The IRM
Quarterly
Summer 2016, Vol. 26 No.2

ISSN: 2152-1972

Inside...

Lindsay (Lin) George Parry, 1922-2016

Phil Schmidt
Newrybar NSW
Australia
phil@magneticearth.com.au

Lin Parry was born at home on a farm near Ballina, on the north coast of NSW, Australia, 29 March 1922, where he spent the first 16 years of his life. There was no bus service to the school in nearby Wardell so he had an extended pre-school with charcoal and the concrete floor of the cow bails substituting for a chalk and blackboard. With his Mother's help Lin soon learned some letters and numbers thereby completing much of the kindergarten material. Finally, at the age of seven Lin went to school.

Starting late, Lin's primary schooling was disjointed. With continuing transport problems and completing two years by correspondence, Lin nevertheless passed the final primary school examination thereby graduating to high school. The eventual transport solution for high school was a bicycle, ride to Wardell, park the bike, cross the river by ferry, and catch the school bus to Ballina high. Due to his fragmented schooling to this point Lin was enrolled in the B class. Nevertheless, at the end of first year Lin was dux of his year. At the end of high school Lin's Leaving Certificate results were: English A; Maths I & II - Hons II; History A; French B; Chemistry B; Geography B, one of the best results on the North Coast.

Based on Lin's Leaving Certificate results he was awarded a Teachers' College Scholarship at Armidale with the aim of becoming a high school teacher. Part of his studies included university courses for which he was awarded a BSc Dip Ed from Sydney University.

Lin married Margaret in 1947 and their son Graham was born in 1948, followed by their daughter Susan in 1952. After teaching briefly at Bathurst High School Lin was appointed to the University of New South Wales (UNSW) when it was still emerging from its foundation in the Sydney Technical College. Conceived as a specialised training institute for engineers, staff were also recruited to teach ancillary subjects, such as Physics, which is where Parry fitted in. The evolution from its technical college origins to a fully-fledged university introduced new expectations of teaching staff, research and publication in particular. Lin was a founding member of the Physics Department and completed his MSc in 1955, which was presented at the first degree ceremony at UNSW. Lin was to spend his entire professional life at the UNSW.

Fig. 1 Lindsay George Parry in the early 1950s.

One of the advantages of university work was sabbatical leave and Lin was able to avail himself of it on three occasions. In 1957 Lin took his family to Canberra where he was able to work on magnetic properties (particularly thermo-magnetic) of various materials and more especially with some of the leaders at ANU. During this first study leave at ANU he was able to work with Frank Stacey. Lin and Margaret and Frank, and his wife Joy, were to become great friends. In his memoirs Lin recalls "when we were considering the grains of magnetite too small to accommodate a full domain structure but not small enough to be one domain he (Frank) produced the theory in a very short time all written up and ready to publish and only needing some experimental evidence. One of the best scholars and the greatest scientist I knew". Therefore Lin took the lead in developing a translation balance for measurement of the temperature dependence of the saturation magnetisations of rocks, to identify the compositions of their magnetically active minerals. He subsequently produced a similar instrument in Sydney and this work became central to his research.

cont'd. on pg. 10..

Visiting Fellow Report

Magnetic characterization of solid by-products from Municipal Solid Waste Incinerators

Valerio Funari
University of Bologna
Dipartimento di Scienze Biologiche Geologiche e Ambientali (BiGeA)
valerio.funari@unibo.it

The main objective of my visit to the IRM was to explore the magnetic properties of the solid by-products, i.e., bottom (BA) and fly ashes (FA), deriving from municipal solid waste incinerators. Despite incineration is one of the most effective options for waste management and minimization, BA and FA represent huge amounts of material that pose severe environmental and health problems. Magnetic minerals are common components of incinerated ashes and my research is driven by the fact that they can be correlated with heavy metals pollution and the presence of toxic ultrafine superparamagnetic (SP) grains.

Samples of BA and FA were collected from municipal solid waste incinerators of northern Italy following the sampling methodology described in Funari et al. (2015). The goal of this project is to decipher the sources of the magnetic properties previously observed in the BA and FA (Funari et al., 2016), and estimate the concentration of SP grains. A general correlation between χ and concentration of certain metals (i.e., Fe, REE, Co) suggested the study of magnetic phases after metal leaching in order to better understand the fate of valuable metals and enhance metal recovery. I also performed magnetic measurements on additional samples of BA and FA that were subjected to bio-hydrometallurgical treatments for metal recovery and environmental stabilisation during my earlier PhD work.

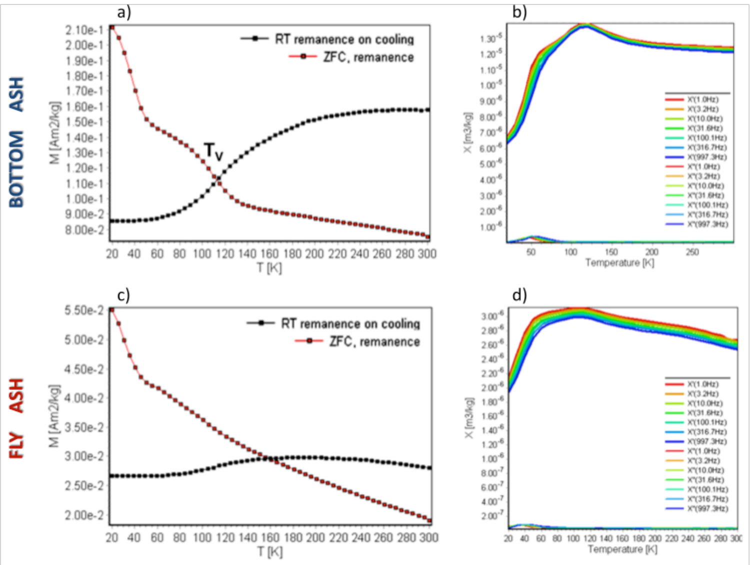


Fig. 1: MPMS measurements of representative BA sample (above) and FA sample (below). Low temperature remanence curves (a, c) are measured after imparting a room temperature SIRM at 2.5 T, during zero-field cooling (ZFC) to 20 K (RT remanence on cooling). While at low temperature, a 2.5 T SIRM is imparted and the remanence is measured on heating back to room temperature (ZFC, remanence). AC susceptibility (b, d) is measured at 7 different frequencies and in fixed field amplitude as a function of temperature; both in-phase (X') and out-of-phase (X'') susceptibility are displayed.

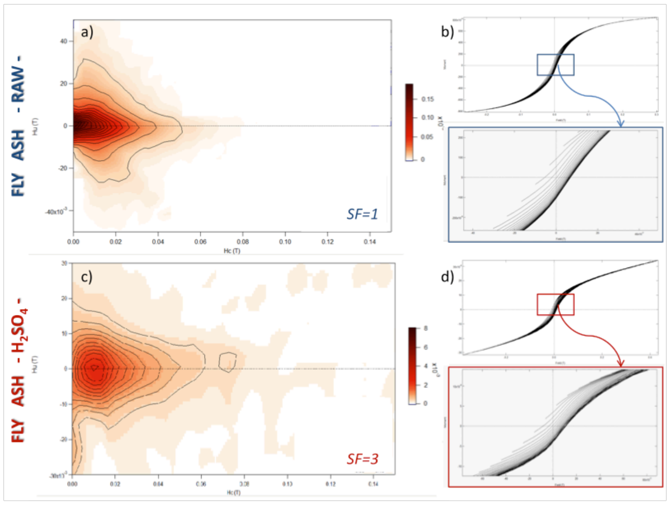


Fig. 2: FORC analysis of a raw FA sample (above) and after H2SO4 leaching (below). The FORC diagrams (a, d) are computed using FORCinel software that allowed the processing with optimum smoothing factor (SF), magnetic drift and first point artefact corrections. The FORC measurements (b, d) are also shown along with a zoom around the origin where every 3rd curve is plotted for clarity.

The BA and FA samples are characterized by narrow hysteresis curves and low coercivity (Bc, 7.2 – 14.1 mT), suggesting a significant reversible component of the magnetization. High temperature susceptibility measurements for both BA and FA mostly indicate magnetite Curie temperatures between 570-580 ºC and the heating-cooling curves are frequently not reversible. The low temperature remanent curves and frequency-dependent AC susceptibility (Fig. 1) were measured on a Magnetic Properties Measurement System (MPMS). The measured sequences show magnetite-like shapes for most of samples, but the Vervey transition in FA samples is not clear probably due to the presence of oxidized/impure magnetite or unblocking of SP grains. Measurements of AC susceptibility by MPMS might support a significant contribution of SP grains in FA: FA samples show larger frequency dependence than BA and the temperature of the peak in both in-phase and out-of-phase susceptibility, which corresponds to the blocking temperature, is shifted towards lower temperature (ca. 30 K for FA; ca. 50 K for BA). However, the presence of impure magnetite containing Cr, Zn, Mn, and Cu, which may conceal the real SP contribution, cannot be ruled out in either BA or in FA. On a Day Plot, the samples lie within the domain of PSD particles, mostly close to the SD-MD mixing lines, but the FA sample treated by H2SO4 in a pH-dependent test (1 pH set-point, 6hrs leaching time) is close to the SP-PSD curves. The analysis of FORC distribution (Fig. 2) confirms PSD magnetic assemblages with contours diverging from the origin of Hu axis and a broad, not well definined, central ridge. The FORC analysis of the FA-H2SO4 sample shows a slightly different shape of contour lines, coercivity distribution, and a sigmoidal SP contribution is recognizable from the zoomed insert of the FORC measurement.

The magnetic measurements at the IRM provided reference data for magnetic properties of BA and FA and these preliminary observations emphasise the metastable nature of these ashes. In addition, we found evidence of a significant contribution of the harmful SP grains (especially in FA) that may affect the current waste management strategies. We plan to use the Banerjee diagrams (Banerjee et al., 1993) to better understand the SP contribution and integrate the magnetic dataset with Mossbauer analysis (already acquired at the IRM) and XRD mineralogy in order to shed some light on the behaviour of magnetic phases during leaching that still remains controversial.

I spent a great time at the IRM and I would like to thank Mike Jackson, Dario Bilardello, and all the IRM staff for their generous help and thank also to Luigi Vigliotti (CNR-ISMAR, Bologna, Italy) who introduced me to rock magnetism and suggested the visit at the IRM.

References

Banerjee, S. K., Hunt, C. P. & Liu, X-M.(1993). Geophys Res Lett 20 (9), 843-846.

Funari, V., Bokhari, S. N., Vigliotti, L., Meisel, T. & Braga, R. (2016). J Hazard Mater 301, 471-479.

Funari, V., Braga, R., Bokhari, S. N., Dinelli, E. & Meisel, T. (2015). Waste Manag 45, 206-216.

Complex iron mineralogy of the 1.4 Ga lower Belt Supergroup: iron oxides, siderite and (nanophase) pyrrhotite

Sarah Slotznick
Geological and Planetary Sciences Division, California Institute of Technology
Now at Department of Earth and Planetary Science, University of California, Berkeley
sslotz@berkeley.edu

The 1.4 Ga Belt Supergroup (Evans et al., 2000), currently exposed in Montana, Idaho, Washington, Alberta, and British Columbia, represents a classic mid-Proterozoic sedimentary succession spanning a wide range of metamorphic conditions with sub-biotite facies in the east increasing to garnet facies in the west (Duke and Lewis, 2010). Paleontologically, the strata contain diverse microfossils, and the second oldest macrofossils on Earth (Horodyski et al., 1989); some of the micro- and macrofossils are interpreted to be eukaryotes—the domain of life that includes all modern macroscopic organisms like plants and animals (e.g. Adam et al., 2014; Knoll et al., 2006). Understanding the depositional conditions of the shales, siltstones, and sandstones of the lower Belt Group can provide information about the environmental conditions surrounding these early eukaryotic life forms with evolutionary implications.

Observing changes in iron chemistry and mineralogy has been utilized for decades to understand ancient redox shifts, due to iron's redox sensitivity as it cycles between +II and +III valence states. Additionally, by collecting samples across a well-understood metamorphic gradient, we can elucidate the metamorphic reactions of iron minerals naturally occurring during burial metamorphism to peel away overprints and reveal primary mineralogy. We utilize bulk rock magnetic techniques in a form of "deep-time" environmental magnetism to constrain the magnetic minerals present within the samples. Combining rock magnetism with textural techniques and field observations, we can ordinate minerals as secondary or primary, with the latter used to determine paleo-redox conditions.

Prior work on the shales and siltstones of the lower Belt Supergroup using these techniques had suggested incredibly complex mixtures of iron minerals even in relatively unmetamorphosed samples and abundant overprinting from secondary diagenetic and metamorphic processes (Slotznick et al., 2016; Slotznick et al., 2015). One of the main goals of my time at the IRM was to confirm some of the magnetic minerals previously identified by rotational remanent magnetization and Hcr' (from the derivative of IRM acquisition) measured using RAPID rock magnetic protocols on Caltech's 2G SQuID magnetometer (Kirschvink et al., 2008) as well as thermal susceptibility measurements on Caltech's KappaBridge. Additionally, I wanted to use hysteresis parameters to constrain grain size and quantify abundances of magnetic minerals in my samples.

At the IRM, I measured room-temperature hysteresis loops of all 63 of my samples and 21 samples were run on the MPMS. Pyrrhotite was confirmed in six samples by the presence of the Besnus transition at 32K (Figure 1A). Samples with pyrrhotite formed a metamorphic isograd with western samples containing pyrrhotite while samples to the east contained only pyrite. Notably this isograd occurs below the biotite isograd highlighting the low-temperatures at which pyrite can metamorphose into pyrrhotite. In addition to pyrrhotite, siderite was also identified by its low-temperature transition in five samples to the west of the newly mapped isograd (Figure 1B). While not imaged texturally, this siderite is interpreted to form as small domains within the Fe-rich dolomite that was seen in samples both east and west of the isograd.

The MPMS experiments showed that even the samples to the east of the isograd had undergone some transformations in iron mineralogy based on the presence of the P-transition in 10 samples (Aubourg and Pozzi, 2010). Interpreted to indicate nanophase pyrrhotite, this transition has a smooth reversible drop/rise in RTSIRM at 35K and is nearly indistinguishable FC and ZFC below 35 K (Figure 1C,D). From experimentation on natural claystones, the P-transition first appeared at 40°C and

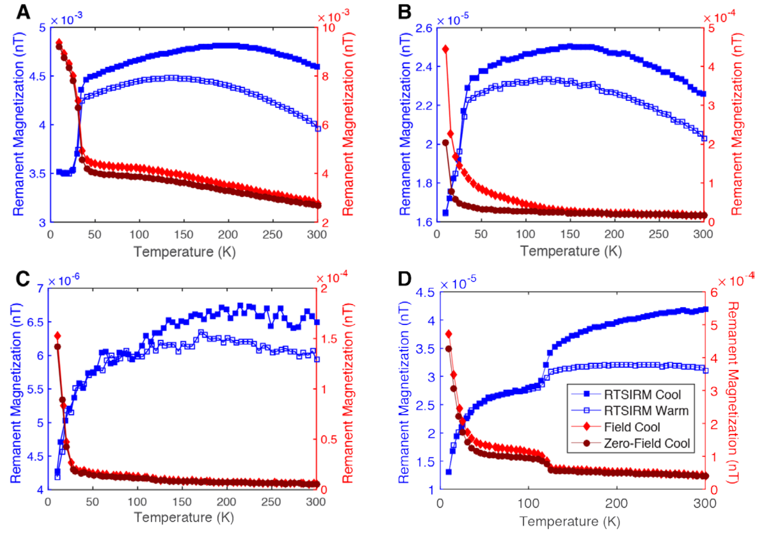


Figure 1: RTSIRM, FC, and ZFC from example shales and siltstones of the lower Belt Supergroup containing A) pyrrhotite, B) pyrrhotite and siderite, C) nanophase pyrrhotite and magnetite, and D) magnetite and nanophase pyrrhotite.

disappeared by 250°C (Aubourg and Pozzi, 2010). This temperature range fits independent temperature constraints on the eastern lower Belt samples ranging between 125°C to 310°C (Eslinger and Savin, 1973; White et al., 2014).

Magnetite was confirmed in 14 samples using the Verwey transition at 120K (Figure 1D), and appeared to be nearly ubiquitous in the low-grade metamorphic samples. Hysteresis parameters highlighted that the magnetite in low-grade samples was pseudo-single domain and was present at <10 ppm. The Fuller test for nature of magnetization suggested this magnetite was detrital. This preserved record of fine-grained detrital iron oxide gives important clues about the redox conditions suggesting oxic water conditions may have been more prevalent than previously believed. Based on their dependence on oxygen for metabolic functions and biosynthetic reactions, eukaryotes are tied to oxic conditions; therefore, this paleoenvironmental interpretation lends support to the paleontological signs for eukaryotes in the Belt Supergroup.

References

Adam, Z., Mogk, D., Skidmore, M., and Butterfield, N., Microfossils from the Greyson Formation, Lower Belt Supergroup: Support for early Mesoproterozoic biozonation, in Proceedings Geological Society of America Abstracts with Programs2014, Volume 46, p. 71.

Aubourg, C., and Pozzi, J.-P., 2010, Toward a new< 250 C pyrrhotite–magnetite geothermometer for claystones: Earth and Planetary Science Letters, v. 294, no. 1, p. 47-57.

Duke, E. F., and Lewis, R. S., 2010, Near infrared spectra of white mica in the Belt Supergroup and implications for metamorphism: American Mineralogist, v. 95, no. 7, p. 908-920.

Eslinger, E. V., and Savin, S. M., 1973, Oxygen isotope geothermometry of the burial metamorphic rocks of the Precambrian Belt Supergroup, Glacier National Park, Montana: Geological Society of America Bulletin, v. 84, no. 8, p. 2549-2560.

Evans, K. V., Aleinikoff, J. N., Obradovich, J. D., and Fanning, C. M., 2000, SHRIMP U-Pb geochronology of volcanic rocks, Belt Supergroup, western Montana: evidence for rapid deposition of sedimentary strata: Canadian Journal of Earth Sciences, v. 37, no. 9, p. 1287-1300.

Horodyski, R. J., Winston, D., and Whipple, J. W., 1989, Paleontology of the middle Proterozoic belt supergroup, in Winston, D., Horodyski, R. J., and Whipple, J. W., eds., Middle Proterozoic Belt Supergroup, Western Montana: Great Falls, Montana to Spokane, Washington: 28th International Geological Congress, Field Trip Guidebook T334, p. 7-26.

Kirschvink, J. L., Kopp, R. E., Raub, T. D., Baumgartner, C. T., and Holt, J. W., 2008, Rapid, precise, and high-sensitivity acquisition of paleomagnetic and rock-magnetic data: Development of a low-noise automatic sample changing system for superconducting rock magnetometers: Geochemistry Geophysics Geosystems, v. 9, no. 5.

Knoll, A. H., Javaux, E. J., Hewitt, D., and Cohen, P., 2006, Eukaryotic organisms in Proterozoic oceans: Philosophical Transactions of the Royal Society B: Biological Sciences, v. 361, no. 1470, p. 1023-1038.

Slotznick, S. P., Winston, D., Webb, S. M., Kirschvink, J. L., and Fischer, W. W., 2016, Iron mineralogy and redox conditions during deposition of the Mid-Proterozoic Appekunny Formation, Belt Supergroup, Glacier National Park: Geological Society of America Special Papers, v. 522.

Slotznick, S. P., Zieg, J., Webb, S. M., Kirschvink, J. L., and Fischer, W. W., 2015, Iron Mineralogy and Redox Chemistry of the Mesoproterozoic Newland Formation in the Helena Embayment, Belt Supergroup, Montana: Northwest Geology, v. 44, p. 55-72.

White, J., Gammons, C. H., and Zieg, G., 2014, Paragenesis of cobalt and nickel in the Black Butte shale-hosted copper deposit, Belt Basin, Montana, USA: Mineralium Deposita, v. 49, no. 3, p. 335-351.

The next

Visiting Fellow Application

deadline is coming up on

October 31st

Find details at
https://irm.umn.edu

And don't forget to follow
the IRM on

Facebook!

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

Petryshyn, V. A., F. A. Corsetti, C. M. Frantz, S. P. Lund, and W. M. Berelson (2016), Magnetic susceptibility as a biosignature in stromatolites, Earth and Planetary Science Letters, 437, 66-75.

Suk, D. (2016), Environmental conditions for the presence of magnetofossils in the Last Glacial Maximum inferred from magnetic parameters of sediments from the Ulleung Basin, East Sea, Marine Geology, 372, 53-65.

Environmental magnetism and Climate

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.

Avinash, K., P. J. Kurian, A. K. Warrier, R. Shankar, T. C. Vineesh, and R. Ravindra (2016), Sedimentary sources and processes in the eastern Arabian Sea: Insights from environmental magnetism, geochemistry and clay mineralogy, Geoscience Frontiers, 7(2), 253-264.

Bolikhovskaya, N. S., S. S. Faustov, and A. K. Markova (2016), Pleistocene climatic stratigraphy and environments of the Terek-Kuma Lowland (NW Caspian sea region) inferred from palynological, paleomagnetic and rodent records of the long Otkaznoye sediment sequence, Quaternary International, 409, 16-32.

Cao, L. W., S. Y. Hu, A. Erwin, S. L. Shi, and G. Yin (2016), The spatio-temporal variation of magnetic properties of tree leaves in Linfen, China and its indication to the atmospheric pollution of heavy metals, Chinese Journal of Geophysics-Chinese Edition, 59(5), 1729-1742.

Cao, Y., Y. S. Du, Z. S. Pang, F. P. Gao, Y. L. Du, and X. M. Liu (2016), Iron transport and deposition mechanisms in the Taochong iron-rich skarn deposit, Middle-Lower Yangtze Valley, Eastern China, Ore Geology Reviews, 72, 1037-1052.

Cerny, J., M. T. Ramirez-Herrera, M. F. Bogalo, A. Goguitchaichvili, R. Castillo-Aja, J. Morales, J. A. Sanchez-Cabeza, and A. Ruiz-Fernandez (2016), Magnetic record of extreme marine inundation events at Las Salinas site, Jalisco, Mexican Pacific coast, International Geology Review, 58(3), 342-357.

Channell, J. E. T., R. J. Harrison, I. Lascu, I. N. McCave, F. D. Hibbert, and W. E. N. Austin (2016), Magnetic record of deglaciation using FORC-PCA, sortable-silt grain size, and magnetic excursion at 26 ka, from the Rockall Trough (NE Atlantic), Geochemistry Geophysics Geosystems, 17(5), 1823-1841.

Chudanicova, M., S. M. Hutchinson, J. Hradecky, and J. Sedlacek (2016), Environmental magnetism as a dating proxy for recent overbank sediments of (peri-)industrial regions in the Czech Republic and UK, Catena, 142, 21-35.

Dallanave, E., V. Bachtadse, E. M. Crouch, L. Tauxe, C. L. Shepherd, H. E. G. Morgans, C. J. Hollis, B. R. Hines, and S. Sugisaki (2016), Constraining early to middle Eocene climate evolution of the southwest Pacific and Southern Ocean, Earth and Planetary Science Letters, 433, 380-392.

Duparc, Q., S. A. S. Dare, P. A. Cousineau, and J. Goutier (2016), Magnetite chemistry as a provenance indicator in archean metamorphosed sedimentary rocks, Journal of Sedimentary Research, 86(5), 542-563.

Font, E., J. Ponte, T. Adatte, A. Fantasia, F. Florindo, A. Abrajevitch, and J. Mirao (2016), Tracing acidification induced by Deccan Phase 2 volcanism, Palaeogeography Palaeoclimatology Palaeoecology, 441, 181-197.

Giusberti, L., F. B. Galazzo, and E. Thomas (2016), Variability in climate and productivity during the Paleocene-Eocene Thermal Maximum in the western Tethys (Forada section), Climate of the Past, 12(2), 213-240.

Gorka-Kostrubiec, B., M. Teisseyre-Jelenska, and S. K. Dytlow (2016), Magnetic properties as indicators of Chernozem soil development, Catena, 138, 91-102.

Grison, H., E. Petrovsky, A. Kapicka, and S. Stejskalova (2016), Magnetic and chemical parameters of andic soils and their relation to selected pedogenesis factors, Catena, 139, 179-190.

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.

Jordanova, N., D. Jordanova, and P. Petrov (2016), Soil magnetic properties in Bulgaria at a national scale-Challenges and benefits, Global and Planetary Change, 137, 107-122.

Just, J., N. R. Nowaczyk, L. Sagnotti, A. Francke, H. Vogel, J. H. Lacey, and B. Wagner (2016), Environmental control on the occurrence of high-coercivity magnetic minerals and formation of iron sulfides in a 640 ka sediment sequence from Lake Ohrid (Balkans), Biogeosciences, 13(7), 2093-2109.

Kissel, C., Z. F. Liu, J. H. Li, and C. Wandres (2016), Magnetic minerals in three Asian rivers draining into the South China Sea: Pearl, Red, and Mekong Rivers, Geochemistry Geophysics Geosystems, 17(5), 1678-1693.

Korff, L., T. von Dobeneck, T. Frederichs, S. Kasten, G. Kuhn, R. Gersonde, and B. Diekmann (2016), Cyclic magnetite dissolution in Pleistocene sediments of the abyssal northwest Pacific Ocean: Evidence for glacial oxygen depletion and carbon trapping, Paleoceanography, 31(5), 600-624.

Li, Q., L. Yi, S. Z. Liu, H. J. Yu, Y. P. Chen, X. Y. Xu, P. Li, and C. L. Deng (2016), Rock magnetic properties of the Lz908 borehole sediments from the southern Bohai Sea, eastern China, Chinese Journal of Geophysics-Chinese Edition, 59(5), 1717-1728.

Liu, D. X., J. H. Ma, Y. L. Sun, and Y. M. Li (2016), Spatial distribution of soil magnetic susceptibility and correlation with heavy metal pollution in Kaifeng City, China, Catena, 139, 53-60.

Liu, S. Z., C. L. Deng, J. L. Xiao, J. H. Li, G. A. Paterson, L. Chang, L. Yi, H. F. Qin, and R. X. Zhu (2016), High-resolution enviromagnetic records of the last deglaciation from Dali Lake, Inner Mongolia, Palaeogeography Palaeoclimatology Palaeoecology, 454, 1-11.

Lourenco, A. M., and C. R. Gomes (2016), Integration of magnetic measurements, chemical and statistical analysis in characterizing agricultural soils (central Portugal), Environmental Earth Sciences, 75(11).

Luo, C., Y. Zheng, H. B. Zheng, R. Tada, and D. S. Rits (2016), Temporal and spatial variations in magnetic properties of suspended particular matter in the Yangtze River drainage and their implications, Journal of Asian Earth Sciences, 124, 204-213.

Macaulay, E. A., E. R. Sobel, A. Mikolaichuk, M. Wack, S. A. Gilder, A. Mulch, A. B. Fortuna, S. Hynek, and F. Apayarov (2016), The sedimentary record of the Issyk Kul basin, Kyrgyzstan: climatic and tectonic inferences, Basin Research, 28(1), 57-80.

Morales, J., M. D. Hernandez-Bernal, P. Corona-Chavez, A. Gogichaishvili, and F. Bautista (2016), Further evidence for magnetic susceptibility as a proxy for the evaluation of heavy metals in mining wastes: case study of Tlalpujahua and El Oro Mining Districts, Environmental Earth Sciences, 75(4).

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.

Oliva-Urcia, B., A. Munoz, J. C. Larasoana, A. Luzon, A. Perez, A. Gonzalez, Z. Jiang, Q. Liu, and T. Roman-Berdiel (2016), Response of alluvial systems to Late Pleistocene climate changes recorded by environmental magnetism in the Anavieja Basin (Iberian Range, NE Spain), Geologica Acta, 14(2), 139-154.

Roza, J., B. Jackson, E. Heaton, and R. Negrini (2016), Paleomagnetic secular variation and environmental magnetism of Holocene-age sediments from Tulare Lake, CA, Quaternary Research, 85(3), 391-398.

Sancho, C., M. Calle, J. L. Pena-Monne, M. Duval, B. Oliva-Urcia, E. L. Pueyo, G. Benito, and A. Moreno (2016), Dating the Earliest Pleistocene alluvial terrace of the Alcanadre River (Ebro Basin, NE Spain): Insights into the landscape evolution and involved processes, Quaternary International, 407, 86-95.

Savian, J. F., L. Jovane, M. Giorgioni, F. Iacoviello, D. Rodelli, A. P. Roberts, L. Chang, F. Florindo, and M. Sprovieri (2016), Environmental magnetic implications of magnetofossil occurrence during the Middle Eocene Climatic Optimum (MECO) in pelagic sediments from the equatorial Indian Ocean, Palaeogeography Palaeoclimatology Palaeoecology, 441, 212-222.

Shimono, T., and T. Yamazaki (2016), Environmental rock-magnetism of Cenozoic red clay in the South Pacific Gyre, Geochemistry Geophysics Geosystems, 17(4), 1296-1311.

Sullivan, N. B., D. J. Over, M. Chuluun, and P. M. Myrow (2016), Subsidence and drowning of a carbonate platform in south-central Mongolia (Gobi Altai region) during the late Eifelian to early Givetian: A synthesis of conodont data, magnetic susceptibility, and paleoecology, Journal of Asian Earth Sciences, 115, 204-213.

Wang, Q. S., Y. G. Song, Z. J. Zhao, and J. J. Li (2016), Color characteristics of Chinese loess and its paleoclimatic significance during the last glacial-interglacial cycle, Journal of Asian Earth Sciences, 116, 132-138.

Wang, X., B. Kraatz, J. Meng, B. Carrapa, P. Decelles, M. Clementz, S. Abdulov, and F. H. Chen (2016), Central Asian aridification during the late Eocene to early Miocene inferred from preliminary study of shallow marine-eolian sedimentary rocks from northeastern Tajik Basin, Science China-Earth Sciences, 59(6), 1242-1257.

Williams, G. E., P. W. Schmidt, and G. M. Young (2016), Strongly seasonal Proterozoic glacial climate in low palaeolatitudes: Radically different climate system on the pre-Ediacaran Earth, Geoscience Frontiers, 7(4), 555-571.

Wu, Y., Z. Y. Zhu, S. F. Qiu, Y. L. Han, J. X. Cai, and Z. G. Rao (2016), Magnetic stratigraphy constraints on the Matuyama-Brunhes boundary recorded in a loess section at the southern margin of Chinese Loess Plateau, Geophysical Journal International, 204(2), 1072-1085.

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.

Xiong, J. G., Y. L. Li, Y. Z. Zhong, S. P. Si, and Y. F. Yao (2016), Paleomagnetism of the Jianshui basin in Yunnan, SW China, and geomorphological evolution of the Yunnan Plateau since the Neogene, Journal of Asian Earth Sciences, 123, 67-77.

Xuan, C., J. E. T. Channel, and D. A. Hodell (2016), Quaternary magnetic and oxygen isotope stratigraphy in diatom-rich sediments of the southern Gardar Drift (IODP Site U1304, North Atlantic), Quaternary Science Reviews, 142, 74-89.

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.

Fundamental Rock and Mineral Magnetism

Abrajevitch, A., L. M. Kondratyeva, E. M. Golubeva, K. Kodama, and R. S. Hori (2016), Magnetic properties of iron minerals produced by natural iron- and manganese-reducing groundwater bacteria, Geophysical Journal International, 206(2), 1340-1351.

Charles, N., F. Choulet, S. Sizaret, Y. Chen, L. Barbanson, A. Ennaciri, L. Badra, and Y. Branquet (2016), Internal structures and dating of non-sulphide Zn deposits using rock magnetism: insights from the Moroccan High Atlas, Mineralium Deposita, 51(1), 151-175.

Evans, B. W., W. Hildreth, O. Bachmann, and B. Scaillet (2016), In defense of magnetite-ilmenite thermometry in the Bishop Tuff and its implication for gradients in silicic magma reservoirs, American Mineralogist, 101(1-2), 469-482.

Finn, D. R., and R. S. Coe (2016), A new protocol for three-axis static alternating field demagnetization of rocks, Geochemistry Geophysics Geosystems, 17(5), 1815-1822.

Koulialias, D., J. Kind, M. Charilaou, P. G. Weidler, J. F. Loffler, and A. U. Gehring (2016), Variable defect structures cause the magnetic low-temperature transition in natural monoclinic pyrrhotite, Geophysical Journal International, 204(2), 961-967.

Liu, D. L., H. B. Li, T. Q. Lee, Z. M. Sun, J. Liu, L. Han, and M. L. Chevalier (2016), Magnetic mineral characterization close to the Yingxiu-Beichuan fault surface rupture zone of the Wenchuan earthquake (Mw 7.9, 2008) and its implication for earthquake slip processes, Journal of Asian Earth Sciences, 115, 468-479.

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.

McEnroe, S. A., P. Robinson, N. Miyajima, K. Fabian, D. Dyar, and E. Sklute (2016), Lamellar magnetism and exchange bias in billion-year-old titanohematite with nanoscale ilmenite exsolution lamellae: I. Mineral and magnetic characterization, Geophysical Journal International, 206(1), 470-486.

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: geochemistry, rock magnetism and nondestructive magnetic detection with SQUID gradiometer, Earth Planets and Space, 68.

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

Agarwal, A., A. Kontny, D. C. Srivastava, and R. O. Greiling (2016), Shock pressure estimates in target basalts of a pristine crater: A case study in the Lonar crater, India, Geological Society of America Bulletin, 128(1-2), 19-28.

Berger, J. A., et al. (2016), A global Mars dust composition refined by the Alpha-Particle X-ray Spectrometer in Gale Crater, Geophysical Research Letters, 43(1), 67-75.

Collareta, A., M. D'Orazio, M. Gemelli, A. Pack, and L. Folco (2016), High crustal diversity preserved in the lunar meteorite Mount DeWitt 12007 (Victoria Land, Antarctica), Meteoritics & Planetary Science, 51(2), 351-371.

Diaz-Michelena, M., R. Kilian, R. Sanz, F. Rios, and O. Baeza (2016), Mars MOURA magnetometer demonstration for high-resolution mapping on terrestrial analogues, Geoscientific Instrumentation Methods and Data Systems, 5(1), 127-142.

Glikson, A., A. Hickman, and R. Crossley (2016), Evidence for a shock-metamorphic breccia within a buried impact crater, Lake Raeside, Yilgarn Craton, Western Australia, Australian Journal of Earth Sciences, 63(1), 99-109.

Glikson, A., A. Hickman, N. J. Evans, C. L. Kirkland, J. W. Park, R. Rapp, and S. Romano (2016), A new similar to 3.46 Ga asteroid impact ejecta unit at Marble Bar, Pilbara Craton, Western Australia: A petrological, microprobe and laser ablation ICPMS study, Precambrian Research, 279, 103-122.

Isac, A., M. Mandea, M. Purucker, and B. Langlais (2016), A comparative analysis of the magnetic field signals over impact structures on the Earth, Mars and the Moon, Advances in Space Research, 57(1), 477-492.

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.

Li, J., L. S. Chan, and Y. L. Li (2016), The blueberry (iron nodule) from the Shark Bay area, Western Australia and its implication to the genetic environments of iron nodules on Mars, Science China-Earth Sciences, 59(3), 640-650.

Treiman, A. H., et al. (2016), Mineralogy, provenance, and diagenesis of a potassic basaltic sandstone on Mars: CheMin X-ray diffraction of the Windjana sample (Kimberley area, Gale Crater), Journal of Geophysical Research-Planets, 121(1), 75-106.

Magnetic Fabrics and Anisotropy

Agarwal, A., K. K. Agarwal, R. Bali, C. Prakash, and G. Joshi (2016), Back-thrusting in Lesser Himalaya: Evidences from magnetic fabric studies in parts of Almora crystalline zone, Kumaun Lesser Himalaya, Journal of Earth System Science, 125(4), 873-884.

Arzadun, G., R. N. Tomezzoli, and N. N. Cesaretti (2016), Tectonic insight based on anisotropy of magnetic susceptibility and compaction studies in the Sierras Australes thrust and fold belt (southwest Gondwana boundary, Argentina), Tectonics, 35(4), 1015-1031.

Gong, G. H., H. L. Chen, F. Wang, X. B. Lin, and L. F. Meng (2016), The Ductile Deformation Characteristics of Caledonian Intracontinental Orogeny in the Northeastern Jiangshan-Shaoxing Tectonic Zone: Insights from Magnetic Fabric Study and Its Geodynamic Implication, Acta Geologica Sinica-English Edition, 90(1), 75-87.

Lennox, P. G., H. de Wall, and D. W. Durney (2016), Correlation between magnetic fabrics, strain and biotite microstructure with increasing mylonitisation in the pretectonic Wyangala Granite, Australia, Tectonophysics, 676, 170-197.

Renjith, A. R., M. A. Mamtani, and J. L. Urai (2016), Fabric analysis of quartzites with negative magnetic susceptibility - Does AMS provide information of SPO or CPO of quartz?, Journal of Structural Geology, 82, 48-59.

Soriano, C., E. Beamud, M. Garces, and M. H. Ort (2016), 'Anomalous' magnetic fabrics of dikes in the stable single domain/superparamagnetic threshold, Geophysical Journal International, 204(2), 1040-1059.

Mineralogy and Petrology

Apukhtina, O. B., et al. (2016), Postmagmatic magnetite-apatite assemblage in mafic intrusions: a case study of dolerite at Olympic Dam, South Australia, Contributions to Mineralogy and Petrology, 171(1).

Tornos, F., F. Velasco, and J. M. Hanchar (2016), Iron-rich melts, magmatic magnetite, and superheated hydrothermal systems: The El Laco deposit, Chile, Geology, 44(6), 427-430.

Paleointensity and records of the geomagnetic field

Channell, J. E. T., D. A. Hodell, and J. H. Curtis (2016), Relative paleointensity (RPI) and oxygen isotope stratigraphy at IODP Site U1308: North Atlantic RPI stack for 1.2-2.2 Ma (NARPI-2200) and age of the Olduvai Subchron, Quaternary Science Reviews, 131, 1-19.

de Groot, L. V., A. Pimentel, and A. Di Chiara (2016), The multimethod palaeointensity approach applied to volcanics from Terceira: full-vector geomagnetic data for the past 50 kyr, Geophysical Journal International, 206(1), 590-604.

Driscoll, P. E., and D. A. D. Evans (2016), Frequency of Proterozoic geomagnetic superchrons, Earth and Planetary Science Letters, 437, 9-14.

Klausner, V., A. R. R. Papa, C. M. N. Candido, M. O. Domingues, and O. Mendes (2016), An alternative way to identify local geomagnetically quiet days: a case study using wavelet analysis, Annales Geophysicae, 34(4), 451-462.

Lascu, I., J. M. Feinberg, J. A. Dorale, H. Cheng, and R. L. Edwards (2016), Age of the Laschamp excursion determined by U-Th dating of a speleothem geomagnetic record from North America, Geology, 44(2), 139-142.

Lifton, N. (2016), Implications of two Holocene time-dependent geomagnetic models for cosmogenic nuclide production rate scaling, Earth and Planetary Science Letters, 433, 257-268.

Lund, S., E. Platzman, and T. Johnson (2016), Full-vector paleomagnetic secular variation records from latest quaternary sediments of Lake Malawi (10.0 degrees S, 34.3 degrees E), Quaternary Science Reviews, 144, 16-27.

Lund, S., L. Keigwin, and D. Darby (2016), Character of Holocene paleomagnetic secular variation in the tangent cylinder: Evidence from the Chukchi Sea, Physics of the Earth and Planetary Interiors, 256, 49-58.

Sagnotti, L., P. Macri, and R. G. Lucchi (2016), Geomagnetic palaeosecular variation around 15 ka ago from NW Barents Sea cores (south of Svalbard), Geophysical Journal International, 204(2), 785-797.

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.

Sprain, C. J., J. M. Feinberg, J. W. Geissman, B. Strauss, and M. C. Brown (2016), Paleointensity during periods of rapid reversal: A case study from the Middle Jurassic Shamrock batholith, western Nevada, Geological Society of America Bulletin, 128(1-2), 223-238.

Paleomagnetism

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.

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.

D'Agrella, M. S., R. I. F. Trindade, M. V. B. Queiroz, V. T. Meira, L. Janikian, A. S. Ruiz, and F. Bispo-Santos (2016), Reassessment of Aguapei (Salto do Ceu) paleomagnetic pole, Amazonian Craton and implications for Proterozoic supercontinents, Precambrian Research, 272, 1-17.

Derder, M. E. M., et al. (2016), Discovery of a Devonian mafic magmatism on the western border of the Murzuq basin (Saharan metacraton): Paleomagnetic dating and geodynamical implications, Journal of African Earth Sciences, 115, 159-176.

Ernst, R. E., et al. (2016), Long-lived connection between southern Siberia and northern Laurentia in the Proterozoic, Nature Geoscience, 9(6), 464-+.

Ertepinar, P., C. G. Langereis, A. J. Biggin, L. V. de Groot, F. Kulakoglu, S. Omura, and A. Suel (2016), Full vector archaeomagnetic records from Anatolia between 2400 and 1350 BCE: Implications for geomagnetic field models and the dating of fires in antiquity, Earth and Planetary Science Letters, 434, 171-186.

Evans, D. A. D., R. I. F. Trindade, E. L. Catelani, M. S. D'Agrella, L. M. Heaman, E. P. Oliveira, U. Soderlund, R. E. Ernst, A. V. Smirnov, and J. M. Salminen (2016), Return to Rodinia? Moderate to high palaeolatitude of the Sao Francisco/Congo craton at 920 Ma, in Supercontinent Cycles through Earth History, edited by Z. X. Li, D. A. D. Evans and J. B. Murphy, pp. 167-190.

Fernandez-Lozano, J., D. Pastor-Galan, G. Gutierrez-Alonso, and P. Franco (2016), New kinematic constraints on the Cantabrian orocline: A paleomagnetic study from the Penalba and Truchas synclines, NW Spain, Tectonophysics, 681, 195-208.

Guo, J. F., R. H. Xie, and Y. L. Zou (2016), Simulation of NMR responses in sandstone and restricted diffusion, Chinese Journal of Geophysics-Chinese Edition, 59(7), 2703-2712.

Gurer, O. F., E. Sangu, M. Ozburan, A. Gurbuz, A. Gurer, and H. Sinir (2016), Plio-Quaternary kinematic development and paleostress pattern of the Edremit Basin, western Turkey, Tectonophysics, 679, 199-210.

Hamilton, E. M., R. D. Elmore, B. L. Weaver, S. Dulin, and J. Jackson (2016), Paleomagnetic and petrologic study of the age, origin, and significance of early and late Paleozoic events in the Long Mountain Granite, Wichita Mountains, Oklahoma, Geological Society of America Bulletin, 128(1-2), 187-202.

Hisarli, Z. M., M. C. Cinku, T. Ustaomer, M. Keskin, and N. Orbay (2016), Neotectonic deformation in the Eurasia-Arabia collision zone, the East Anatolian Plateau, E Turkey: evidence from palaeomagnetic study of Neogene-Quaternary volcanic rocks, International Journal of Earth Sciences, 105(1), 139-165.

Huang, K. N., and N. D. Opdyke (2016), Paleomagnetism of the Upper Triassic rocks from south of the Ailaoshan Suture and the timing of the amalgamation between the South China and the Indochina Blocks, Journal of Asian Earth Sciences, 119, 118-127.

Kasbohm, J., D. A. D. Evans, J. E. Panzik, M. Hofmann, and U. Linnemann (2016), Palaeomagnetic and geochronological data from Late Mesoproterozoic redbed sedimentary rocks on the western margin of Kalahari craton, in Supercontinent Cycles through

Earth History, edited by Z. X. Li, D. A. D. Evans and J. B. Murphy, pp. 145-165.

Keppie, F. (2016), How subduction broke up Pangaea with implications for the supercontinent cycle, in Supercontinent Cycles through Earth History, edited by Z. X. Li, D. A. D. Evans and J. B. Murphy, pp. 265-288.

Khokhlov, A., and G. Hulot (2016), Principal component analysis of palaeomagnetic directions: converting a Maximum Angular Deviation (MAD) into an alpha(95) angle, Geophysical Journal International, 204(1), 274-291.

Kilian, T. M., W. Bleeker, K. Chamberlain, D. A. D. Evans, and B. Cousens (2016), Palaeomagnetism, geochronology and geochemistry of the Palaeoproterozoic Rabbit Creek and Powder River dyke swarms: implications for Wyoming in supercraton Superia, in Supercontinent Cycles through Earth History, edited by Z. X. Li, D. A. D. Evans and J. B. Murphy, pp. 15-45.

Knott, T. R., M. J. Branney, M. K. Reichow, D. R. Finn, R. S. Coe, M. Storey, D. Barfod, and M. McCurry (2016), Mid-Miocene record of large-scale Snake River-type explosive volcanism and associated subsidence on the Yellowstone hotspot track: The Cassia Formation of Idaho, USA, Geological Society of America Bulletin, 128(7-8), 1121-1146.

Koc, A., D. J. J. van Hinsbergen, N. Kaymakci, and C. G. Langereis (2016), Late Neogene oroclinal bending in the central Taurides: A record of terminal eastward subduction in southern Turkey?, Earth and Planetary Science Letters, 434, 75-90.

Korte, M., and M. Mandea (2016), Geopotential field anomalies and regional tectonic features - two case studies: southern Africa and Germany, Solid Earth, 7(3), 751-768.

Koymans, M. R., C. G. Langereis, D. Pastor-Galan, and D. J. J. van Hinsbergen (2016), Paleomagnetism.org: An online multi-platform open source environment for paleomagnetic data analysis, Computers & Geosciences, 93, 127-137.

Li, Y. J., D. P. Wei, and Q. S. Liu (2016), Paleomagnetic constraints on plate tectonic process at south mid-Atlantic ridge, Chinese Journal of Geophysics-Chinese Edition, 59(5), 1705-1716.

Makvandi, S., M. Ghasemzadeh-Barvarz, G. Beaudoin, E. C. Grunsky, M. B. McClenaghan, and C. Duchesne (2016), Principal component analysis of magnetite composition from volcanogenic massive sulfide deposits: Case studies from the Izok Lake (Nunavut, Canada) and Halfmile Lake (New Brunswick, Canada) deposits, Ore Geology Reviews, 72, 60-85.

Mankinen, E. A., and C. M. Wentworth (2016), Paleomagnetic record determined in cores from deep research wells in the Quaternary Santa Clara basin, California, Geosphere, 12(1), 35-57.

Marton, E., D. Pavelic, A. Vranjkovic, and V. Cosovic (2016), Reappraisal of the palaeomagnetism of the Miocene intramontane Pag and Drnis-Sinj basins, External Dinarides (Croatia), Tectonophysics, 676, 125-134.

Meert, J. G., R. Van der Voo, and J. Patel (2016), A Neoarchean paleomagnetic pole from the Kisii Series of western Kenya: Implications for crustal mobility, Precambrian Research, 279, 91-102.

Morris, A., and M. Maffione (2016), yy Is the Troodos ophiolite (Cyprus) a complete, transform fault-bounded Neotethyan ridge segment?, Geology, 44(3), 199-202.

Morris, A., A. H. F. Robertson, M. W. Anderson, and E. Hodgson (2016), Did the Kyrenia Range of northern Cyprus rotate with the Troodos-Hatay microplate during the tectonic evolution of the eastern Mediterranean?, International Journal of Earth Sciences, 105(1), 399-415.

Murphy, J. B., C. Quesada, G. Gutierrez-Alonso, S. T. Johnston, and A. Weil (2016), Reconciling competing models for the tectonostratigraphic zonation of the Variscan orogen in Western Europe, Tectonophysics, 681, 209-219.

Niu, J. W., Z. X. Li, and W. G. Zhu (2016), Palaeomagnetism and geochronology of mid-Neoproterozoic Yanbian dykes, South China: implications for a c. 820-800 Ma true polar wander event and the reconstruction of Rodinia, in Supercontinent Cycles through Earth History, edited by Z. X. Li, D. A. D. Evans and J. B. Murphy, pp. 191-211.

Oda, H., C. Xuan, and Y. Yamamoto (2016), Toward robust deconvolution of pass-through paleomagnetic measurements: new tool to estimate magnetometer sensor response and laser interferometry of sample positioning accuracy, Earth Planets and Space, 68.

Oliva-Urcia, B., I. Gil-Pena, A. Maestro, J. Lopez-Martinez, J. Galindo-Zaldivar, R. Soto, A. Gil-Imaz, J. Rey, and O. Pueyo (2016), Paleomagnetism from Deception Island (South Shetlands archipelago, Antarctica), new insights into the interpretation of the volcanic evolution using a geomagnetic model, International Journal of Earth Sciences, 105(5), 1353-1370.

Paine, J., R. De Ritis, G. Ventura, M. Longo, D. Ravat, F. Speranza, and M. Chiappini (2016), Inverse modelling of the reversely magnetized, shallow plumbing system hosting oil reservoirs of the Auca Mahuida volcano (Payeina retroarc, Neuquen Basin, Argentina), Geophysical Journal International, 204(2), 852-867.

Panzik, J. E., D. A. D. Evans, J. J. Kasbohm, R. Hanson, W. Gose, and J. Desormeau (2016), Using palaeomagnetism to determine late Mesoproterozoic palaeogeographic history and tectonic relations of the Sinclair terrane, Namaqua orogen, Namibia, in Supercontinent Cycles through Earth History, edited by Z. X. Li, D. A. D. Evans and J. B. Murphy, pp. 119-143.

Pellegrino, A. G., R. Maniscalco, F. Speranza, C. Hernandez-Moreno, and G. Sturiale (2016), Paleomagnetism of the Hyblean Plateau, Sicily: a review of the existing data set and new evidence for lack of block rotation from the Scicli-Ragusa Fault System, Italian Journal of Geosciences, 135(2), 300-307.

Pisarevsky, S. A., G. Rosenbaum, U. Shaanan, D. Hoy, F. Speranza, and T. Mochales (2016), Paleomagnetic and geochronological study of Carboniferous forearc basin rocks in the Southern New England Orogen (Eastern Australia), Tectonophysics, 681, 263-277.

Rodriguez-Pinto, A., E. L. Pueyo, P. Calvin, E. Sanchez, J. Ramajo, A. M. Casas, M. J. Ramon, A. Pocovi, A. Barnolas, and T. Roman (2016), Rotational kinematics of a curved fold: The Balzes anticline (Southern Pyrenees), Tectonophysics, 677, 171-189.

Sagnotti, L., B. Giaccio, J. C. Liddicoat, S. Nomade, P. R. Renne, G. Scardia, and C. J. Sprain (2016), How fast was the Matuyama-Brunhes geomagnetic reversal? A new subcentennial record from the Sulmona Basin, central Italy, Geophysical Journal International, 204(2), 798-812.

Salminen, J. M., R. Klein, S. Mertanen, L. J. Pesonen, S. Frojdo, I. Manttari, and O. Eklund (2016), Palaeomagnetism and U-Pb geochronology of c. 1570 Ma intrusives from Aland archipelago, SW - Finland implications for Nuna, in Supercontinent Cycles through Earth History, edited by Z. X. Li, D. A. D. Evans and J. B. Murphy, pp. 95-118.

Sandjo, A. F. Y., T. Njanko, E. Njonfang, E. Errami, P. Rochette, and E. Fozing (2016), Transpressional granite-emplacement model: Structural and magnetic study of the Pan-African Bandja granitic pluton (West Cameroon), Journal of Earth System Science, 125(1), 179-202.

Schillinger, W. E., E. R. Morris, R. S. Coe, and D. R. Finn (2016), Development of a 0.5 T magnetic-core alternating-field demagnetizer, Geochemistry Geophysics Geosystems, 17(4), 1283-1295.

Stojanovic, D., J. C. Aitchison, J. R. Ali, T. Ahmad, and R. A. Dar (2016), Paleomagnetic investigation of the Early Permian Panjal Traps of NW India; regional tectonic implications, Journal of Asian Earth Sciences, 115, 114-123.

Torres-Carrillo, X. G., L. A. Delgado-Argote, H. Bohnel, R. S. Molina-Garza, and B. Weber (2016), Palaeomagnetic assessment of plutons from the southern Peninsular Ranges batholith and the Jurassic Vizcaino igneous suites, Baja California, Mexico, International Geology Review, 58(4), 489-509.

Tsuchiyama, Y., H. Zaman, S. Sotham, Y. Samuth, E. Sato, H. S. Ahn, K. Uno, K. Tsumura, M. Miki, and Y. Otofuji (2016), Paleomagnetism of Late Jurassic to Early Cretaceous red beds from the Cardamom Mountains, southwestern Cambodia: Tectonic deformation of the Indochina Peninsula, Earth and Planetary Science Letters, 434, 274-288.

van Hinsbergen, D. J. J., et al. (2016), Tectonic evolution and paleogeography of the Kirsehir Block and the Central Anatolian Ophiolites, Turkey, Tectonics, 35(4), 983-1014.

Vernikovsky, V. A., D. V. Metelkin, A. E. Vernikovskaya, N. Y. Matushkin, A. Y. Kazansky, P. I. Kadilnikov, I. V. Romanova, M. T. D. Wingate, A. N. Larionov, and N. V. Rodionov (2016), Neoproterozoic tectonic structure of the Yenisei Ridge and formation of the western margin of the Siberian craton based on new geological, paleomagnetic, and geochronological data, Russian Geology and Geophysics, 57(1), 47-68.

Veselovskiy, R. V., M. L. Bazhenov, and A. A. Arzamastsev (2016), Paleomagnetism of Devonian dykes in the northern Kola Peninsula

and its bearing on the apparent polar wander path of Baltica in the Precambrian, Tectonophysics, 675, 91-102.

von Lichtan, I. J., J. D. L. White, V. Manville, and C. Ohneiser (2016), Giant rafted pumice blocks from the most recent eruption of Taupo volcano, New Zealand: Insights from palaeomagnetic and textural data, Journal of Volcanology and Geothermal Research, 318, 73-88.

Wang, H. H., J. H. Li, H. T. Zhang, L. Xu, and W. B. Li (2016), The absolute paleoposition of the North China Block during the Middle Ordovician, Science China-Earth Sciences, 59(3), 573-582.

Weil, A. B., A. Yonkee, and M. Schultz (2016), Tectonic evolution of a Laramide transverse structural zone: Sweetwater Arch, south central Wyoming, Tectonics, 35(5), 1090-1120.

Wilson, P. I. R., K. J. W. McCaffrey, R. W. Wilson, I. Jarvis, and R. E. Holdsworth (2016), Deformation structures associated with the Trachyte Mesa intrusion, Henry Mountains, Utah: Implications for sill and laccolith emplacement mechanisms, Journal of Structural Geology, 87, 30-46.

Zhang, T., W. X. Han, X. M. Fang, W. L. Zhang, C. H. Song, and M. D. Yan (2016), Intensified tectonic deformation and uplift of the Altyn Tagh range recorded by rock magnetism and growth strata studies of the western Qaidam Basin, NE Tibetan Plateau, Global and Planetary Change, 137, 54-68.

Zhdanova, A. I., D. V. Metelkin, V. A. Vernikovsky, and N. Y. Matushkin (2016), The first paleomagnetic data on dolerites from Jeannette Island (New Siberian Islands, Arctic), Doklady Earth Sciences, 468(2), 580-583.

Zhou, Y. N., et al. (2016), Paleomagnetic study on the Triassic rocks from the Lhasa Terrane, Tibet, and its paleogeographic implications, Journal of Asian Earth Sciences, 121, 108-119.

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.

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.

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.

Ganguli, S. S., G. K. Nayak, N. Vedanti, and V. P. Dimri (2016), A regularized Wiener-Hopf filter for inverting models with magnetic susceptibility, Geophysical Prospecting, 64(2), 456-468.

Harrouchi, L., M. Hamoudi, A. Bendaoud, and L. Beguiret (2016), Application of 3D Euler deconvolution and improved tilt angle to the aeromagnetic data of In Ouzzal terrane, western Hoggar, Algeria, Arabian Journal of Geosciences, 9(7).

Hartmann, L. A., J. F. Savian, and W. R. Lopes (2016), Airborne geophysical characterization of geotectonic relationships in the southern Ribeira Belt, Luis Alves Craton, and northern Dom Feliciano Belt, Brazilian Shield, International Geology Review, 58(4), 471-488.

Khojamli, A., F. D. Ardejani, A. Moradzadeh, A. N. Kalate, A. R. Kahoo, and S. Porkhial (2016), Estimation of Curie point depths and heat flow from Ardebil province, Iran, using aeromagnetic data, Arabian Journal of Geosciences, 9(5).

Kosaroglu, S., A. Buyuksarac, and A. Aydemir (2016), Modeling of shallow structures in the Cappadocia region using gravity and aeromagnetic anomalies, Journal of Asian Earth Sciences, 124, 214-226.

Lamri, T., S. Djemai, M. Hamoudi, B. Zoheir, A. Bendaoud, K. Ouzegane, and M. Amara (2016), Satellite imagery and airborne geophysics for geologic mapping of the Edembo area, Eastern Hoggar (Algerian Sahara), Journal of African Earth Sciences, 115, 143-158.

Langenheim, V. E., R. C. Jachens, L. J. P. Muffler, and M. A. Clynne (2016), Implications for the structure of the Hat Creek fault and transfer of right-lateral shear from the Walker Lane north of Lassen Peak, northern California, from gravity and magnetic data, Geosphere, 12(3), 790-808.

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.

Nguyen, L. C., and P. Mann (2016), Gravity and magnetic constraints on the Jurassic opening of the oceanic Gulf of Mexico and the location and tectonic history of the Western Main transform fault along the eastern continental margin of Mexico, Interpretation-a Journal of Subsurface Characterization, 4(1), SC23-SC33.

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.

Oladunjoye, M. A., A. I. Olayinka, M. Alaba, and M. A. Adabanija (2016), Interpretation of high resolution aeromagnetic data for lineaments study and occurrence of Banded Iron Formation in Ogbomoso area, Southwestern Nigeria, Journal of African Earth Sciences, 114, 43-53.

Pal, S. K., J. Vaish, S. Kumar, and A. K. Bharti (2016), Coal fire mapping of East Basuria Colliery, Jharia coalfield using vertical derivative technique of magnetic data, Journal of Earth System Science, 125(1), 165-178.

Paoletti, V., S. Gruber, N. Varley, M. D'Antonio, R. Supper, and K. Motschka (2016), Insights into the Structure and Surface Geology of Isla Socorro, Mexico, from Airborne Magnetic and Gamma-Ray Surveys, Surveys in Geophysics, 37(3), 601-623.

Perez-Perez, A. R., H. E. Romero, and L. D'Onofrio (2016), A statistical and graphical workflow for the analysis of magnetic susceptibility data from drill cuttings in a hydrocarbon exploration setting, Geophysics, 81(2), J35-J46.

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.

Salem, A., and M. Y. Ali (2016), Mapping basement structures in the northwestern offshore of Abu Dhabi from high-resolution aeromagnetic data, Geophysical Prospecting, 64(3), 726-740.

Sheibi, M., H. Mirnejad, and M. P. Moghaddam (2016), Magnetic susceptibility anisotropy as a predictive exploration tool of metasomatic iron oxide deposits: Example from the Panj-Kuh iron ore body, NE Iran, Ore Geology Reviews, 72, 612-628.

Tontini, F. C., C. E. J. de Ronde, B. J. Scott, S. Soengkono, V. Stagpoole, C. Timm, and M. Tivey (2016), Interpretation of gravity and magnetic anomalies at Lake Rotomahana: Geological and hydrothermal implications, Journal of Volcanology and Geothermal Research, 314, 84-94.

Wang, Y. G., J. Zhang, K. P. Ge, X. Chen, and F. J. Nie (2016), Improved tilt-depth method for fast estimation of top and bottom depths of magnetic bodies, Applied Geophysics, 13(2), 249-256.

Weidmann, C., M. Gimenez, F. L. Klinger, and O. Alvarez (2016), Anomalous values of gravity and magnetism in the western margin of Gondwana, Tectonophysics, 667, 1-15.

Xiong, S. Q., J. Tong, Y. Y. Ding, and Z. K. Li (2016), Aeromagnetic data and geological structure of continental China: A review, Applied Geophysics, 13(2), 227-237.

Yan, T. J., Y. G. Wu, Y. Yuan, and L. N. Chen (2016), Edge detection of potential field data using an enhanced analytic signal tilt angle, Chinese Journal of Geophysics-Chinese Edition, 59(7), 2694-2702.

Stratigraphy

Ahn, H. S., T. Kidane, Y. Yamamoto, and Y. Otofuji (2016), Low geomagnetic field intensity in the Matuyama Chron: palaeomagnetic study of a lava sequence from Afar depression, East Africa, Geophysical Journal International, 204(1), 127-146.

Andronikov, A. V., I. E. Andronikova, C. W. Loehn, B. Lafuente, J. A. M. Ballenger, G. T. Crawford, and D. S. Lauretta (2016), Implications from chemical, structural and mineralogical studies of magnetic microspherules from around the lower Younger Dryas boundary (New Mexico, USA), Geografiska Annaler Series a-Physical Geography, 98(1), 39-59.

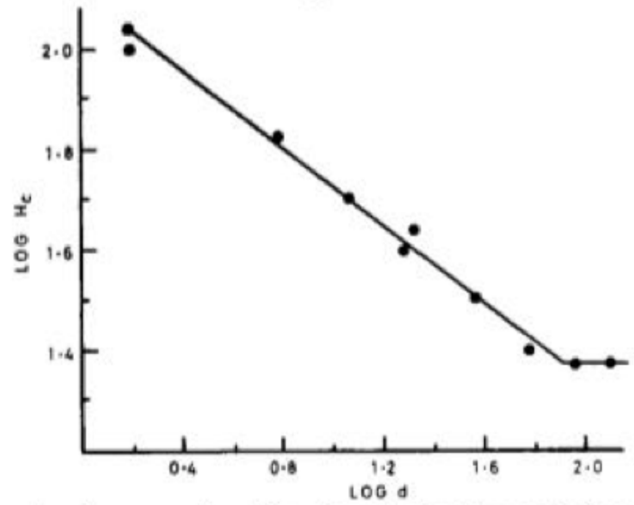
Bazhenov, M. L., N. M. Levashova, J. G. Meert, I. V. Golovanova, K. N. Danukalov, and N. M. Fedorov (2016), Late Ediacaran magnetostratigraphy of Baltica: Evidence for Magnetic Field Hyperactivity?, Earth and Planetary Science Letters, 435, 124-135.

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.

Duan, Z. Q., Q. S. Liu, X. F. Shi, Z. Q. Yao, J. X. Liu, and K. Su (2016), Reconstruction of high-resolution magnetostratigraphy of the Changjiang (Yangtze) River Delta, China, Geophysical Journal International, 204(2), 948-960.

Liu, J. X., Q. S. Liu, X. H. Zhang, J. Liu, Z. Q. Wu, X. Mei, X. F. Shi, and Q. H. Zhao (2016), Magnetostratigraphy of a long Quaternary sediment core in the South Yellow Sea, Quaternary Science Reviews, 144, 1-15.

cont'd. from pg. 1...



Coercive force as a function of grain size (logarithmic plot).

Fig. 2 The power relation between coercivity and grain-size determined by Parry (1965) confirmed Stacey's theory albeit the annealing beforehand yielded magnetically softer titanomagnetites.

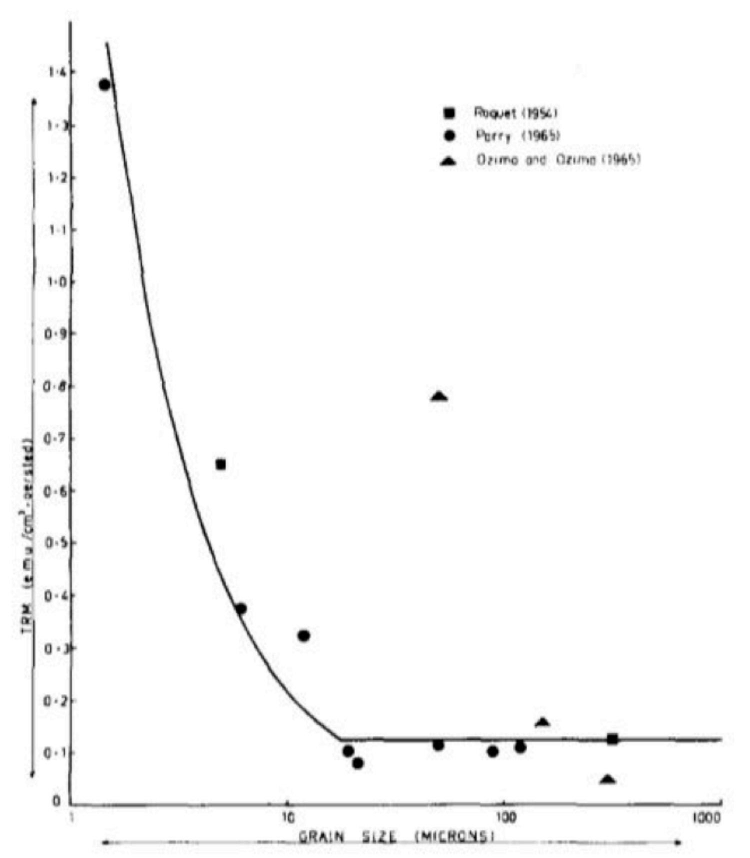


Fig. 3 Dickson et al.'s Fig. 1 combining Roquet (1954)'s, Parry (1965)'s and Ozima and Ozima (1965)'s thermoremanent magnetisation (TRM) vs grain-size results showing the abrupt onset of multidomain behaviour above 20 µm where TRM is no longer a function of grain-size or coercivity.

The translation balance had two interesting applications resulting directly from his ANU contacts. One was with John Lovering, a geochemist with a special interest in meteorites, which had magnetic remanences apparently predating their arrival on the Earth. Parry's role was to identify the Fe-Ni alloy phases, evolution of which during cooling controlled the remanences. Another ANU collaborator was Ted Irving, who was establishing the polar wander path for Australia. Irving had found rocks near Kiama, south of Sydney in NSW, which had consistently reversed remanence over a 50 million year age range. We now know of this as the Kiaman reverse superchron, but its plausibility was subject to some doubt at the time. One of the contrary postulates was that there was a subtle but systematic difference between the magnetic constituents of reversed and normally magnetised rocks, allowing the possibility of self-reversing remanence by one of the mechanisms suggested by Louis Néel. Parry's measurements on Irving's rocks showed no such effect.

For the second crucial sabbatical in 1964, in Newcastle, Parry joined what was then the strongest rock magnetism group anywhere, led by Keith Runcorn. By then the phenomenon of thermoremanence had been quite intensively observed but the theory was lagging. A satisfying interpretation of its grain size dependence was still needed and a basic difficulty was that there were no well controlled experiments that made clear just what the dependence was. Parry filled the gap by using an elutriator to separate magnetite grains of different sizes and dispersing them in a non-magnetic matrix to simulate rocks for which he measured all the standard properties, including thermoremanence. The result was a data set that became a standard reference for magnetic properties of dispersed fine grains. It clearly identified the range of grain sizes displaying pseudo-single domain properties, resolving the question of what distinguishes the grains that are responsible for most of the magnetically stable rocks from the single domains of Néel's pioneering theory and true multidomains. During this time Lin wrote, and Margaret typed, his PhD thesis which was awarded by UNSW in 1965.

Lin's third sabbatical in 1972 was with Rod Wilson's group, Liverpool University, where he continued studying the magnetic properties of fine particles using Rod's vast sample collection from young lavas and dykes.

By nature, Lin Parry was a collaborator, disinclined to emphasise what he, himself, was doing. He saw the physical problems that arose in other people's work and applied his experimental skills to resolving them. The names of graduate students he supervised later in his career are distributed through the literature with little indication of his role in inspiring their work. The following list of publications is far from comprehensive but gives an idea of the developments of his research interest through the years, from beach sands and meteorites to common garden rocks, while at the same time focussed very much on the magnetisation of micron to sub-micron titanomagnetite particles. Lin characteristically assumed junior authorship in publications with his students.

Curnow, C.E., Parry, L.G., 1954. Oxidation changes in natural ilmenite. Nature, 1954, Vol.174(4441), p.1101.

Lovering, J.F., Parry, L.G. and Jaeger, J.C., 1960. Temperatures and mass losses in iron meteorites during ablation in the earth's atmosphere. Geochimica et

Fig. 4 Lin with his post-grad students in 1971. Clockwise beginning left front, A.A. Rahman (MSc PhD), L.G. Little (MSc), M.F. Westcott-Lewis (MSc PhD), A.D. Duncan (MSc) and B.W. Robins (PhD).

Cosmochimica Acta, 1960, Vol.19(3), pp.159-158.

Lovering, J.F. and Parry, L.G., 1962. Thermomagnetic analysis of co-existing nickel-iron metal phases in iron meteorites and the thermal histories of the meteorites. Geochimica et Cosmochimica Acta, 1962, Vol.26(3), pp.361-382.

Parry, L.G., 1965. Magnetic properties of dispersed magnetite inclusion of high Curie point within a titanomagnetite powders. Philos. Mag., 11: 303—312.

Dickson, G.O., Everitt, C.W.F., Parry, L.G. and Stacey, F.D., 1966. Origin of thermoremanent magnetization. Earth and Planetary Science Letters, 1966, Vol.1(4), pp.222-224.

Westcott-Lewis, M.F. and Parry, L.G., 1971. Thermoremanence in synthetic rhombohedral iron—titanium oxides. Aust. J. Phys., 24: 735—742.

Rahman, A.A., Duncan, A.D. and Parry, L.G., 1973. Magnetization of multidomain magnetite particles. Riv. Ital. Geofis., 22: 259—266.

Rahman, A.A. and Parry, L.G., 1978. Titanomagnetites prepared at different oxidation conditions: Hysteresis properties. Physics of the Earth and Planetary Interiors, 1978, Vol.16(3), pp.232-239.

Parry, L.G., 1975. Magnetization of Micron Sized Magnetite Particles. Australian Journal of Physics 28(6) 693 - 706

Rahman, A.A. and Parry, L.G., 1975. Self shielding of inclusions in titanomagnetite grains. Physics of the Earth and Planetary Interiors, 1975, Vol.11(2), pp.139-146.

Parry, L.G., 1979. Magnetization of multidomain particles of magnetite. Physics of the Earth and Planetary Interiors, 1979, Vol.19(1), pp.21-30.

Parry, L.G., 1980. Shape-related factors in the magnetization of immobilized magnetite particles.
Physics of the Earth and Planetary Interiors, 1980, Vol.22(2), pp.144-154.

Rahman, A.A. and Parry, L.G., 1980. Titanomagnetites prepared at different oxidation conditions: Influence of magnetite-rich inclusions. Physics of the Earth and Planetary Interiors, 1980, Vol.21(1), pp.15-21.

Parry, L.G., 1981. The influence of fine structures on the remanence of multidomain particles of magnetite and titanomagnetite. Physics of the Earth and Planetary Interiors, 1981, Vol.26(1), pp.63-71.

Hao, Jin-Qi, Parry, L.G., Tuck, G.J. and Stacey, F.D., 1982. The piezomagnetic effect in rocks: a comparison of measurements in high and low fields. Physics of the Earth and Planetary Interiors, 1982, Vol.29(2), pp.173-182.

Parry, L.G., 1982. Magnetization of immobilized particle dispersions with two distinct particle sizes. Physics of the Earth and Planetary Interiors, 1982, Vol.28(3), pp.230-241.

Acknowledgements

I should like to acknowledge information and photos provided to me by Lin's son Graham and Frank Stacey. The main photograph was provided to Graham from the UNSW Archives.

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