental conditions over the Earth's surface through time; and the microscale physical and chemical processes by which these large-scale phenomena leave their imprint in the natural remanence of geomaterials and in their magnetic mineral characteristics. Fundamental studies of mineral magnetism (magnetic ordering and intrinsic properties, intraparticle spin structures, etc) and rock magnetism (magnetic behavior of interacting and noninteracting populations with distributions of particle size and of easy-axis orientation) represent the largest single research area for Visiting Fellows, followed closely by environmental studies and characterization of paleomagnetic remanence carriers (Fig 2). The total output of visiting and in-house researchers amounts to about 800 peer-reviewed publications to date.

IRM Conferences, Workshops, and Summer School

The biennial Santa Fe meetings feature a limited number of presentations and extended informal discussions on the current state and future trends in magnetic research. The series began at the Santa Fe campus of St John's College in 1992, and has returned there nine times subsequently; the meeting has twice been transplanted to other venues (Erice, Sicily in 2002 and Cargèse, Corsica in 2008) to enable greater participation by our European colleagues and to benefit from their particular areas of strength in research. As described in the previous issue of the Quarterly, we plan to shift the future meeting schedule to odd-numbered years, and current plans are to hold the next meeting in Australia in 2017.

St John's College in Santa Fe, site of ten conferences on rock magnetism and its applications.

The biennial Summer Schools in Rock Magnetism offer an intense 10-day instruction in rock magnetism theory and hands-on lab training to graduate students and post-doctoral researchers in the geosciences. Three Summer Schools have been held to date (2011, 2013 and 2015) and 64 students from 44 different academic institutions in 18 countries have completed the course. The fourth is scheduled for June 1-10, 2016.

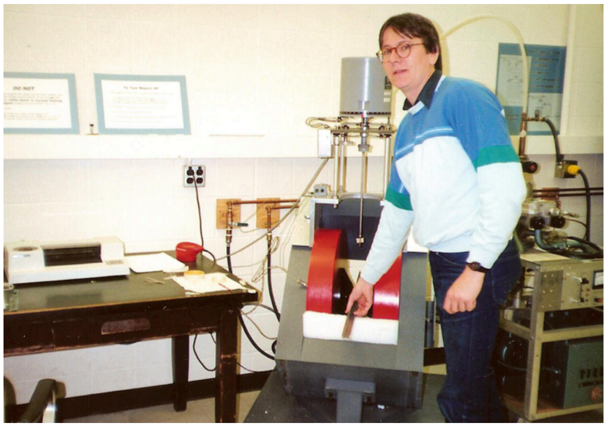
IRM Future Developments

As described in the previous issue of the Quarterly, a big change is in store for our facility: after 25 years of operation in the Shepherd Labs building, we will be relocating to a completely renovated space in the new home of the Earth Science Department and parts of the School of Physics and Astronomy at the University of Minnesota. We anticipate that this relocation will significantly improve facility operations through increased efficiency of spatial arrangements, as well as by integrating IRM more closely with the other geoscience research groups on campus, providing greater access by facility users to the intellectual and laboratory resources of the entire department. In addition, our lab will be on the second floor and our neighbors will include theoretical physicists and the Department of Astrophysics.

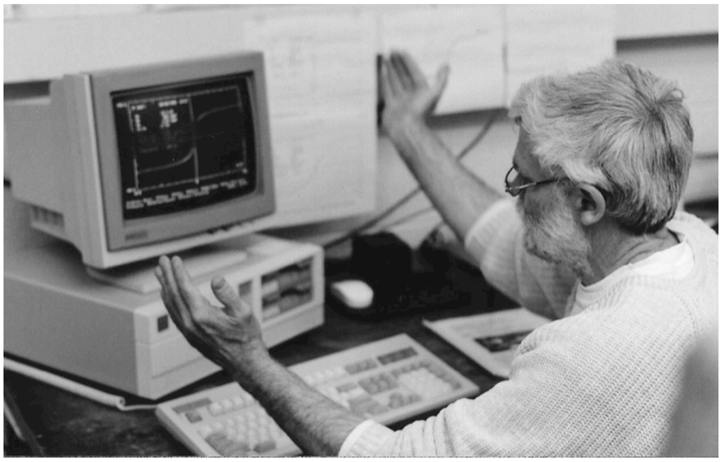
All Past and Present IRM RAC members:

Stefanie Brachfeld (Montclair State U.) 2012-present
Laurie Brown (UMass Amherst) 2015-present
Bob Butler (U. of Arizona) 1990-1996, chair 1994-1996
Jim Channell (U. of Florida) 1998-2004
Brad Clement (IODP) 2013-present, chair 2015-present
Rob Coe (UC-Santa Cruz) 2001-2006, chair 2002-2006
Cathy Constable (Scripps) 2009-present, chair 2010-2013
Dan Dahlberg (U. of Minnesota, Physics) 1992-2000
David Dunlop (U. of Toronto) 1990-1996, chair 1990-1994
Mike Fuller (U.C. Santa Barbara) 1990-1994
Jeff Gee (Scripps) 2005-2010
John Geissman (U. of New Mexico) 2006-2009
Sue Halgedahl (U. of Utah) 1994-2000
Richard Harrison (Univ of Cambridge) 2015-present
Friedrich Heller (ETH-Zurich) 1996-2002
Dennis Kent (Lamont-Doherty) 1994-1998
John King (U. of Rhode Island) 1994-2000, chair 1996-2000
Ken Kodama (Lehigh U.) 1996-2002, chair 2000-2002
France Lagroix (Inst. de Physique du Globe de Paris) 2015-present
Cor Langereis, (U. of Utrecht) 2002-2006
Chris Leighton (U. of Minnesota, Chem. Eng. & Mat. Sci.) 2008-2014
Chad McCabe (Louisiana State U.) 1992-1994
Suzanne McEnroe (Geol. Survey of Norway) 2010-2014, chair 2013-2014
Ron Merrill (U. of Washington) 2001-2004
Özden Özdemir (U. of Toronto) 2005-2010
Yongxin Pan (Chinese Academy of Sciences) 2011-2014
R. Lee Penn (U. of Minnesota, Chemistry) 2014-present
Rich Reynolds (USGS) 1990-1994; 2010-2012
Andrew Roberts (Southampton; Australian National U.) 2009-2013
Pierre Rochette (CEREGE) 2002-2008
Roy Roshko (U. of Manitoba, Physics) 2001-2008
Mike Sharrock (3M Corp) 1990-1992
Aleksey Smirnov (Michigan Tech.) 2013-present
John Tarduno (U. of Rochester) 2005-2010, chair 2006-2010
Lisa Tauxe (Scripps) 1998-2004
Rob Van der Voo (U. of Michigan) 1990-1992
Ben Weiss (MIT) 2010-present
Toshi Yamazaki (Geol. Survey of Japan) 2007-2011

An IRM Photo Album

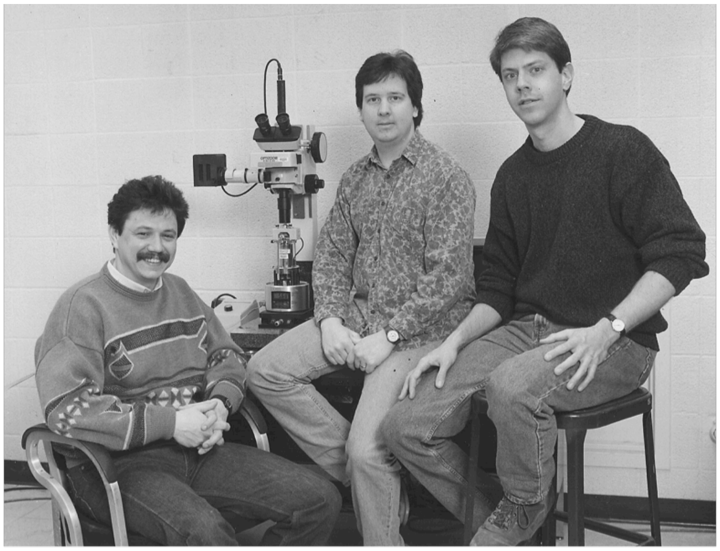


Pre-IRM post-doc Horst-Ulrich Worm operating VSM#1, ca 1989.



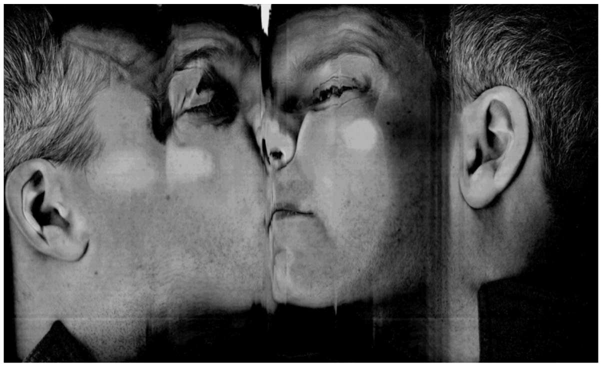
Jim Marvin measuring a rather sizeable hysteresis loop on the AGM, ca 1992.

IRM people in front of Shepherd Labs, 1993: (left to right) Subir Banerjee, Bruce Moskowitz, Stefanie Brachfeld, Chris Hunt, Peat Sølheid, Weiwei Sun, Sherry Foss, Gin Kletetschka, Li Xu, Jim Marvin, Scott Rubin.



IRM post-docs, 1994: Taras Pokhil, Bernie Housen, Rick Oches, with the first MFM.

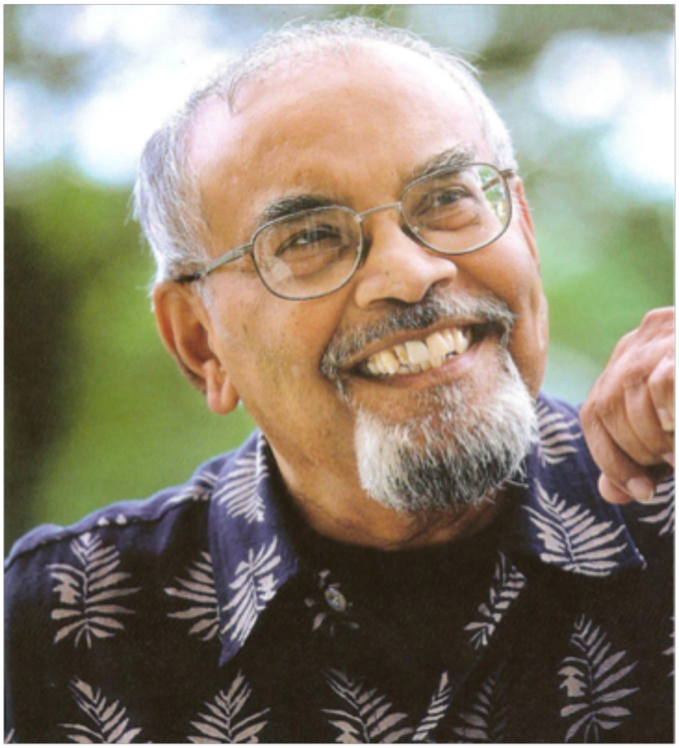
IRM staff/faculty 1994 (left to right) Chris Hunt, Jim Marvin, Bruce Moskowitz, Subir Banerjee.



Panoramic self-portrait (gouache on digital scanner) by Christoph Eberhard Geiss (IRM Visiting Fellow 1993; IRM PhD student 1994-1999; IRM post-doc 1999-2001; IRM Visiting Fellow 2004, 2006, 2008).

David Williamson manning the AGM ca 1997.

A few of the 1996-1997 Visiting Fellows (clockwise from upper left): Andrei Kosterov (Univ. Montpellier), Adry Van Velzen (Oxford Univ.), Harald Peterman (Univ. Bremen), Luca Lanci (ETH-Zurich). Photos by Bernie Housen.



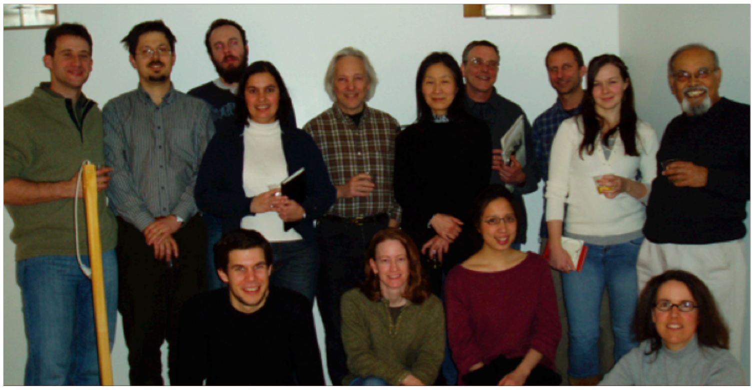
Subir 2001.

Visiting Fellow Alex Zwing (LMU Munich) 2001.

"Santa Erice" conference participants, 2002.

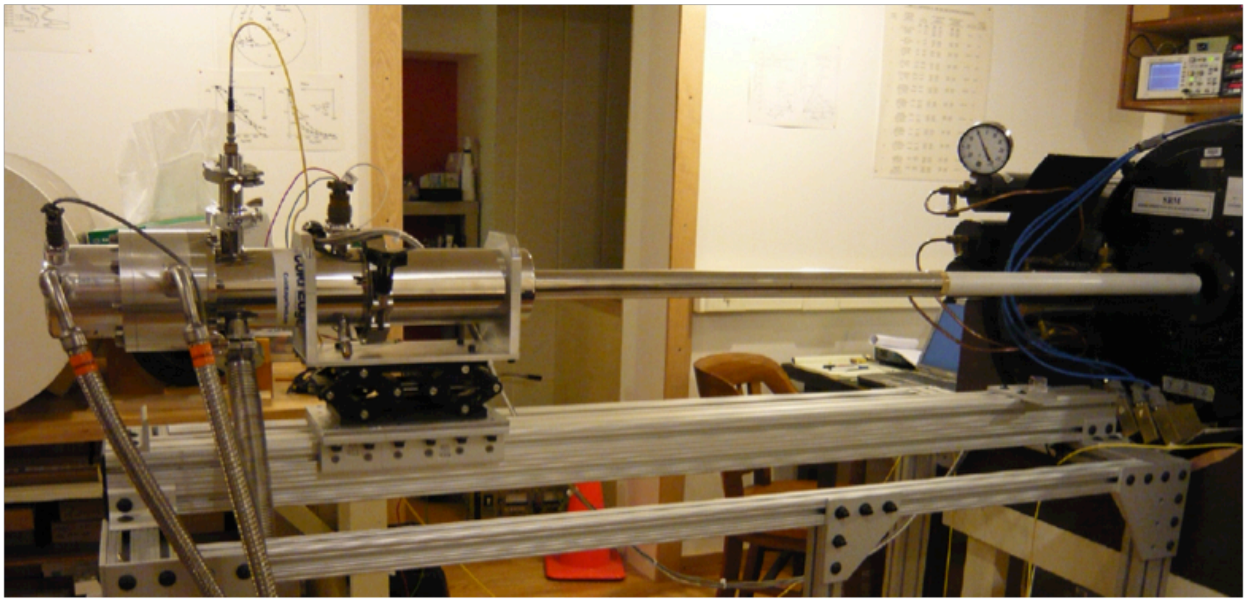
IRM resident researchers ca 2008. front: Jasmine Erbs, Thelma Berquó, Yifan Hu, Josh Feinberg, Mike Jackson. back: Amy Chen, Ioan ("Nono") Lascu, Peat Sølheid, Subir Banerjee, R. Lee Penn, Jess Till, Julie Bowles.

"Santa Cargèse" conference, 2008:
(left) outdoor poster session;
(right) the unforgettable boat trip to the Scandola Nature Preserve.



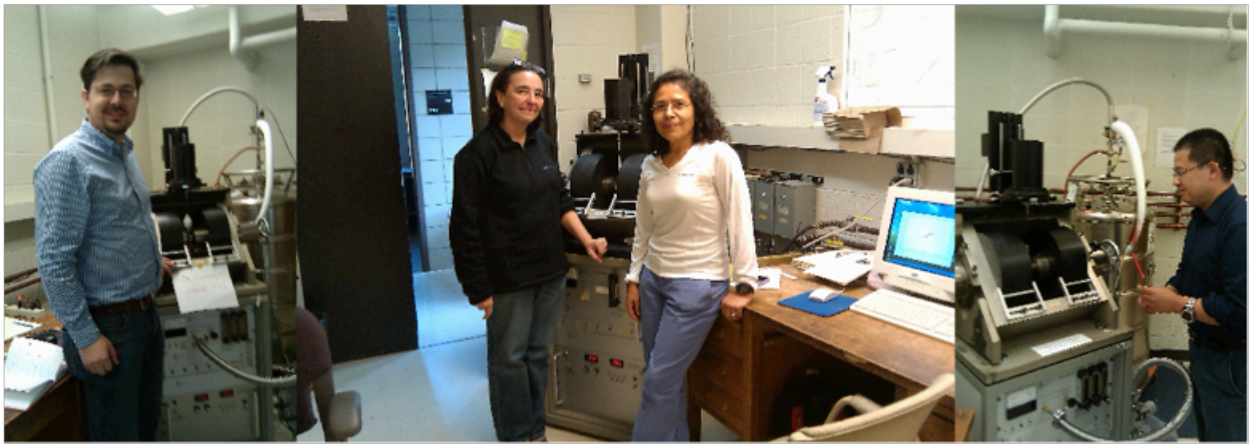
The newly completed shielded room 2008. front: Unidentified, Julie Bowles, Amy Chen, R. Lee Penn; (back): Josh Feinberg, Ramon Egli, Ioan ("Nono") Lascu, Thelma Berquó, Bruce Moskowitz, Emi Ito, Mike Jackson, Peat Sølheid, Jess Till, Subir Banerjee.

At Subir's retirement fest 2008 (left to right) Yifan Hu, Brian Carter(-Stiglitz), Rachel (Carter-)Stiglitz, Taras Pokhil, Julie Bowles, Peat Sølheid, Max Brown, Jim Thill.



Low-temperature sample probe and 2G magnetometer, 2009.

8th Santa Fe Conference, 2010, field trip stop at outcrop of Bandelier Tuff.

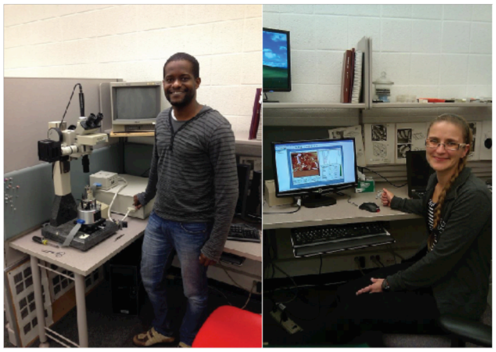


The PMC VSMs, 2011: Ramon Egli (left) ; Ana Maria Soler and Beatriz Ortega (center); Huapei Wang (right).

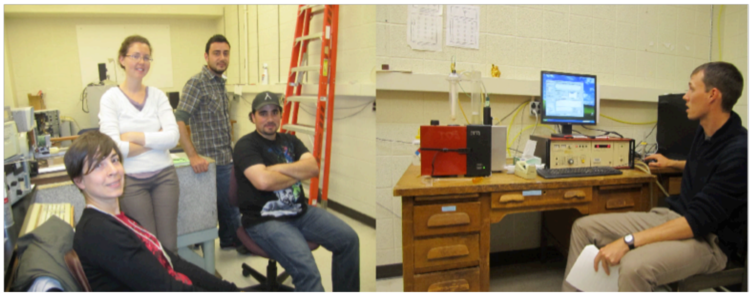
Prof Ed Nater, UM Dept of Soils, Water & Climate, leading students of the 1st Summer School in sampling a soil profile for magnetic analysis (2011).

Students of the 1st Summer School in a glacial pothole on a field trip to Interstate (MN-WI) Park (2011).

Field trip of the Second Summer School, 2013, Taylors Falls, MN: (left to right) Dario Bilardello, Sara Satolli, Peat Sølheid.



MFM1 (Digital Instruments) operated by Edivaldo dos Santos (left, 2013) and Johanna Salminen (right, 2011).



At the 2nd Summer School, students Sara Satolli, Irina Seliverstov, Antonio Turtù and Samer Hariri were mesmerized by Nick Swanson-Hysell and the Kappabridge (2013).

Sketching pigs whilst blindfold at the closing ceremony of the Second Summer School, 2013.

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@umn.edu
www.irm.umn.edu

The 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 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/Founding Director; **Bruce Moskowitz**, Professor/Director; **Joshua Feinberg**, Assistant Professor/Associate Director; **Mike Jackson, Peat Sølheid** and **Dario Bilardello**, Staff Scientists.

Funding for the *IRM* is provided by the **National Science Foundation**, the **W. M. Keck 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:

Dario Bilardello
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: dario@umn.edu
www.irm.umn.edu

UNIVERSITY OF MINNESOTA