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Inside...

Report on the 2016 Summer School on Rock Magnetism

Group photo at the Interstate State Park, view of Minnesota from the 1.1 Billion year old basalts.

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The fourth Summer School on Rock Magnetism has just come to an end, and just like all other Summer Schools before it was a lot of fun to host: At the IRM we are very grateful to all the participants who contributed in making it so successful, despite having advanced the program by a full year!

The format of the summer school consisted of ten days of morning classes and afternoon lab sessions. The majority of the morning lectures was delivered by Bruce Moskowitz, with specific classes taught by Josh Feinberg, Mike Jackson and Dario Bilardello. Additionally, we were lucky to receive a visit and a guest lecture on Paleointensity by Lennart de Groot, from the Fort Hoofddijk laboratory in Utrecht. Classes covered all main aspects of magnetism, from the underlying physics of electron spin, orbital configurations and (super) exchange to the applications of paleomagnetism and environmental magnetism, and provided a very solid foundation for the applied component of the course: for many students this was the first course entirely dedicated to rock magnetism, which boosted the students' understanding of magnetic techniques in geoscience research.

Eighteen participants travelled to Minnesota from as far as Indonesia for our short course, representing eleven nationalities and traveling from seven countries. Each participant brought much enthusiasm and different expertise to the IRM, which contributed to making the course varied and comprehensive. The Summer Schools on Rock Magnetism are specifically tailored to the interests of the participating students: as part as the application we ask students for their research interests, allowing us to design appropriate laboratory projects that encompass the gamut of research backgrounds. The 2016 students' research interests varied broadly and encompassed very diverse research topics, including nuclear and mining waste, corals, soils and sediments, biomagnetism, diagenesis, stratigraphy, magnetic fabrics and serpentinites. Based on these topics, four projects on Environmental Magnetism (led by Peter Solheid), Archeomagnetism and Paleointensity (led by Josh Feinberg), Sedimentary Magnetism (led by Dario Bilardello), and Volcanic Remanence Carriers (led by Mike Jackson), were specifically put-together, giving the summer school participants a means of putting into practice the material covered in the morning classes, with a focus on their specific interests.

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Visiting Fellow Report

Cohenite - a stable magnetic carrier in iron meteorites.

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Iron meteorites offer the best constraints on thermal and magnetization history of early solar systems because most are remnants of the oldest bodies, which accreted and melted in <1.5 Myr, forming silicate mantles and iron-nickel metallic cores [1]. Among the important magnetic minerals of iron meteorites kamacite (α-Fe cell with less than 6% of Ni) and taenite (γ-Fe-cell with more than 20 % of Ni), ferrimagnetic cohenite ($Fe_{2.95}Ni_{0.05}C$) shows an exceptional magnetic behavior. According to Sugiura and Strangway [2] cohenite carries the most stable component of natural remanent magnetization in the Abbee meteorite and, therefore, may be able to memorize signals from a strong magnetic field in the early solar system. The cohenite (an analogue to cementite Fe_3C in steels) has an orthorhombic symmetry and a Curie temperature (T_C) of 210 °C [2]. Interestingly, cohenite exhibits very prominent magnetic domain patterns already visible under an optical microscope using a ferrofluid [3]. This behavior makes cohenite predestined to study the in-situ thermomagnetic behavior. As the Asylum Research MFP-3D magnetic force microscope (MFM) at the IRM has a heating stage at ambient conditions, it was possible to observe the magnetic domain structure in cohenite of the Morasko iron meteorite [4] by heating above T_C and back to room temperature .The MFM cantilevers are made from silicon or silicon nitride coated with CoCr. The MFP-3D collects high-pixel-density images (up to 5k x 5k) with high-speed data capture up to 5 MHz.

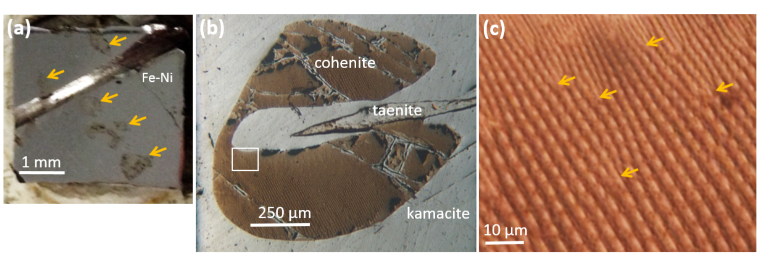

Figure 1. Cohenite revealed by Bitter colloid in Morasko meteorite. (a) Cohenite grains (arrows) in a Fe-Ni matrix. (b) A flexuous globular cohenite grain. The white box marks the interfacial area studied by MFM. (c) Magnified view showing elongated dark rows, bright island-shaped stripes and branched, dislocation-shaped rows (arrows).

When the polished piece of the meteorite is covered with a ferrofluid colloid, numerous mm-sized cohenite grains can be recognized (s. arrows in Fig. 1a). Frequently, globular flexuous cohenite grains are in contact with taenite and kamacite (Fig. 1b). At a higher magnification, well-developed Bitter pattern are visible in cohenite grains (Fig. 1c). We present here the MFM results from an interfacial area between cohenite and kamacite (see white box in Fig. 1b).

Evolution of magnetic domains at the cohenite-kamacite interface during heating and cooling through the TC of cohenite is illustrated in Fig. 2. At 23°C (see the first image at the top, left of Fig. 2), the magnetic MFM structure appears to be similar to those revealed by Bitter pattern (Fig. 1c) and also contains straight and branched rows and fine stripes. A closer look however reveals that MFM images contain more details. E.g. around each bright stripe there are plenty of submicronical closure mini-domains. Heating up to 200°C (follow the red arrow in Fig. 2) provokes a progressive smearing of the cohenite magnetic structure. Simultaneously, martensitic zig-zag shaped plates are developed in kamacite. At the Curie point, magnetic features disappear in cohenite while in kamacite the zig-zag shaped plates are still present. Furthermore, at the TC of cohenite a strong magnetic contrast is observed with a tiny rim area running along the interface (red arrow in Fig. 2). During cooling (follow the blue arrow in Fig. 2) a nearly reversible recovery of the magnetic microstructures occurs.

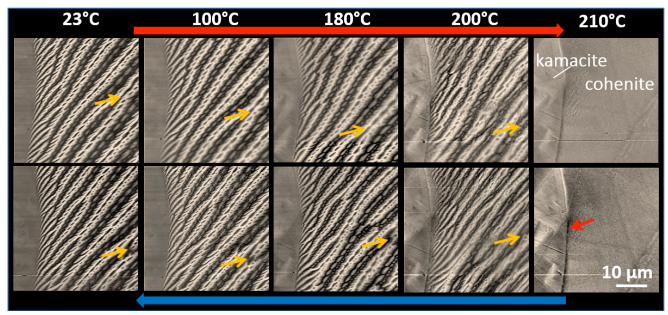

Figure 2. MFM imaging of a cohenite-kamacite interface during heating and cooling runs around Curie point. Yellow arrows marks the position of the reference branched shaped feature. Red arrow marks strong magnetic contrast within the tiny rim area. Please refer to online version for color. The shown scale bar is the same for all images.

Our data visualize the high thermomagnetic stability of cohenite when it is annealed to 210°C under ambient conditions. We also observed no smeared magnetic structures in cohenite, no zig-zag shaped plates in kamacite or tiny rims at the cohenite-kamacite interface in the initial state (see images at 23°C in Fig. 2). We interpret this observation as evidence that after the impact with earth, the meteorite was not heated above 210°C. Therefore, the observed magnetic domain structures probably were recorded in stellar atmospheres. More studies are needed to understand the complex MFM structures of cohenite as well as their stability after eating to 700 °C.

Acknowledgements

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References

[1] Yang J., Goldstein J. I., and Scott E. R. D. 2007. Iron meteorite evidence for early formation and catastrophic disruption of protoplanets. Nature 446: 888–891.

[2] Sugiura N., and Strangway D.-W. 1981. The magnetic properties of the Abee meteorite: evidence for a strong magnetic field in the early solar system. Proceedings of Lunar and Planetary Science 12B: 1243–1256.

[3] Luecke W., Kontny A., and Kramar U. 2014. Geochemical zoning and magnetic mineralogy at Fe,Ni-alloy-troilite interfaces of three iron meteorites from Morasko, Coahuila II, and Mundrabilla. Meteoritics and Planetary Science 49: 750–771.

[4] Szurgot M., Rozniakowski K., Wojtatowicz T. W., and Polański K. 2008. Investigation of microstructure and thermophysical properties of Morasko iron meteorites. Crystal Research and Technology 43: 921–930.

Low-temperature magnetic properties of synthetic titanomagnetites and the mysterious effects of super-glue.

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Titanomagnetite(TM)-bearing igneous rocks are widely used in paleomagnetic studies, which makes the TM solid solution, $Fe_{3-x}Ti_xO_4$ ($0 \leq x \leq 1$) one of the most important series of natural magnetic minerals. However, many aspects of TM mineral magnetism remain poorly understood to date. It was shown that the Curie temperatures (T_C) of natural Mg^{2+}- and Al^{3+}-bearing TM samples strongly depend on thermal history (Bowles et al. 2013). For some samples those changes in T_C were accompanied by drastic changes in the low-temperature properties. As a non-destructive characterisation method for TMs, low-temperature measurements have been used in varies studies. However, the effects of substitutional elements (such as Mg and Al) on the low-temperature magnetic properties have not been studied in detail up to date. Therefore we have measured low temperature magnetic properties of synthetic TM samples with varying Ti-contents, varying cation substitution of Mg^{2+} and Al^{3+} and different thermal histories to improve our understanding of the low temperature behavior of natural samples.

Several studies have been conducted on the low temperature behavior of TMs (Radhakrishnamurty and Likhite, 1993; Torres et al. 1997; Walz et al. 1997; Moskowitz et al. 1998; Carter-Stiglitz et al. 2006; Church et al. 2011). They all noted systematic changes in the magnetic properties with Ti-content. At temperatures of 50-80 K in low-Ti (x<=40), an isotropic point (Ti) has been observed which correlates with a shift of a peak in susceptibility. This shift depends on the frequency and differs in magnitude for different Ti-compositions (Radhakrishnamurty and Likhite, 1993). The same phenomenon was observed by Carter-Stiglitz et al. (2006) and ascribed to thermally activated electron hopping within the B site. Over the same temperature interval, Torres et al. (1997) and Walz et al. (1997) describe a magnetic relaxation, varying with amount of Ti. Moskowitz et al. (1998) find that, in addition to the frequency-dependence, the low temperature susceptibility depends progressively more on temperature the higher the amount of Ti. This leads them to suggest that for TMs with Ti-contents of x < 0.4 the low-temperature behavior depends on both electron and lattice relaxation as well as the impact of isotropic points on the magnetic properties.

For the experiments conducted at IRM we synthesized TMs in the compositional range of TM25-TM60 with varying amounts of Mg^{2+} and/or Al^{3+} substitution of up to 0.12 per formula unit. All of the synthetic samples, with exception of a pure TM60 and a TM50 with 0.6 Mg^{2+} and Al^{3+} substitution per formula unit, show significant changes in T_C when annealed at temperatures between 325-400°C for 10-103h. At IRM we used the Magnetic Property Measurement System (MPMS) to measure low temperature susceptibility as function of temperature and frequency, as well as low temperature remanence of our sample. A common artefact when measuring RT remanence on warming in the MPMS are sudden jumps in the data (see Fig.1), which are thought to arise from shifting of individual grains of the sample (all our samples were in powder form).

In order to immobilize the individual grains and in hope of avoiding these artefacts, we mixed in some

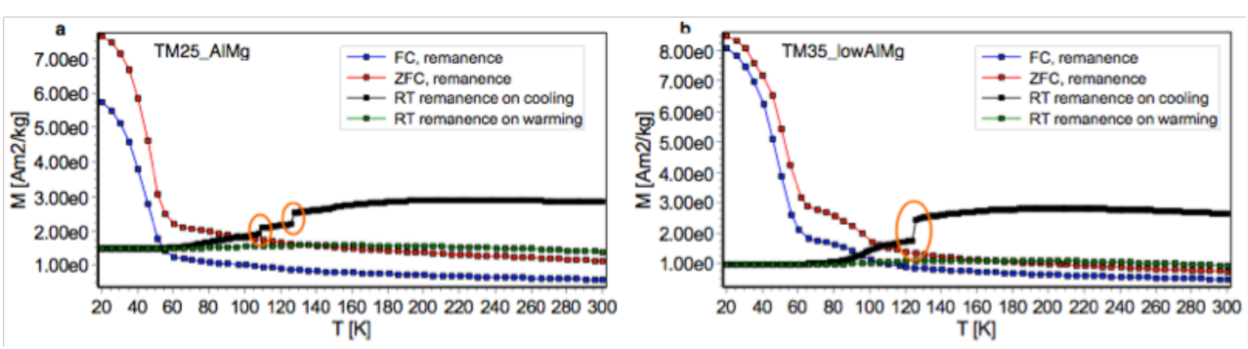


Figure 1. Examples for sudden jumps in RT remanence curves: A TM25 sample with 0.8 Mg2+ and Al3+ substitution per formula unit (a) shows two small jumps, a TM35 sample with 0.6 Mg2+ and Al3+ substitution (b) shows one big jump.

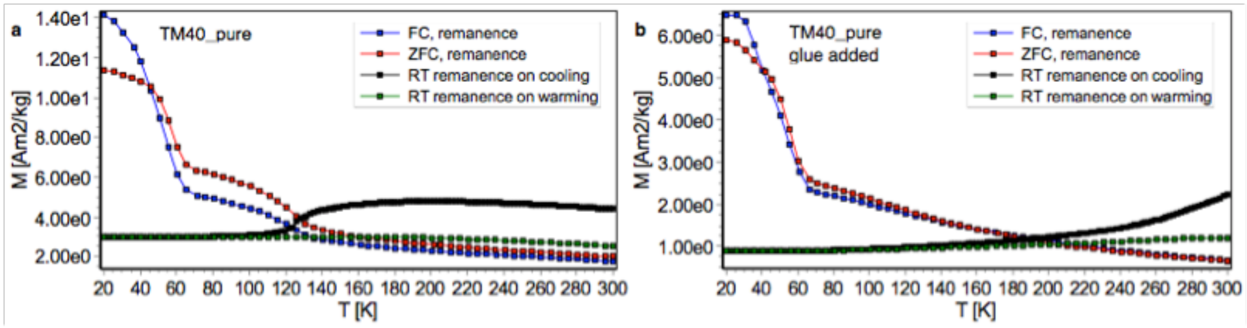


Figure 2. FC, ZFC, and RT remanence curves of a TM40 sample before (a) and after (b) the addition of super-glue.

drops of superglue with the sample powder when preparing the MPMS specimen. However, we weren't aware of the full scope of ramifications caused by the addition of superglue:

Figure 2 shows a comparison of the FC, ZFC and RT remanence curves of a TM40 sample before (Fig. 2 a) and after (Fig. 2b) adding super-glue. The shapes of both, the FC and ZFC remanence change distinctly: where there are two changes in slope (at around 70K and 130K) before adding the glue only the one at 70K remains after the glue was added. Additionally the shape of the RT remanence curve on cooling changes from a kind of concave shape to a convex one.

Also very drastic are the changes in low temperature susceptibility (Fig. 3): The overall susceptibility seems to have dropped significantly after adding the glue. The frequency dependence of susceptibility between ~40-120K is preserved but the sharp change in slope at 130K is completely absent in the specimen after the addition of the glue. Additionally the susceptibility becomes frequency dependent again around 270K.

The distinct frequency-independent kink in susceptibility at 130k (before adding the glue) matches with the second slope change in the FC and ZFC remanence curves and is described by Church et al. (2011) as the upper remanence decay temperature associated with Ti. The absence of both, the kink in susceptibility and the upper change in slope in the remanence curves suggests that adding super-glue to the sample somehow suppresses the isotropic point, i.e. inhibits electron hopping within the octahedral (B) site. However, the exact mechanism underlying this phenomenon remains unknown. We would therefore advise future users to refrain from adding super-glue to their specimens.

References

Bowles, J.A., Jackson, M.J., Berquó, T.S., Solheid, P.A. and Gee, J.S. (2013), Nature Communications, 4, 1916.

Carter-Stiglitz, B., Moskowitz, B., Solheid, P., Berquó, T.S., Jackson, M. and Kosterov, A. (2006), J. Geophys. Res., 111, B12S05.

Church, N., Feinberg J.M. and Harrison, R. (2011), Geochem. Geophys. Geosyst., 12, Q07Z27.

Jackson, M. and Bowles, J.A. (2014), Geochem. Geophys. Geosyst., 15, doi:10.1002/2014GC005527.

Moskowitz, B.M., Jackson, M.J. and Kissel, C. (1998), Earth Planet. Sci. Lett., 157, 141-149.

Radhakrishnamurty, C. and Likhite, S.D. (1993), Phys. Earth Planet. Inter., 76, 131-136.

Torres, L., Walz, F., Bendimya, K., de Francisco, C. and Kronmüller, H. (1997), Physica Status Solidi A, 161, 289.

Walz, F., Torres, L., Bendimya, K., de Francisco, C. and Kronmüller, H. (1997), Physica Status Solidi A, 164, 805-20.

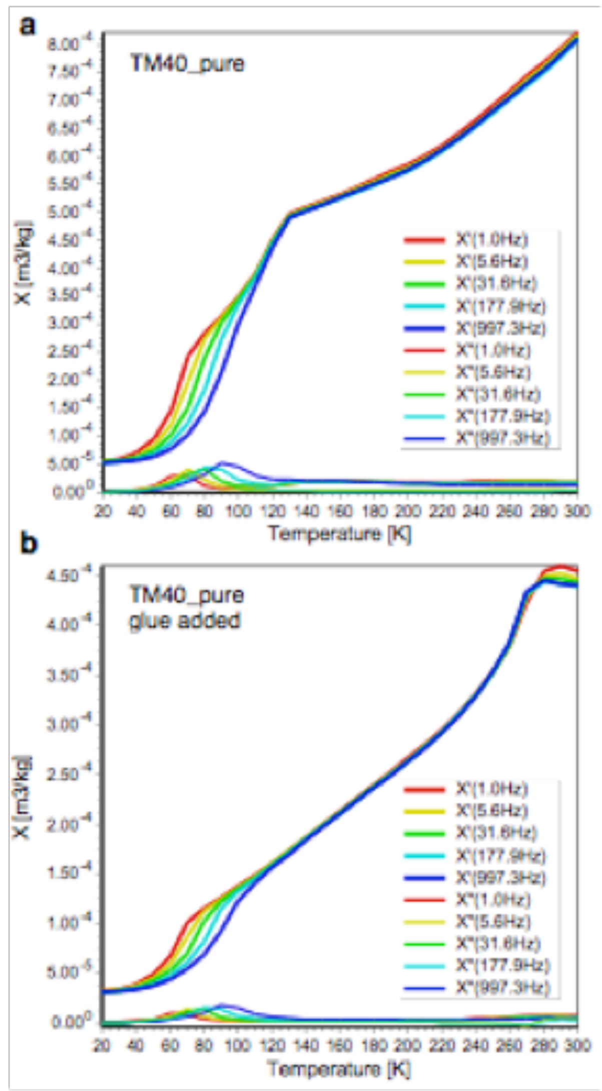


Figure 3. Susceptibility as function of temperatuer and frequency for a TM40 sample before (a) and after (b) the addition of super-glue.

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.

Biomagnetism

Amor, M., V. Busigny, P. Louvat, A. Gelabert, P. Cartigny, M. Durand-Dubief, G. Ona-Nguema, E. Alphandery, I. Chebbi, and F. Guyot (2016), Mass-dependent and -independent signature of Fe isotopes in magnetotactic bacteria, Science, 352(6286), 705-708.

Chen, Y. R., et al. (2016), Novel species and expanded distribution of ellipsoidal multicellular magnetotactic prokaryotes, Environmental Microbiology Reports, 8(2), 218-226.

Dong, Y., J. H. Li, W. C. Zhang, W. Y. Zhang, Y. Zhao, T. Xiao, L. F. Wu, and H. M. Pan (2016), The detection of magnetotactic bacteria in deep sea sediments from the east Pacific Manganese Nodule Province, Environmental Microbiology Reports, 8(2), 239-249.

Etique, M., F. P. A. Jorand, and C. Ruby (2016), Magnetite as a precursor for green rust through the hydrogenotrophic activity of the iron-reducing bacteria Shewanella putrefaciens, Geobiology, 14(3), 237-254.

Huizar-Felix, A. M., D. Munoz, I. Orue, C. Magen, A. Ibarra, J. M. Barandiaran, A. Muela, and M. L. Fdez-Gubieda (2016), Assemblies of magnetite nanoparticles extracted from magnetotactic bacteria: A magnetic study, Applied Physics Letters, 108(6).

Meyra, A. G., G. J. Zarragoicoechea, and V. A. Kuz (2016), A magnetosome chain viewed as a bio-elastic magnet, Physical Chemistry Chemical Physics, 18(18), 12768-12773.

Picard, A., M. Obst, G. Schmid, F. Zeitvogel, and A. Kappler (2016), Limited influence of Si on the preservation of Fe mineral-encrusted microbial cells during experimental diagenesis, Geobiology, 14(3), 276-292.

Environmental magnetism and Climate

Aguilar, I., C. Beck, F. Audemard, A. L. Develle, M. Boussafir, C. Campos, and C. Crouzet (2016), Last millennium sedimentation in the Gulf of Cariaco (NE Venezuela): Evidence for morphological changes of gulf entrance and possible relations with large earthquakes, Comptes Rendus Geoscience, 348(1), 70-79.

Akter, M., M. A. Kader, S. Pierreux, M. T. Gebremikael, P. Boeckx, and S. Sleutel (2016), Control of Fe and Mn availability on nitrogen mineralization in subtropical paddy soils, Geoderma, 269, 69-78.

Amirkhanov, H. A., D. V. Ozherelyev, M. V. Sablin, and A. K. Agadzhanyan (2016), Faunal remains from the Oldowan site of Muhkai II in the North Caucasus: Potential for dating and palaeolandscape reconstruction, Quaternary International, 395, 233-241.

Andersen, D. W., N. C. Shostak, K. M. Locke, N. P. Ramstetter, and E. P. Metzger (2016), Composition of sediment records late Quaternary paleogeographic evolution of Santa Clara Valley, California, Geosphere, 12(2), 366-376.

Angerer, T., S. G. Hagemann, D. H. G. Walde, G. P. Halverson, and A. J. Boyce (2016), Multiple metal sources in the glaciomarine facies of the Neoproterozoic Jacadigo iron formation in the "Santa Cruz deposit", Corumba, Brazil, Precambrian Research, 275, 369-393.

Ao, H., A. P. Roberts, M. J. Dekkers, X. D. Liu, E. J. Rohling, Z. G. Shi, Z. S. An, and X. Zhao (2016), Late Miocene-Pliocene Asian monsoon intensification linked to Antarctic ice-sheet growth, Earth and Planetary Science Letters, 444, 75-87.

Bandaru, V. L., P. B. Gawali, P. T. Hanamgond, and D. Kannan (2016), Heavy metal monitoring of beach sands through environmental magnetism technique: a case study from Vengurla and Aravali beaches of Sindhudurg district, Maharashtra, India, Environmental Earth Sciences, 75(8).

Bourliva, A., L. Papadopoulou, and A. Aidona (2016), Study of road dust magnetic phases as the main carrier of potentially harmful trace elements, Science of the Total Environment, 553, 380-391.

Gune, M., B. G. Harshavardhana, K. Balakrishna, H. N. Udayashankar, R. Shankar, and B. R. Manjunatha (2016), Rock magnetic fingerprinting of soil from a coal-fired thermal power plant, Environmental Monitoring and Assessment, 188(5).

Jensen, B. J. L., M. E. Evans, D. G. Froese, and V. A. Kravchinsky (2016), 150,000 years of loess accumulation in central Alaska, Quaternary Science Reviews, 135, 1-23.

Jia, J., D. S. Xia, Y. J. Wang, B. Wang, H. Lu, and S. Zhao (2016), East Asian monsoon evolution during the Eemian, as recorded in the western Chinese Loess Plateau, Quaternary International, 399, 156-164.

Jordanova, N., and D. Jordanova (2016), Rock-magnetic and geochemical characteristics of relict Vertisols-signs of past climate and recent pedogenic development, Geophysical Journal International, 205(3), 1437-1454.

Li, Y., Y. G. Song, X. L. Chen, J. C. Li, Y. Mamadjanov, and J. Aminov (2016), Geochemical composition of Tajikistan loess and its provenance implications, Palaeogeography Palaeoclimatology Palaeoecology, 446, 186-194.

Li, X. L., S. W. Pei, Z. X. Jia, Y. Guan, D. W. Niu, and H. Ao (2016), Paleoenvironmental conditions at Madigou (MDG), a newly discovered Early Paleolithic site in the Nihewan Basin, North China, Quaternary International, 400, 100-110.

Liu, S. F., X. F. Shi, G. Yang, S. Khokiattiwong, and N. Kornkanitnan (2016), Distribution of major and trace elements in surface sediments of the western Gulf of Thailand: Implications to modern sedimentation, Continental Shelf Research, 117, 81-91.

Liu, J., H. Wang, F. F. Wang, J. D. Qiu, Y. Saito, J. F. Lu, L. Y. Zhou, G. Xu, X. L. Du, and Q. Chen (2016), Sedimentary evolution during the last similar to 1.9 Ma near the western margin of the modern Bohai Sea, Palaeogeography Palaeoclimatology Palaeoecology, 451, 84-96.

Lu, H. H., Y. D. Xu, Y. Niu, Z. Wang, H. Wang, J. X. Zhao, W. G. Zhang, and X. M. Zheng (2016), Late Quaternary loess deposition in the southern Chaiwopu Basin of the northern Chinese Tian Shan foreland and its palaeoclimatic implications, Boreas, 45(2), 304-321.

Mahmoodi, M., F. Khormali, A. Amini, and S. Ayoubi (2016), Weathering and soils formation on different parent materials in Golestan Province, Northern Iran, Journal of Mountain Science, 13(5), 870-881.

Marie, D. C., M. A. E. Chaparro, M. A. Irurzun, J. M. Lavornia, C. Marinelli, R. Cepeda, H. N. Bohnel, A. G. C. Miranda, and A. M. Sinito (2016), Magnetic mapping of air pollution in Tandil city (Argentina) using the lichen Parmotrema pilosum as biomonitor, Atmospheric Pollution Research, 7(3), 513-520.

Maxbauer, D. P., J. M. Feinberg, and D. L. Fox (2016), Magnetic mineral assemblages in gills and paleosols as the basis for paleoprecipitation proxies: A review of magnetic methods and challenges, Earth-Science Reviews, 155, 28-48.

Meijers, M. J. M., B. E. Strauss, M. Ozkaptan, J. M. Feinberg, A. Mulch, D. L. Whitney, and N. Kaymakci (2016), Age and paleoenvironmental reconstruction of partially remagnetized lacustrine sedimentary rocks (Oligocene Aktoprak basin, central Anatolia, Turkey), Geochemistry Geophysics Geosystems, 17(3), 914-939.

Nguyen, T. T. H., W. G. Zhang, Z. Li, J. Li, C. Ge, J. Y. Liu, X. X. Bai, H. Feng, and L. Z. Yu (2016), Magnetic properties of sediments of the Red River: Effect of sorting on the source-to-sink pathway and its implications for environmental reconstruction, Geochemistry Geophysics Geosystems, 17(2), 270-281.

Nishida, N., et al. (2016), Sedimentary processes and depositional environments of a continuous marine succession across the Lower-Middle Pleistocene boundary: Kokumoto Formation, Kazusa Group, central Japan, Quaternary International, 397, 3-15.

Oda, H., I. Miyagi, J. Kawai, Y. Suganuma, M. Funaki, N. Imae, T. Mikouchi, T. Matsuzaki, and Y. Yamamoto (2016), Volcanic ash in bare ice south of Sor Rondane Mountains, Antarctica: geochem-

istry, rock magnetism and nondestructive magnetic detection with SQUID gradiometer, Earth Planets and Space, 68.
Pulley, S., and K. Rowntree (2016), Stages in the life of a magnetic grain: Sediment source discrimination, particle size effects and spatial variability in the South African Karoo, Geoderma, 271, 134-143.
Ramirez-Herrera, M. T., M. F. Bogalo, J. Cerny, A. Goguitchaichvili, N. Corona, M. L. Machain, A. C. Edwards, and S. Sosa (2016), Historic and ancient tsunamis uncovered on the Jalisco-Colima Pacific coast, the Mexican subduction zone, Geomorphology, 259, 90-104.
Rybacki, K. S., L. R. Kump, E. J. Hanski, and V. A. Melezhik (2016), Weathering during the Great Oxidation Event: Fennoscandia, arctic Russia 2.06 Ga ago, Precambrian Research, 275, 513-525.
Sun, X. F., Y. H. Li, X. B. Feng, C. Q. Lu, H. Y. Lu, S. W. Yi, S. J. Wang, and S. Y. Wu (2016), Pedostratigraphy of aeolian deposition near the Yunxian Man site on the Hanjiang River terraces, Yunxian Basin, central China, Quaternary International, 400, 187-194.
Szczepaniak-Wnuk, I., and B. Gorka-Kostrubiec (2016), Magnetic particles in indoor dust as marker of pollution emitted by different outside sources, Studia Geophysica Et Geodaetica, 60(2), 297-315.
Wang, X. S. (2016), Investigation of the pollution in the street dust at Xuzhou, China, using magnetic, micro-morphological and Mossbauer spectra analyses, Environmental Earth Sciences, 75(10).
Zhang, J., et Yurtseven-Sandker, A., and M. T. Cioppa (2016), Magnetic susceptibility mapping of the Sudbury area, Ontario, Canada: evaluating pollution distributions decades later, Canadian Journal of Earth Sciences, 53(5), 466-484.
Zhang, J., et al. (2016), Magnetostratigraphic age and monsoonal evolution recorded by the thickest Quaternary loess deposit of the Lanzhou region, western Chinese Loess Plateau, Quaternary Science Reviews, 139, 17-29.
Zhao, G. Y., Y. Han, X. M. Liu, L. Chang, B. Lu, Q. Chen, X. L. Guo, J. H. Yan, and J. Yan (2016), Can the magnetic susceptibility record of Chinese Red Clay sequence be used for palaeomonsoon reconstructions?, Geophysical Journal International, 204(3), 1421-1429.
Zykin, V. S., V. S. Zykina, and L. G. Smolyaninova (2016), New Data on the Most Ancient Early Quaternary Glaciation in Gornyi Altai, Doklady Earth Sciences, 466(1), 20-23.

Fundamental Rock and Mineral Magnetism

Alkadour, B., J. I. Mercer, J. P. Whitehead, J. van Lierop, and B. W. Southern (2016), Surface vacancy mediated pinning of the magnetization in gamma-Fe2O3 nanoparticles: A micromagnetic simulation study, Physical Review B, 93(14).
Balaev, D. A., A. A. Krasikov, A. A. Dubrovskiy, S. I. Popkov, S. V. Stolyar, O. A. Bayukov, R. S. Iskhakov, V. P. Ladygina, and R. N. Yaroslavtsev (2016), Magnetic properties of heat treated bacterial ferrihydrite nanoparticles, Journal of Magnetism and Magnetic Materials, 410, 171-180.
Chang, L., D. Heslop, A. P. Roberts, D. Rey, and K. J. Mohamed (2016), Discrimination of biogenic and detrital magnetite through a double Verwey transition temperature, Journal of Geophysical Research-Solid Earth, 121(1), 3-14.
Fujii, M., K. Okino, T. Sato, H. Sato, and K. Nakamura (2016), Origin of magnetic highs at ultramafic hosted hydrothermal systems: Insights from the Yokoniwa site of Central Indian Ridge, Earth and Planetary Science Letters, 441, 26-37.
Guerrero-Suarez, S., and F. Martin-Hernandez (2016), Haematite natural crystals: non-linear initial susceptibility at low temperature, Geophysical Journal International, 205(3), 1886-1899.
Guillaume, A., J. M. Scholtyssek, A. Lak, A. Kassner, F. Ludwig, and M. Schilling (2016), Magnetorelaxometry of few Fe3O4 nanoparticles at 77 K employing a self-compensated SQUID magnetometer, Journal of Magnetism and Magnetic Materials, 408, 46-50.
Ma, J., and K. Z. Chen (2016), Controllable superferromagnetism-induced exchange bias effect in goethite microparticles after zero-field-cooling process, Journal of Applied Physics, 119(7).
Manalo, P. C., C. B. Dimalanta, N. T. Ramos, D. V. Faustino-Eslava, K. L. Queao, and G. P. Yumul (2016), Magnetic Signatures and Curie Surface Trend Across an Arc-Continent Collision Zone: An Example from Central Philippines, Surveys in Geophysics, 37(3), 557-578.
Martin-Garcia, L., A. Mascaraque, B. M. Pabon, R. Bliem, G. S. Parkinson, G. Chen, A. K. Schmid, and J. de la Figuera (2016), Spin reorientation transition of magnetite (001), Physical Review B, 93(13).
Robinson, P., S. A. McEnroe, N. Miyajima, K. Fabian, and N. Church (2016), Remanent magnetization, magnetic coupling, and interface ionic configurations of intergrown rhombohedral and cubic Fe-Ti oxides: A short survey, American Mineralogist, 101(3), 518-530.
Yang, T., M. J. Dekkers, and B. Zhang (2016), Seismic heating signatures in the Japan Trench subduction plate-boundary fault zone: evidence from a preliminary rock magnetic 'geothermometer', Geophysical Journal International, 205(1), 332-344.
Yang, T., X. S. Yang, Q. B. Duan, J. Y. Chen, and M. J. Dekkers (2016), Rock magnetic expression of fluid infiltration in the Yingxiu-Beichuan fault (Longmen Shan thrust belt, China), Geochemistry Geophysics Geosystems, 17(3), 1065-1085.

High Pressure, Extraterrestiram and Planetary Magnetism

Dygert, N., G. Hirth, and Y. Liang (2016), A flow law for ilmenite in dislocation creep: Implications for lunar cumulate mantle overturn, Geophysical Research Letters, 43(2), 532-540.
Eitel, M., S. A. Gilder, J. Spray, L. Thompson, and J. Pohl (2016), A paleomagnetic and rock magnetic study of the Manicouagan impact structure: Implications for crater formation and geodynamo effects, Journal of Geophysical Research-Solid Earth, 121(2), 436-454.
Espinosa-Cardena, J. M., J. O. Campos-Enriquez, and M. Unsworth (2016), Heat flow pattern at the Chicxulub impact crater, northern Yucatan, Mexico, Journal of Volcanology and Geothermal Research, 311, 135-149.
Formisano, M., C. Federico, S. De Angelis, M. C. De Sanctis, and G. Magni (2016), A core dynamo in Vesta?, Monthly Notices of the Royal Astronomical Society, 458(1), 695-707.
Leroux, H., D. Jacob, M. Marinova, R. H. Hewins, B. Zanda, S. Pont, J. P. Lorand, and M. Humayun (2016), Exsolution and shock microstructures of igneous pyroxene clasts in the Northwest Africa 7533 Martian meteorite, Meteoritics & Planetary Science, 51(5), 932-945.
Nichols, C. I. O., J. F. J. Bryson, J. Herrero-Albillos, F. Kronast, F. Nimmo, and R. J. Harrison (2016), Pallasite paleomagnetism: Quiescence of a core dynamo, Earth and Planetary Science Letters, 441, 103-112.
Putirka, K. (2016), Rates and styles of planetary cooling on Earth, Moon, Mars, and Vesta, using new models for oxygen fugacity, ferric-ferrous ratios, olivine-liquid Fe-Mg exchange, and mantle potential temperature, American Mineralogist, 101(3), 819-840.
Richter, F., M. Chaussidon, R. Mendybaev, and E. Kite (2016), Reassessing the cooling rate and geologic setting of Martian meteorites MIL 03346 and NWA 817, Geochimica Et Cosmochimica Acta, 182, 1-23.
Ricolleau, A., and Y. W. Fei (2016), Equation of state of the high-pressure Fe_3O_4 phase and a new structural transition at 70 GPa, American Mineralogist, 101(3), 719-725.
Tomkins, A. G., L. Bowlt, M. Genge, S. A. Wilson, H. E. A. Brand, and J. L. Wykes (2016), Ancient micrometeorites suggestive of an oxygen-rich Archaean upper atmosphere, Nature, 533(7602), 235-+.
van Ginneken, M., M. J. Genge, L. Folco, and R. P. Harvey (2016), The weathering of micrometeorites from the Transantarctic Mountains, Geochimica Et Cosmochimica Acta, 179, 1-31.
Yant, M., A. D. Rogers, H. Nekvasil, Y. Y. S. Zhao, and T. Bristow (2016), Spectral characterization of acid weathering products on Martian basaltic glass, Journal of Geophysical Research-Planets, 121(3), 516-541.

Magnetic Fabrics and Anisotropy

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, 205(1), 479-489.
Caballero-Miranda, C. I., L. M. Alva-Valdivia, J. A. Gonzalez-Rangel, A. Gogitchaishvili, J. Urrutia-Fucugauchi, and A. Kontny (2016), Vertical AMS variation within basalt flow profiles from the Xitle volcano (Mexico) as indicator of heterogeneous strain in lava flows, Journal of Volcanology and Geothermal Research, 311, 9-28.
Caricchi, C., F. Cifelli, C. Kissel, L. Sagnotti, and M. Mattei (2016), Distinct magnetic fabric in weakly deformed sediments from extensional basins and fold-and-thrust structures in the Northern Apennine orogenic belt (Italy), Tectonics, 35(2), 238-256.
Felletti, F., E. Dall'Olio, and G. Muttoni (2016), Determining flow di-

rections in turbidites: An integrated sedimentological and magnetic fabric study of the Miocene Marnoso Arenacea Formation (northern Apennines, Italy), Sedimentary Geology, 335, 197-215.
Lanci, L., and E. Zanella (2016), The anisotropy of magnetic susceptibility of uniaxial superparamagnetic particles: Consequences for its interpretation in magnetite and maghemite bearing rocks, Journal of Geophysical Research-Solid Earth, 121(1), 27-37.
Lubnina, N. V., A. V. Stepanova, R. E. Ernst, M. Nilsson, and U. Soderlund (2016), New U-Pb baddeleyite age, and AMS and paleomagnetic data for dolerites in the Lake Onega region belonging to the 1.98-1.95 Ga regional Pechenga-Onega Large Igneous Province, Gff, 138(1), 54-78.
Montalbano, S., H. Diot, and O. Bolle (2016), Asymmetrical magnetic fabrics in the Egersund doleritic dike swarm (SW Norway) reveal sinistral oblique rifting before the opening of the Iapetus, Journal of Structural Geology, 85, 18-39.
Oliva-Urcia, B., A. M. Casas, B. Moussaid, J. J. Villalain, H. El Ouardi, R. Soto, S. Torres-Lopez, and T. Roman-Berdiel (2016), Tectonic fabrics vs. mineralogical artifacts in AMS analysis: A case study of the Western Morocco extensional Triassic basins, Journal of Geodynamics, 94-95, 13-33.
Pacakova, B., A. Mantlikova, D. Niznansky, S. Kubickova, and J. Vejpravova (2016), Understanding particle size and distance driven competition of interparticle interactions and effective single-particle anisotropy, Journal of Physics-Condensed Matter, 28(20).
Xie, X. J., F. Xian, Z. K. Wu, X. H. Kong, and Q. F. Chang (2016), Asian Monsoon variation over the late Neogene-early Quaternary recorded by Anisotropy of Magnetic Susceptibility (AMS) from Chinese loess, Quaternary International, 399, 183-189.

Mineralogy and Petrology

Ageeva, O., G. Habler, D. Topa, T. Waitz, C. Li, A. Pertsev, T. Griffiths, O. Zhilicheva, and R. Abart (2016), Plagioclase hosted Fe-Ti-oxide micro-inclusions in an oceanic gabbro-plagiogranite association from the mid Atlantic ridge at 13 degrees 34' N, American Journal of Science, 316(2), 85-109.
Frisby, C., M. Bizimis, and S. Mallick (2016), Seawater-derived rare earth element addition to abyssal peridotites during serpentinization, Lithos, 248, 432-454.
Majumdar, A. S., J. Hovelmann, C. Vollmer, J. Berndt, S. K. Mondal, and A. Putnis (2016), Formation of Mg-rich Olivine Pseudomorphs in Serpentinized Dunite from the Mesoarchean Nuasahi Massif, Eastern India: Insights into the Evolution of Fluid Composition at the Mineral-Fluid Interface, Journal of Petrology, 57(1), 3-26.
McCollom, T. M., F. Klein, M. Robbins, B. Moskowitz, T. S. Berquo, N. Jons, W. Bach, and A. Templeton (2016), Temperature trends for reaction rates, hydrogen generation, and partitioning of iron during experimental serpentinization of olivine, Geochimica Et Cosmochimica Acta, 181, 175-200.
Miller, H. M., J. M. Matter, P. Kelemen, E. T. Ellison, M. E. Conrad, N. Fierer, T. Ruchala, M. Tominaga, and A. S. Templeton (2016), Modern water/rock reactions in Oman hyperalkaline peridotite aquifers and implications for microbial habitability, Geochimica Et Cosmochimica Acta, 179, 217-241.
Nystrom, J. O., F. Henriquez, J. A. Naranjo, and H. R. Naslund (2016), Magnetite spherules in pyroclastic iron ore at El Laco, Chile, American Mineralogist, 101(3), 587-595.
Zviagin, V., P. Richter, T. Bontgen, M. Lorenz, M. Ziese, D. R. T. Zahn, G. Salvan, M. Grundmann, and R. Schmidt-Grund (2016), Comparative study of optical and magneto-optical properties of normal, disordered, and inverse spinel-type oxides, Physica Status Solidi B-Basic Solid State Physics, 253(3), 429-436.

Paleointensity and records of the geomagnetic field

Berndt, T., A. R. Muxworthy, and K. Fabian (2016), Does size matter? Statistical limits of paleomagnetic field reconstruction from small rock specimens, Journal of Geophysical Research-Solid Earth, 121(1), 15-26.
Bourne, M. D., J. M. Feinberg, T. W. Stafford, M. R. Waters, E. Lundelius, and S. L. Forman (2016), High-intensity geomagnetic field 'spike' observed at ca. 3000 cal BP in Texas, USA, Earth and Planetary Science Letters, 442, 80-92.
Brown, M. C., and M. Korte (2016), A simple model for geomagnetic field excursions and inferences for palaeomagnetic observations, Physics of the Earth and Planetary Interiors, 254, 1-11.
Fukuma, K., and M. Kono (2016), A LabVIEW software for Thellier paleointensity measurements with an automated three-component spinner magnetometer TSpin, Earth Planets and Space, 68.
Horiuchi, K., K. Kamata, S. Maejima, S. Sasaki, N. Sasaki, T. Yamazaki, S. Fujita, H. Motoyama, and H. Matsuzaki (2016), Multiple Be-10 records revealing the history of cosmic-ray variations across the Iceland Basin excursion, Earth and Planetary Science Letters, 440, 105-114.
Lund, S., J. Stoner, M. Okada, and E. Mortazavi (2016), Paleomagnetic field variability and chronostratigraphy of Brunhes-Chron deep-sea sediments from the Bering Sea: IODP Expedition 323, Deep-Sea Research Part Ii-Topical Studies in Oceanography, 125, 107-116.
Poletti, W., R. I. F. Trindade, G. A. Hartmann, N. Damiani, and R. M. Rech (2016), Archeomagnetism of Jesuit Missions in South Brazil (1657-1706 AD) and assessment of the South American database, Earth and Planetary Science Letters, 445, 36-47.
Reshetnyak, M. Y., and V. E. Pavlov (2016), Evolution of the Dipole Geomagnetic Field. Observations and Models, Geomagnetism and Aeronomy, 56(1), 110-124.
Sanchez-Duque, A., V. Mejia, N. D. Opdyke, K. Huang, and A. Rosales-Rivera (2016), Plio-Pleistocene paleomagnetic secular variation and time-averaged field: Ruiz-Tolima volcanic chain, Colombia, Geochemistry Geophysics Geosystems, 17(2), 538-549.
Schnepp, E., R. Leonhardt, M. Korte, and J. Klett-Drechsel (2016), Validity of archaeomagnetic field recording: an experimental pottery kiln at Coppengrave, Germany, Geophysical Journal International, 205(1), 622-635.
Shaar, R., L. Tauxe, H. Ron, Y. Ebert, S. Zuckerman, I. Finkelstein, and A. Agnon (2016), Large geomagnetic field anomalies revealed in Bronze to Iron Age archeomagnetic data from Tel Megiddo and Tel Hazor, Israel, Earth and Planetary Science Letters, 442, 173-185.
Smirnov, A. V., J. A. Tarduno, E. V. Kulakov, S. A. McEnroe, and R. K. Bono (2016), Palaeointensity, core thermal conductivity and the unknown age of the inner core, Geophysical Journal International, 205(2), 1190-1195.
Tanaka, H., and Y. Yamamoto (2016), Palaeointensities from Pliocene lava sequences in Iceland: emphasis on the problem of Arai plot with two linear segments, Geophysical Journal International, 205(2), 694-714.
Usapkar, A., P. Dewangan, F. K. Badesab, A. Mazumdar, T. Ramprasad, K. S. Krishna, and N. Basavaiah (2016), High resolution Holocene paleomagnetic secular variation records from Bay of Bengal, Physics of the Earth and Planetary Interiors, 252, 49-76.
Yang, X. Q., Q. S. Liu, K. F. Yu, W. Y. Huang, L. Y. Zhu, H. D. Zhang, J. Liu, and J. H. Li (2016), Paleosecular variations of the geomagnetic field during the Holocene from Eastern Asia, Physics of the Earth and Planetary Interiors, 254, 25-36.

Paleomagnetism

Cottrell, R. D., J. A. Tarduno, R. K. Bono, M. S. Dare, and G. Mitra (2016), The inverse microconglomerate test: Further evidence for the preservation of Hadean magnetizations in metasediments of the Jack Hills, Western Australia, Geophysical Research Letters, 43, 421-4220, doi:10.1002/2016GL068150.
Bazhenov, M. L., R. Van der Voo, Z. Menzo, A. R. Dominguez, J. G. Meert, and N. M. Levashova (2016), Paleomagnetism and dating of a thick lava pile in the Permian Bakaly formation of eastern Kazakhstan: Regularities and singularities of the paleomagnetic record in thick lava series, Physics of the Earth and Planetary Interiors, 253, 5-20.
Buchan, K. L., R. N. Mitchell, W. Bleeker, M. A. Hamilton, and A. N. LeCheminant (2016), Paleomagnetism of ca. 2.13-2.11 Ga Indin and ca. 1.885 Ga Ghost dyke swarms of the Slave craton: Implications for the Slave craton APW path and relative drift of Slave, Superior and Siberian cratons in the Paleoproterozoic, Precambrian Research, 275, 151-175.
Ccedil;inku, M. C., Z. M. Hisarli, Y. Yilmaz, B. Uuml;lker, N. Kaya, E. Ouml;ksum, N. Orbay, and Z. U. Ouml;zbey (2016), The tectonic history of the Nide-Krehir Massif and the Taurides since the Late Mesozoic: Paleomagnetic evidence for two-phase orogenic curvature in Central Anatolia, Tectonics, 35(3), 772-811.
Cinku, M. C., Z. M. Hisarli, Y. Yilmaz, B. Ulker, N. Kaya, E. Oksum, N. Orbay, and Z. U. Ozbey (2016), The tectonic history of the

Nide-Krehir Massif and the Taurides since the Late Mesozoic: Paleomagnetic evidence for two-phase orogenic curvature in Central Anatolia, Tectonics, 35(3), 772-811.

Gladysheva, O. G., and V. V. Popov (2016), Paleomagnetic study of the Tunguska catastrophe epicenter, Geomagnetism and Aeronomy, 56(2), 229-238.

Hassan, R., R. D. Muller, M. Gurnis, S. E. Williams, and N. Flament (2016), A rapid burst in hotspot motion through the interaction of tectonics and deep mantle flow, Nature, 533(7602), 239-+.

He, P. L., X. L. Huang, Y. G. Xu, H. Y. Li, X. Wang, and W. X. Li (2016), Plume-orogenic lithosphere interaction recorded in the Haladala layered intrusion in the Southwest Tianshan Orogen, NW China, Journal of Geophysical Research-Solid Earth, 121(3), 1525-1545.

Henkel, K., T. Haberzettl, G. St-Onge, J. B. Wang, M. Ahlborn, G. Daut, L. P. Zhu, and R. Mausbacher (2016), High-resolution paleomagnetic and sedimentological investigations on the Tibetan Plateau for the past 16 ka cal BPThe Tangra Yumco record, Geochemistry Geophysics Geosystems, 17(3), 774-790.

Hernandez-Moreno, C., F. Speranza, and A. Di Chiara (2016), Paleomagnetic rotation pattern of the southern Chile fore-arc sliver (38 degrees S-42 degrees S): A new tool to evaluate plate locking along subduction zones, Journal of Geophysical Research-Solid Earth, 121(2), 469-490.

Holm, R. J., G. Rosenbaum, and S. W. Richards (2016), Post 8 Ma reconstruction of Papua New Guinea and Solomon Islands: Microplate tectonics in a convergent plate boundary setting, Earth-Science Reviews, 156, 66-81.

Hoshi, H., and K. Yamada (2016), Paleomagnetic study of Plio-Pleistocene sediments in the concentrated deformation zone along the eastern margin of the Japan Sea, Quaternary International, 397, 573-588.

Lemna, O. S., V. Bachtadse, U. Kirscher, C. Rolf, and N. Petersen (2016), Paleomagnetism of the Jurassic Transantarctic Mountains revisited - Evidence for large dispersion of apparent polar wander within less than 3 Myr, Gondwana Research, 31, 124-134.

Minguez, D., K. P. Kodama, and T. Engelder (2016), Paleomagnetism of the Oatka Creek Member of the Marcellus Formation: A Devonian paleopole for North America, Geological Society of America Bulletin, 128(5-6), 707-718.

Mitchell, R. N., T. D. Raub, S. C. Silva, and J. L. Kirschvink (2015), Was the Cambrian explosion both an effect and an artifact of true polar wander? American Journal of Science, 315(10), 945-957.

Mochales, T., E. L. Pueyo, A. M. Casas, and A. Barnolas (2016), Restoring paleomagnetic data in complex superposed folding settings: The Boltana anticline (Southern Pyrenees), Tectonophysics, 671, 281-298.

Mohanty, S. (2015), Precambrian continent assembly and dispersal events of South Indian and East Antarctic Shields, International Geology Review, 57(16), 1992-2027.

Pavon-Carrasco, F. J., E. Tema, M. L. Osete, and R. Lanza (2016), Statistical Analysis of Palaeomagnetic Data from the Last Four Centuries: Evidence of Systematic Inclination Shallowing in Lava Flow Records, Pure and Applied Geophysics, 173(3), 839-848.

Pimentel, A., V. Zanon, L. V. de Groot, A. Hipolito, A. Di Chiara, and S. Self (2016), Stress-induced comenditic trachyte effusion triggered by trachybasalt intrusion: multidisciplinary study of the AD 1761 eruption at Terceira Island (Azores), Bulletin of Volcanology, 78(3).

Prezzi, C. B., M. J. Orgeira, O. Martinez, R. D. Acevedo, F. Ponce, G. Goldmann, I. Magneres, and J. Rabassa (2016), Circular structures of Bajada del Diablo (Argentina): geophysical signatures, Geophysical Journal International, 205(2), 876-899.

Sao, C. C., et al. (2016), Magnetic polarity of Masol 1 Locality deposits, Siwalik Frontal Range, northwestern India, Comptes Rendus Palevol, 15(3-4), 407-416.

Schettino, A., and C. Macchiavelli (2016), Plate kinematics of the central Atlantic during the Oligocene and early Miocene, Geophysical Journal International, 205(1), 408-426.

Semami, F. A., M. De Kock, U. Soderlund, A. Gumsley, R. Da Silva, N. Beukes, and R. Armstrong (2016), New U-Pb geochronologic and palaeomagnetic constraints on the late Palaeoproterozoic Hartley magmatic event: evidence for a potential large igneous province in the Kaapvaal Craton during Kalahari assembly, South Africa, Gff, 138(1), 164-182.

Shah, J., A. A. P. Koppers, M. Leitner, R. Leonhardt, A. R. Muxworthy, C. Heunemann, V. Bachtadse, J. A. D. Ashley, and J. Matzka (2016), Palaeomagnetic evidence for the persistence or geomagnetic main field anomalies in the South Atlantic, Earth and Planetary Science Letters, 441, 113-124.

Shaw, J., and S. T. Johnston (2016), Terrane wrecks (coupled oroclines) and paleomagnetic inclination anomalies, Earth-Science Reviews, 154, 191-209.

Sprain, C. J., J. M. Feinberg, P. R. Renne, and M. Jackson (2016), Importance of titanohematite in detrital remanent magnetizations of strata spanning the Cretaceous-Paleogene boundary, Hell Creek region, Montana, Geochemistry Geophysics Geosystems, 17(3), 660-678.

Torres-Lopez, S., A. M. Casas, J. J. Villalain, H. El Ouardi, and B. Moussaid (2016), Pre-Cenomanian vs. Cenozoic folding in the High Atlas revealed by palaeomagnetic data, Terra Nova, 28(2), 110-119.

Visan, M., C. G. Panaiotu, C. Necula, and A. Dumitru (2016), Palaeomagnetism of the Upper Miocene-Lower Pliocene lavas from the East Carpathians: contribution to the paleosecular variation of geomagnetic field, Scientific Reports, 6.

Wabo, H., M. O. De Kock, M. B. Klausen, U. Soderlund, and N. J. Beukes (2016), Paleomagnetism and chronology of B-1 marginal sills of the Bushveld Complex from the eastern Kaapvaal Craton, South Africa, Gff, 138(1), 133-151.

Wabo, H., J. R. Olsson, M. O. Kock, F. Humbert, U. Soderlund, and M. B. Klausen (2016), New U-Pb age and paleomagnetic constraints from the Uitkomst Complex, South Africa: clues to the timing of intrusion, Gff, 138(1), 152-163.

Wang, H., Z. Y. Yang, Y. B. Tong, L. Gao, X. Q. Jing, and H. F. Zhang (2016), Palaeomagnetic results from Palaeogene red beds of the Chuan-Dian Fragment, southeastern margin of the Tibetan Plateau: implications for the displacement on the Xianshuihe-Xiaojiang fault systems, International Geology Review, 58(11), 1363-1381.

Wei, W., Y. Chen, M. Faure, G. Martelet, W. Lin, Q. C. Wang, Q. R. Yan, and Q. L. Hou (2016), An early extensional event of the South China Block during the Late Mesozoic recorded by the emplacement of the Late Jurassic syntectonic Hengshan Composite Granitic Massif (Hunan, SE China), Tectonophysics, 672, 50-67.

Yu, Y., X. L. Huang, P. L. He, and J. Li (2016), I-type granitoids associated with the early Paleozoic intracontinental orogenic collapse along pre-existing block boundary in South China, Lithos, 248, 353-365.

Zhang, Y., D. Jia, H. W. Yin, M. C. Liu, W. R. Xie, G. Q. Wei, and Y. X. Li (2016), Remagnetization of lower Silurian black shale and insights into shale gas in the Sichuan Basin, south China, Journal of Geophysical Research-Solid Earth, 121(2), 491-505.

Prospecting and Surveying

Abramova, D. Y., S. V. Filippov, L. M. Abramova, I. M. Varentsov, and I. N. Lozovskii (2016), Changes of lithospheric magnetic anomalies with altitude (According to the CHAMP satellite), Geomagnetism and Aeronomy, 56(2), 239-248.

Ahmad, L., M. T. Shah, and S. D. Khan (2016), Reflectance spectroscopy and remote sensing data for finding sulfide-bearing alteration zones and mapping geology in Gilgit-Baltistan, Pakistan, Earth Science Informatics, 9(1), 113-121.

Bedrosian, P. A. (2016), Making it and breaking it in the Midwest: Continental assembly and rifting from modeling of EarthScope magnetotelluric data, Precambrian Research, 278, 337-361.

Chen, G. X., Q. M. Cheng, and H. L. Zhang (2016), Matched filtering method for separating magnetic anomaly using fractal model, Computers & Geosciences, 90, 179-188.

Ehmann, S., C. Virgil, A. Hordt, and M. Leven (2016), Directional location of buried objects using three-component magnetic borehole data demonstrated for the case of a drill string, Geophysical Journal International, 205(3), 1916-1925.

Gemail, K., N. M. Abd-El Rahman, B. M. Ghiath, and R. N. Aziz (2016), Integration of ASTER and airborne geophysical data for mineral exploration and environmental mapping: a case study, Gabal Dara, North Eastern Desert, Egypt, Environmental Earth Sciences, 75(7).

Jouniaux, L., and F. Zyserman (2016), A review on electrokinetically induced seismo-electrics, electro-seismics, and seismo-magnetics for Earth sciences, Solid Earth, 7(1), 249-284.

Kadioglu, S., and Y. K. Kadioglu (2016), Visualization of buried anti-tank landmines and soil pollution: analyses using ground penetrating radar method with attributes and petrographical methods, Near Surface Geophysics, 14(2), 183-195.

Liddell, M., M. Unsworth, and J. Pek (2016), Magnetotelluric imaging of anisotropic crust near Fort McMurray, Alberta: implications for engineered geothermal system development, Geophysical Journal International, 205(3), 1365-1381.

Oha, I. A., K. M. Onuoha, A. N. Nwegbu, and A. U. Abba (2016), Interpretation of high resolution aeromagnetic data over southern Benue Trough, southeastern Nigeria, Journal of Earth System Science, 125(2), 369-385.

Padilha, A. L., I. Vitorello, M. B. Padua, and R. A. Fuck (2016), Deep magnetotelluric signatures of the early Neoproterozoic Cariris Velhos tectonic event within the Transversal sub-province of the Borborema Province, NE Brazil, Precambrian Research, 275, 70-83.

Rao, D. B., and T. Annapurna (2016), Gravity and Magnetic Surveys and Interpretation in the Northern Part of the K-G Basin, Journal of the Geological Society of India, 87(5), 601-609.

Rao, P., M. Radhakrishna, K. Haripriya, B. S. Rao, and D. Chandrasekharam (2016), Magnetic anomalies over the Andaman Islands and their geological significance, Journal of Earth System Science, 125(2), 359-368.

Yuan, B. Q., H. A. Zhang, C. G. Zhang, H. H. Xu, and Y. K. Yan (2016), The characteristics of gravity and magnetic fields and the distribution of tight sandstone gas in the eastern Ordos Basin, China, Geophysical Journal International, 205(1), 665-679.

Spectroscopy

Di Genova, D., K. U. Hess, M. O. Chevrel, and D. B. Dingwell (2016), Models for the estimation of Fe3+/Fe-tot ratio in terrestrial and extraterrestrial alkali- and iron-rich silicate glasses using Raman spectroscopy, American Mineralogist, 101(3), 943-952.

Ducher, M., M. Blanchard, D. Vantelon, R. Nemausat, and D. Cabaret (2016), Probing the local environment of substitutional Al in goethite using X-ray absorption spectroscopy and first-principles calculations, Physics and Chemistry of Minerals, 43(3), 217-227.

Iturregui, A., N. Arrieta, J. Aramendia, I. Arrizabalaga, X. Murelaga, J. I. Baceta, M. A. Olazabal, I. Martinez-Arkarazo, and J. M. Madariaga (2016), In-situ and laboratory Raman spectroscopic analysis on beachrock deposits: Characterisation of the trapped materials, Journal of Raman Spectroscopy, 47(3), 329-336.

Kamzin, A. S. (2016), Mossbauer investigations of Fe and Fe3O4 magnetic nanoparticles for hyperthermia applications, Physics of the Solid State, 58(3), 532-539.

Lalla, E. A., A. Sanz-Arranz, G. Lopez-Reyes, A. Sansano, J. Medina, D. Schmanke, G. Klingelhoefer, J. A. Rodriguez-Losada, J. Martinez-Frias, and F. Rull (2016), Raman-Mossbauer-XRD studies of selected samples from "Los Azulejos" outcrop: A possible analogue for assessing the alteration processes on Mars, Advances in Space Research, 57(11), 2385-2395.

Stratigraphy

Akulov, N. I., I. M. Mashchuk, and V. V. Akulova (2015), Pleistocene sediments of Lake Baikal: Lithology and stratigraphic correlation, Stratigraphy and Geological Correlation, 23(1), 94-113.

Hyodo, M., et al. (2016), High resolution stratigraphy across the early-middle Pleistocene boundary from a core of the Kokumoto Formation at Tabuchi, Chiba Prefecture, Japan, Quaternary International, 397, 16-26.

Kaya, F., N. Kaymakci, F. Bibi, J. T. Eronen, C. Pehlevan, A. C. Erkman, C. G. Langereis, and M. Fortelius (2016), Magnetostratigraphy and paleoecology of the hominid-bearing locality Corakyerler, Tuglu Formation (Cankiri Basin, Central Anatolia), Comments on Inorganic Chemistry, 36(3).

Kuzmin, Y. V., and A. Y. Kazanskii (2015), Debatable questions of Siberia settlement by early humans, Stratigraphy and Geological Correlation, 23(1), 114-118.

Liu, P., Z. J. Wu, C. L. Deng, H. W. Tong, H. F. Qin, S. H. Li, B. Y. Yuan, and R. X. Zhu (2016), Magnetostratigraphic dating of the Shanshenmiaozui mammalian fauna in the Nihewan Basin, North China, Quaternary International, 400, 202-211.

Lund, S. P., and E. Platzman (2016), Paleomagnetic chronostratigraphy of late Holocene Zaca Lake, California, Holocene, 26(5), 814-821.

Nawrocki, J., M. Lanczont, O. Rosowiecka, and A. B. Bogucki (2016), Magnetostratigraphy of the loess-palaeosol key Palaeolithic section at Korolevo (Transcarpathia, W Ukraine), Quaternary International, 399, 72-85.

Qiao, Q. Q., B. C. Huang, J. D. A. Piper, T. Deng, and C. Y. Liu (2016), Neogene magnetostratigraphy and rock magnetic study of the Kashi Depression, NW China: Implications to neotectonics in the SW Tianshan Mountains, Journal of Geophysical Research-Solid Earth, 121(3), 1280-1296.

Satolli, S., and A. Turtu (2016), Early Cretaceous magnetostratigraphy of the Salto del Cieco section (Northern Apennines, Italy), Newsletters on Stratigraphy, 49(2), 361-382.

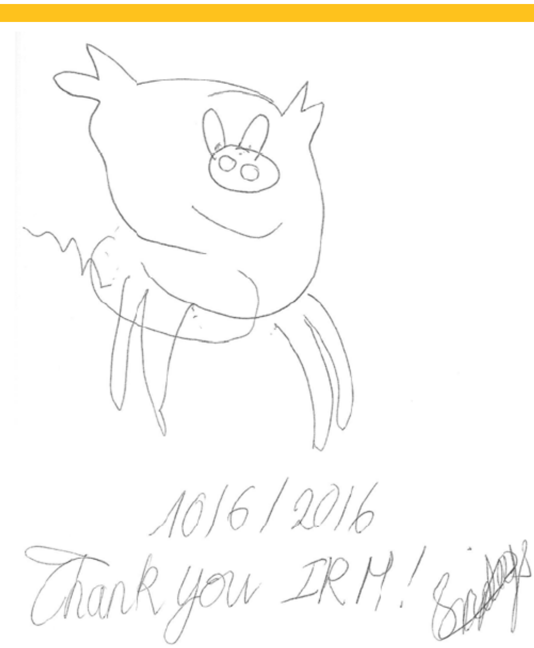
Tudryn, A., et al. (2016), Stratigraphy and paleoenvironment during the Late Pliocene at Masol paleonto-archeological site (Siwalik Range, NW India): Preliminary results, Comptes Rendus Palevol, 15(3-4), 440-452.

Synthesis

Ferreira, N. M., M. C. Ferro, S. M. Mikhalev, F. M. Costa, J. R. Frade, and A. V. Kovalevsky (2016), Guidelines to design multicomponent ferrospinels for high-temperature applications, Rsc Advances, 6(39), 32540-32548.

Han, C. L., D. J. Zhu, H. Z. Wu, Y. Li, L. Cheng, and K. H. Hu (2016), TEA controllable preparation of magnetite nanoparticles (Fe_3O_4 NPs) with excellent magnetic properties, Journal of Magnetism and Magnetic Materials, 408, 213-216.

Sarveena, J. M. Vargas, D. K. Shukla, C. T. Meneses, P. M. Zelis, M. Singh, and S. K. Sharma (2016), Synthesis, phase composition, Mossbauer and magnetic characterization of iron oxide nanoparticles, Physical Chemistry Chemical Physics, 18(14), 9561-9568.



Spider-pig drawn whilst blindfold by a 2016 Summer School on Rock Magnetism participant.

cont'd. from pg. 1...

Environmental Magnetism

The Environmental Magnetism group looked at magnetic properties of lacustrine sediments from Sharkey Lake, from Southern Minnesota. The sediments from Sharkey Lake were cored by students at Carleton College in Northville MN and stored at the Lacustrine Research Center at the University of Minnesota, were resampled to determine down-core variations in magnetic properties in search of magnetic fingerprints of climate change and anthropogenic activity. Bulk susceptibility (χ), ARM/χ, SIRM/χ, ARM/χ, the S-ratio, as well as hysteresis parameters were evaluated in order to determine grain-size/domain-state and concentration variations of magnetic minerals. The magnetic mineralogy and coercivity distributions were also investigated. Main findings of the study are that the down-core variation in magnetic parameters delineate three portions of the core: a shallow section with softer and finer magnetite particles, likely biogenic; a larger mid section comprising harder and coarser particles, both magnetite and some siderite in the lowest portion; and a deeper section of softer and finer magnetite and siderite particles. Results were interpreted as indicating a reduction in grain-size (increased SP-SD) due to agricultural activity leading to increased erosion, with some potential down-core dissolution of magnetite.

Archeomagnetism and Paleointensity

The Archeomagnetism group searched for the 1000 BCE paleointensity spike in archeological artifacts from South America. The spike, known as the "Levantine spike", was initially recognized in the Middle East, in Iran, Syria, Israel and Turkey, but was subsequently also observed in North America. This group specifically worked with artifacts from two Peruvian sites, with specimens younger, older, and of about 1000 years BCE. The study revolved around magnetic characterization and stability experiments to determine whether the specimens fit the requirements for a Thellier experiment (magnetite as magnetic carrier, PSD-SD grain-size range, little hematite and/or goethite, and no alteration during heating), and then proceeded to perform Pseudo-Thellier experiments. No evidence for the geomagnetic spike was observed from these experiments, yet it remained unclear whether the results of the experiments reflected true paleointensity variation or changes in magnetic mineralogy. However, the study proved that at least half of the specimens were suitable for a full Thellier paleointensity determination.

Sedimentary Magnetism

The DRM group looked at magnetic properties of natural sediments from North America and Brazil, evaluating the magnetic behavior of different magnetic mineralogies. A more in-depth project involved analyzing the magnetic remanence of a North American sediment that was re-deposited in the lab under varying field conditions: a constant 50 uT field intensity, and inclinations of 0°, 30°, 60° and 90°. The sediment was thoroughly characterized in terms of magnetic mineralogy and grain-size, through low and high temperature remanence and susceptibility analyses, measurement of hysteresis parameters and remanence acquisition/demagnetization experiments. Specifically, magnetic measurements allowed determining the stability of the dominant remance carrying grains and their suitability for relative paleointensity estimates. The remanences measured were systematically shallower than the ambient field inclinations, with shallowing factors as small as 0.2, resulting in up to 45° of inclination shallowing, indicating substantial misalignment of the magnetic moments of the remanence carrying grains. Magnetizations were also found to be dependent on the settling field, with decreasing magnetizations for increasing field inclinations, observations that were also reflected in the relative paleointensity estimates.

Volcanic Remanence Carriers

Finally, the Paleomagnetism group looked at the magnetic remanence carried by volcanic rocks, and specifically 1.1 billion year old basalts and andesites associated with the North American Proterozoic failed rifting event. Specimens analyzed were from two sites from within the Lake Superior region, the Schroeder-Lutsen (SL) and the Michipicoten Island Formation (MIF) basalts, and detailed magnetic characterization revealed different magnetic composition among the basalts: the SL basalts possess multiple unblocking and disordering temperatures, around 600° and close to 700°C, whereas the MIF basalts only possess one main unblocking temperature between 430° and 530°C. Hysteresis loops and backfield curves confirm the importance of both ferrimagnetic and antiferromagnetic remanence carriers: while the MIF basalts possess very narrow loops that close around 200 mT, the SL rocks possess much wider loops, which are constricted in the center and don't close in fields up to 1 T. Un-mixing the coercivity distributions captured by the backfield curves also reflect the "softer" and "harder" magnetizations of the MIF and SL basalts, respectively. Integrating the high-temperature susceptibility data with low-temperature data acquired on the MPMSs, reveals that while the magnetizations of the MIF are carried by titanomagnetites, the SL basalts are highly oxidized and possess much maghemite and hematite. Additionally, this group's study confirms the notion that for weakly anisotropic samples, the AMS fabrics are strongly affected by previously imparted high-field (de) magnetizations, showing that the order in which the experiments are conducted is critical for a successful study.

Field trip

Like the previous two Summer Schools, the destination for the weekend field trip was Taylor's Falls, in the Interstate State Park. Here, 1.1 Gyr basalts crop out along the St. Croix river, and display giant pot-holes carved by discharge waters of Glacial Lake Duluth from the ice retreat at the end of the last glacial maximum (~11 kyr). Unfortunately, the weather was not as cooperative as in the past and the field trip was compromised by heavy rain. Additionally, and if that wasn't enough,

Group photo taken during the final dinner.

intense road construction prevented us to visit the unconformably overlaying Cambrian Franconia Formation sandstone and hike the picturesque Curtain Falls trail. In fact, because of the road-construction we started the trip on the Wisconsin side of the Park, which was a first-time visit for all of us: this side turns out to be a little “wilder” in terms of scenery and much more picturesque, but with overall less impressive pot-holes, however, it does have a very nice picnic area which serendipitously sheltered us from an intense downpour. After the rain (and lunch) we decided to try our luck back in Minnesota to visit the “familiar” side of the Park: not too far into the park, however, the rain picked up again forcing the group to seek shelter and eventually decide to call it a day. Before hitting the road, a quick visit to a retro “Americana” ice cream and malts joint was the last stop, and added some sweetness to the trip.

Final dinner

As of tradition, on the final evening of the Summer School, the completion of the course was celebrated over a group dinner. This year’s dinner was held at a Mediterranean restaurant by the University, and provided one last opportunity for informal and friendly mingling among participants. We are big fans of tradition at the IRM, and in compliance with the most solid of traditions a brand new Pig Book was inaugurated for the occasion: everyone present took a stab at inking a pig whilst blindfold and we are all very glad to have the book as a memento of another fantastic summer school completed.

Scholarships

Last but not least, we’d like to acknowledge the 2016 recipients of the two scholarships generously provided by the GPE division of the American Geophysical Union, Louise Hawkins of the University of Liverpool, and Courtney Wagner of the University of Utah. Congratulations, again!

We would also like to remind colleagues that the scheduling of the IRM Summer School and Santa Fe Conference were inverted, and therefore the IRM Conference on Rock Magnetism is being planned for next year: more details to follow!

"The IRM Summer School gives you wings": Blindfolded pig-art by Gildo.

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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.

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