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Inside...

Report on the 12th IRM Conference on Rock Magnetism

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The 12th IRM Conference on Rock Magnetism was held June 1st- 4th. The pandemic prevented an in-person meeting, and so we too had to adapt to the new virtual reality. In keeping with tradition, the conference format was kept the same as our in-person Santa Fe meetings, having no concurrent sessions, limiting the number of oral presentations, by invitation only, and leaving ample room for discussion. Also per tradition, two keynote speakers from disciplines (typically) other than rock-magnetism but of relevance to our community were invited. The keynote talks are designed to be more in-depth than the regular session talks, and a total of one hour is scheduled for the talks and Q&A. Moreover, these are linked directly to at least two of the topical sessions, and should therefore provide a broader background and complimentary information in hopes of fostering a more stimulating discussion.

Based on current trends, IRM personnel agreed on the four topical sessions and invited their conveners, after which it was left entirely to the conveners to "shape" the sessions and extend invitations to the speakers of their choice. This year's sessions were:

- **Anisotropy and Applications**, convened by **Suzanne McEnroe** (NTNU, Norway) & **France Lagroix** (IPGP, France);
- **Environmental Magnetism and Proxies**, convened by **Andrew Roberts** (ANU, Australia) & **Anna Lindquist** (Macalester College, USA);
- **Speleothem Magnetism**, convened by: **Ricardo Trindade** (Universidade de São Paulo) & **Joshua Feinberg** (Institute for Rock Magnetism, University of Minnesota); and
- **Advances in Instrumentation and Methods**, convened by **Julie Bowles** (University of Wisconsin – Milwaukee) & **Sonia Tikoo** (Stanford).

Additionally, two virtual poster sessions were held, with voluntary presentations from participants roughly subdivided by topics. Breaking with tradition, however, we allowed a larger number of participants to register, and in fact, given the success and the fact that more people had been trickling in regardless, we reopened the registration after the first day of conference (cyber-security is no joke). A typical Santa Fe conference is capped at 50 participants to maintain an intimate environment that will foster discussion and a collegial atmosphere, how-

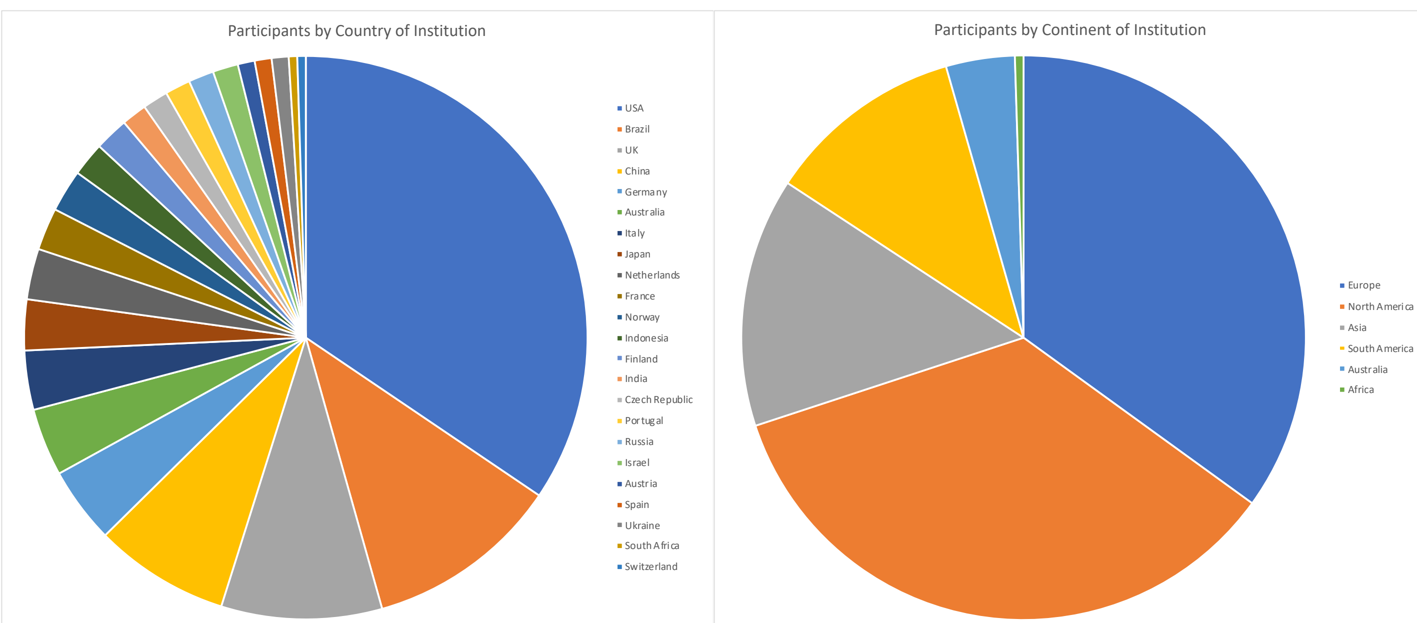

Figure 1. Conference participants demographics: the left panel shows a pie chart of the number participants by their institutions' country, for a total of 23 countries world-wide, whereas the right panel shows the number of participants subdivided by their institutions' continent (6), with an equal share of US and European participants (71), 29 participants from Asia, 23 from South America, 8 from Australia and 1 from Africa.

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Visiting Fellow Reports

Magnetic properties as a function of fluid-rock interaction at plate boundary shear zones

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Fluid circulation and its interaction with the wall-rocks along plate boundary shear zones strongly influence the mechanisms of deformation during the seismic cycle (Sibson, 2013). The circulation of hot fluids commonly triggers thermochemical transformations producing changes in the magnetic properties (Yang et al., 2020). In addition, frictional heating can result in thermal generation of neoformed magnetic minerals, such as magnetite and pyrrhotite.

I am interested in characterizing the magnetic properties of samples from thrust wall-rocks of an exhumed analogue of the shallower portion ($T_{max} \approx$ 100-150 °C) of an actual plate boundary (Vannucchi et al., 2008), cropping out in the Northern Apennines, Italy. Here, geochemical composition of tectonic veins suggested changes in permeability and drainage of deeper hot exotic fluids in disequilibrium with the fault zone during the main seismic event (Cerchiari et al., 2020).

Low temperature experiments were conducted to characterize the magnetic mineralogy and resolve the entity of fluid-rock interaction. Susceptibility versus temperature (χ–T) cycles, in argon, were performed to estimate the frictional-heating experienced during the main seismic events (Yang et al., 2016). Repeated stepwise heating at increasing maximum temperatures was focused on the range 150 to 350 °C to infer the thermochemical conditions associated with fluid circulation and neoformation of magnetic minerals.

Field-cooled (FC) and zero field-cooled (ZFC) remanence curves suggest variable assemblage of magnetite and goethite. The Verwey transition of magnetite varies from well developed (Figure 1a) to faint (Figure 1b) and occurs at 124 K, in agreement with most sedimentary rocks (Jackson and Moskowitz, 2020). RT-SIRM with a continuous increment in magnetization from 300 to 10 K and a very slight drop around 120 K confirm the presence of both magnetite and goethite. Variations were observed in proximity to the main thrusts suggesting a correlation between goethite formation and the circulation of hot aqueous fluids during the co-seismic phase (Cho et al., 2012). Correlations with the degree of lithification and porosity were also observed, but further analyses are necessary to understand the fluid paths and the alteration induced in the wall rocks.

χ–T cycles are reversible up to a maximum temperature of 350 °C (Figure 1c). The magnetic susceptibility sharply increases around 350-400 °C and then becomes zero at about 600 °C. Significant increase of χ in the cooling curves suggests the thermal decomposition of iron-bearing paramagnetic minerals such as Pyrite or clay minerals (Tanikawa et al., 2008). The maximum heating primary signature might be around 350 °C, since above this temperature sediments become thermally altered.

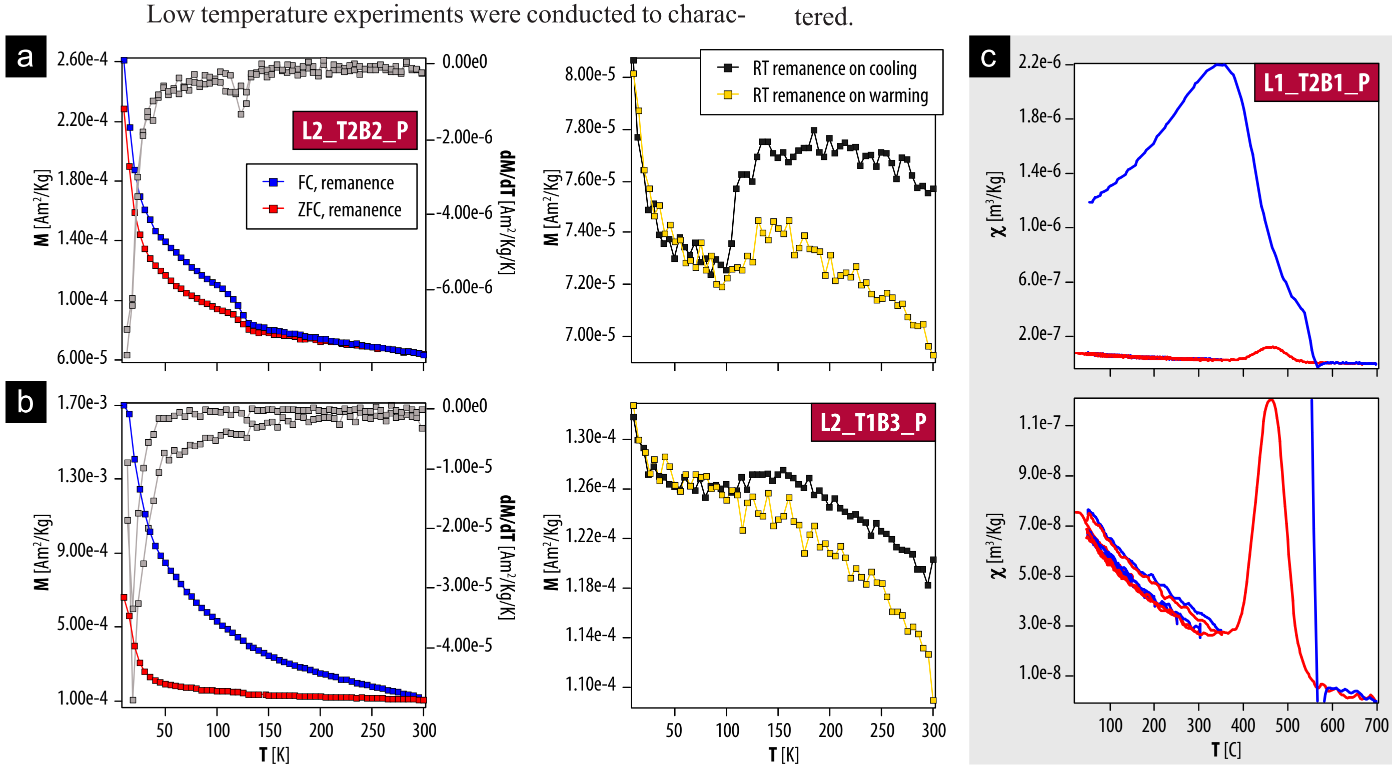

Figure 1. Representatives FC-ZFC and RTSIRM remanence curves suggesting the presence of magnetite (a) and goethite (b); (c) Example of c–T cycles measured on heating (red) and cooling (blue) with relative detail.

Acknowledgements

I would like to thank Dario Bilardello for performing the measurements on my behalf and for the great support in the interpretation of results, despite the difficult current situation of COVID-19 virus. Max Brown, Joshua Feinberg, Bruce Moskowitz and Peat Solheid are thanked for helpful discussions and advices on further experiments.

References

Cerchiari, A., Remitti, F., Mittempergher, S., Festa, A., Lugli, F., Cipriani, A., 2020. Cyclical variations of fluid sources and stress state in a shallow megathrust-zone mélange. Journal of the Geological Society 177, 647–659. https://doi.org/10.1144/jgs2019-072.

Chou, Y.-M., Song, S.-R., Aubourg, C., Lee, T.-Q., Boullier, A.-M., Song, Y.-F., Yeh, E.-C., Kuo, L.-W., Wang, C.-Y., 2012. An earthquake slip zone is a magnetic recorder. Geology 40, 551–554. https://doi.org/10.1130/G32864.1 .

Jackson, M.J., Moskowitz, B., 2020. On the distribution of Verwey transition temperatures in natural magnetites. Geophysical Journal International 224, 1314–1325. https://doi.org/10.1093/gji/ggaa516.

Sibson, R.H., 2013. Stress switching in subduction forearcs: Implications for overpressure containment and strength cycling on megathrusts. Tectonophysics 600, 142–152. https://doi.org/10.1016/j.tecto.2013.02.035.

Tanikawa, W., Mishima, T., Hirono, T., Soh, W., Song, S.-R., 2008. High magnetic susceptibility produced by thermal decomposition of core samples from the Chelungpu fault in Taiwan. Earth and Planetary Science Letters 272, 372–381. https://doi.org/10.1016/j.epsl.2008.05.002.

Vannucchi, P., Remitti, F., Bettelli, G., 2008. Geological record of fluid flow and seismogenesis along an erosive subducting plate boundary. Nature 451, 699–703. https://doi.org/10.1038/nature06486.

Yang, T., Dekkers, M.J., Zhang, B., 2016. Seismic heating signatures in the Japan Trench subduction plate-boundary fault zone: evidence from a preliminary rock magnetic 'geothermometer.' Geophys. J. Int. 205, 319–331. https://doi.org/10.1093/gji/ggw013.

Yang, T., Chou, Y., Ferré, E.C., Dekkers, M.J., Chen, J., Yeh, E., Tanikawa, W., 2020. Faulting Processes Unveiled by Magnetic Properties of Fault Rocks. Rev. Geophys. 58. https://doi.org/10.1029/2019RG000690.

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.

Archaeomagnetism

Biltekin, D., K. K. Eris, and S. Bulut (2021), Anthropogenic influences and climate changes in Lake Hazar (eastern Turkey) during the Late Holocene, Quaternary International, 583, 70-82, doi:10.1016/j.quaint.2021.02.023.

Bradak, B., A. Carrancho, A. H. Lagunilla, J. J. Villalain, G. F. Monnier, G. Tostevin, C. Mallol, G. Pajovic, M. Bakovic, and N. Borovinic (2021), Magnetic fabric and archaeomagnetic analyses of anthropogenic ash horizons in a cave sediment succession (Crvena Stijena site, Montenegro), Geophysical Journal International, 224(2), 795-812, doi:10.1093/gji/ggaa461.

Deenadayalan, K., P. B. Gawali, B. V. Lakshmi, and M. Rai (2020), Rock-magnetic and archaeomagnetic investigations on archaeological artefacts from Maharashtra, India, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 9-26, doi:10.1144/sp497-2019-119.

Kitahara, Y., D. Nishiyama, M. Ohno, Y. Yamamoto, Y. Kuwahara, and T. Hatakeyama (2021), Construction of new archaeointensity reference curve for East Asia from 200 CE to 1100 CE, Physics of the Earth and Planetary Interiors, 310, doi:10.1016/j.pepi.2020.106596.

Kostadinova-Avramova, M., M. Kovacheva, Y. Boyadzhiev, and G. Herve (2020), Archaeomagnetic knowledge of the Neolithic in Bulgaria with emphasis on intensity changes, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 89-111, doi:10.1144/sp497-2019-48.

Kosterov, A., M. Kovacheva, M. Kostadinova-Avramova, P. Minaev, N. Salnaia, L. Surovitskii, S. Yanson, E. Sergienko, and P. Kharitonskii (2021), High-coercivity magnetic minerals in archaeological baked clay and bricks, Geophysical Journal International, 224(2), 1257-1272, doi:10.1093/gji/ggaa508.

Principe, C., and J. Malfatti (2020), Giuseppe Folgheraiter: the italian pioneer of archaeomagnetism, Earth Sciences History, 39(2), 305-335, doi:10.17704/1944-6187-39.2.305.

Smekalova, T., B. Bevan, M. Kashuba, F. Lisetskii, A. Borisov, and N. Kashirskaya (2021), Magnetic surveys locate Late Bronze Age corrals, Archaeological Prospection, 28(1), 3-16, doi:10.1002/arp.1789.

Turner, G. M., R. Kinger, B. McFadgen, and M. Gevers (2020), The first archaeointensity records from New Zealand: evidence for a fifteenth century AD archaeomagnetic 'spike' in the SW Pacific Region?, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 47-72, doi:10.1144/sp497-2019-71.

Zheng, Y., H. B. Zheng, Q. Y. Guo, Q. Yang, Z. J. Hu, X. Y. Yao, X. Y. Zhou, K. L. Zhao, X. Q. Li, and C. L. Deng (2021), Dating the Hemudu Neolithic rice cultivation site, East China, by paleomagnetic chronostratigraphy, Palaeogeography Palaeoclimatology Palaeoecology, 569, doi:10.1016/j.palaeo.2021.110297.

Environmental Magnetism

Ameur, M. B., S. Masmoudi, and C. Yaich (2021), Flood and sandstorm events recorded in holocene sebkha deposits in Southeastern Tunisia: Evidence from magnetic and geochemical properties, Quaternary International, 571, 46-57, doi:10.1016/j.quaint.2020.09.006.

Badesab, F., Gaikwad, V., Nagender Nath, B., Venkateshwarlu, M., Aiswarya, P.V., Tyagi, A., Salunke, K., Fernandes, W., Kadam, N., Sangode, S.J., Sardar, A., and G. Prabhu (2021), Controls of contrasting provenance and fractionation on the sediment magnetic records from the Bay of Bengal, Marine Geology 437 (2021) 106515, https://doi.org/10.1016/j.margeo.2021.106515

Badesab, F., Mascarenhas-Periera, M.B.L., Gaikwad, V., Dewangan, P., Panda, P.P., Deenadayalan, K., Salunke, K., Augastian, B., Patil, J.R., and B.V. Lakshmi (2021), Rock magnetic evidence of tectonic control on the sedimentation and diagenesis in the Andaman Sea over ~1 million years, Marine and Petroleum Geology 130 (2021) 105150, https://doi.org/10.1016/j.marpetgeo.2021.105150

Beaver, C. L., E. A. Atekwana, B. A. Bekins, D. Ntarlagiannis, L. D. Slater, and S. Rossbach (2021), Methanogens and Their Syntrophic Partners Dominate Zones of Enhanced Magnetic Susceptibility at a Petroleum Contaminated Site, Frontiers in Earth Science, 09, doi:10.3389/feart.2021.598172.

Bradak, B., et al. (2021), Late Pleistocene paleosol formation in a dynamic aggradational microenvironment - A case study from the Mala nad Hronom loess succession (Slovakia), Catena, 199, doi:10.1016/j.catena.2020.105087.

Bradak, B., Y. Seto, T. Stevens, G. Ujvari, K. Feher, and C. Koltringer (2021), Magnetic susceptibility in the European Loess Belt: New and existing models of magnetic enhancement in loess, Palaeogeography Palaeoclimatology Palaeoecology, 569, doi:10.1016/j.palaeo.2021.110329.

D'Arcangelo, S., F. Martin-Hernandez, and J. M. Pares (2021), Magnetic properties of cave sediments at Gran Dolina site in Sierra de Atapuerca (Burgos, Spain), Quaternary International, 583, 1-13, doi:10.1016/j.quaint.2021.02.041.

De la Rosa, R., M. Aldana, V. Costanzo-Alvarez, S. Yepez, and C. Amon (2021), The surface expression of hydrocarbon seeps characterized by satellite image spectral analysis and rock magnetic data (Falcon basin, western Venezuela), Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.103036.

Flores, H., S. Lorenz, R. Jackisch, L. Tusa, I. C. Contreras, R. Zimmermann, and R. Gloaguen (2021), UAS-Based Hyperspectral Environmental Monitoring of Acid Mine Drainage Affected Waters, Minerals, 11(2), doi:10.3390/min11020182.

Fu, R. R., K. Hess, P. Jaqueto, V. F. Novello, T. Kukla, R. I. F. Trindade, N. M. Strikis, F. W. Cruz, and O. Ben Dor (2021), High-Resolution Environmental Magnetism Using the Quantum Diamond Microscope (QDM): Application to a Tropical Speleothem, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.604505.

Gaikwad, V., Badesab, F., Dewangan, P., and Kotha, M. (2021), Diagenesis of Magnetic Minerals in Active/Relict Methane Seep: Constraints From Rock Magnetism and Mineralogical Records From Bay of Bengal, Front. Earth Sci. 9:638594, doi: 10.3389/feart.2021.638594.

Grabowski, J., A. Chmielewski, I. Ploch, M. Rogov, J. Smolen, P. Wojcik-Tabol, K. Leszczynski, and K. Maj-Szeliga (2021), Palaeoclimatic changes and inter-regional correlations in the Jurassic/Cretaceous boundary interval of the Polish Basin: portable XRF and magnetic susceptibility study, Newsletters on Stratigraphy, 54(2), 123-158, doi:10.1127/nos/2020/0600.

Grachev, A. M., et al. (2021), The Holocene paleoenvironmental history of Western Caucasus (Russia) reconstructed by multi-proxy analysis of the continuous sediment sequence from Lake Khuko, Holocene, 31(3), 368-379, doi:10.1177/0959683620972782.

Greve, A., M. Kars, and M. J. Dekkers (2021), Fluid Accumulation, Migration and Anaerobic Oxidation of Methane Along a Major Splay Fault at the Hikurangi Subduction Margin (New Zealand): A Magnetic Approach, Journal of Geophysical Research-Solid Earth, 126(2), doi:10.1029/2020jb020671.

Groves, M., A. R. Brunelle, M. J. Power, K. L. Petersen, and Z. J. Lundeen (2021), Late-Holocene seasonal moisture variability: Range Creek Canyon, Utah, USA, Holocene, 31(3), 356-367, doi:10.1177/0959683620972769.

Harshavardhana, B. G., and R. Shankar (2021), Topographical influence on pedogenesis - Insights from Rock Magnetism, Catena, 198, doi:10.1016/j.catena.2020.105013.

Hillman, A. L., A. Yao, M. S. Finkenbinder, and M. B. Abbott (2021), A 17,000-year multi-proxy study of the Indian Summer Monsoon from Lake Dian, Yunnan, China, Palaeogeography Palaeoclimatology Palaeoecology, 567, doi:10.1016/j.palaeo.2021.110292.

Hounslow, M. W., K. T. Ratcliffe, S. E. Harris, J. Nawrocki, K. Wojcik, P. Montgomery, and N. H. Woodcock (2021c), The Telychian (early Silurian) oxygenation event in northern Europe: A geochemical and magnetic perspective, Palaeogeography Palaeoclimatology Palaeoecology, 567, doi:10.1016/j.palaeo.2021.110277.

Hua, H., X. Yin, J. A. Dyer, R. Landis, and L. Axe (2020), Characterizing Reactive Iron Mineral Coatings in Redox Transition Zones, Acs Earth and Space Chemistry, 4(12), 2337-2346, doi:10.1021/acsearthspacechem.0c00233.

Jablonska, M., M. Rachwal, M. Wawer, M. Kadziolka-Gawel, E. Teper, T. Krzykawski, and D. Smolka-Danielowska (2021), Mineralogical and Chemical Specificity of Dusts Originating from Iron and Non-Ferrous Metallurgy in the Light of Their Magnetic Susceptibility, Minerals, 11(2), doi:10.3390/min11020216.

Jiang, Y. Y., Z. X. Sun, Q. B. Wang, Z. G. Sun, Z. D. Jiang, H. Y. Gu, Z. Libohova, and P. R. Owens (2021), Characteristics of the typical loess profile with a macroscopic tephra layer in the northeast China and the paleoclimatic significance, Catena, 198, doi:10.1016/j.catena.2020.105043.

Joao, H. M., F. Badesab, V. Gaikwad, M. Kocherla, and K. Deenadayalan (2021), Controls of mass transport deposit and magnetic mineral diagenesis on the sediment magnetic record from the Bay of Bengal, Marine and Petroleum Geology, 128, doi:10.1016/j.marpetgeo.2021.104994. Kars, M., A. Greve, and L. Zerbst (2021), Authigenic Greigite as an Indicator of Methane Diffusion in Gas Hydrate-Bearing Sediments of the Hikurangi Margin, New Zealand, Frontiers in Earth Science, 9, doi:10.3389/feart.2021.603363.

Kehl, M., S. Vlaminck, T. Kohler, C. Laag, C. Rolf, S. Tsukamoto, M. Frechen, M. Sumita, H. U. Schmincke, and F. Khormali (2021), Pleistocene dynamics of dust accumula-

tion and soil formation in the southern Caspian Lowlands - New insights from the loess-paleosol sequence at Neka-Abelou, northern Iran, Quaternary Science Reviews, 253, doi:10.1016/j.quascirev.2020.106774.
Liu, C. C., G. Dupont-Nivet, W. Wang, and C. L. Deng (2021), Magnetic response to pedogenesis in aerobic soils of different weathering degree, Palaeogeography Palaeoclimatology Palaeoecology, 567, doi:10.1016/j.palaeo.2021.110240.
Moghbeli, Z., H. Owliaie, E. Adhami, M. Najafi-Ghiri, and S. Sanjari (2021), Pedogenesis and spatial distribution of soil magnetic properties along a lithotoposequence in an arid region of Southern Iran, Catena, 198, doi:10.1016/j.catena.2020.104979.
Nosrati, K., M. Akbari-Mahdiabad, S. Ayoubi, and A. L. Collins (2021), An exploratory study on the use of different composite magnetic and colour fingerprints in aeolian sediment provenance fingerprinting, Catena, 200, doi:10.1016/j.catena.2021.105182.
O'Loughlin, E. J., M. I. Boyanov, C. A. Gorski, M. M. Scherer, and K. M. Kemner (2021), Effects of Fe(III) Oxide Mineralogy and Phosphate on Fe(II) Secondary Mineral Formation during Microbial Iron Reduction, Minerals, 11(2), doi:10.3390/min11020149.
Samus, M. G., M. Comerio, M. L. Montes, L. Boff, J. Loffler, R. C. Mercader, and J. C. Bidegain (2021), The origin of gley colors in hydromorphic vertisols: the study case of the coastal plain of the Rio de la Plata estuary, Environmental Earth Sciences, 80(3), doi:10.1007/s12665-021-09391-2.
Shu, Q., Z. J. Zhao, Y. F. Zhao, Y. Chen, and M. H. Zhang (2021), Magnetic Properties of Late Cenozoic Sediments in the Subei Basin: Implications for the Yangtze River Runthrough Time, Journal of Coastal Research, 37(1), 122-131, doi:10.2112/jcoastres-d-20-00039.1.
Song, Y. G., S. L. Yang, J. S. Nie, J. B. Zan, and C. H. Song (2021), Preface (volume I): Quaternary paleoclimate and paleoenvironmental changes in Central Asia, Palaeogeography Palaeoclimatology Palaeoecology, 568, doi:10.1016/j.palaeo.2021.110319.
Till, J. L., B. Moskowitz, and S. W. Poulton (2021), Magnetic Properties of Plant Ashes and Their Influence on Magnetic Signatures of Fire in Soils, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.592659.
von Dobeneck, T., M. Muller, B. Bosbach, and A. Klugel (2021), Ground Magnetic Surveying and Susceptibility Mapping Across Weathered Basalt Dikes Reveal Soil Creep and Pedoturbation, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.592986.
Vu, D. T. A., A. Fanka, A. Salam, and C. Sutthirat (2021), Variety of Iron Oxide Inclusions in Sapphire from Southern Vietnam: Indication of Environmental Change during Crystallization, Minerals, 11(3), doi:10.3390/min11030241.
Wang, W. T., P. Z. Zhang, Z. C. Wang, K. Liu, H. Y. Xu, C. C. Liu, H. P. Zhang, W. J. Zheng, and D. W. Zheng (2021), Multiproxy records in middle-late Miocene sediments from the Wushan Basin: Implications for climate change and tectonic deformation in the northeastern Tibetan Plateau, Geological Society of America Bulletin, 133(1-2), 149-158, doi:10.1130/b35635.1.
Wogau, K. H., N. R. Nowaczyk, H. N. Bohnel, H. W. Arz, and R. Molina-Garza (2021), Environmental magnetism study during the Mid-Late Holocene transition and its cultural implications in Mesoamerica, Quaternary International, 577, 112-130, doi:10.1016/j.quaint.2020.12.042.
Yang, L. W., and J. Jia (2021), Temperature dependence of pedogenic magnetic mineral formation in loess deposits, Quaternary International, 580, 95-99, doi:10.1016/j.quaint.2021.01.022.
Zeeden, C., and U. Hambach (2021), Magnetic Susceptibility Properties of Loess From the Willendorf Archaeological Site: Implications for the Syn/Post-Depositional Interpretation of Magnetic Fabric, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.599491.
Zhang, Q., E. Appel, S. Y. Hu, R. S. Pennington, J. Meyer, U. Neumann, M. Burchard, F. Allstadt, L. S. Wang, and A. Koutsodendris (2020), Nano-Magnetite Aggregates in Red Soil on Low Magnetic Bedrock, Their Changes During Source-Sink Transfer, and Implications for Paleoclimate Studies, Journal of Geophysical Research-Solid Earth, 125(10), doi:10.1029/2020jb020588.
Zhao, M. T., M. M. Ma, M. He, Y. D. Qiu, and X. M. Liu (2021), Evaluation of the four potential Cretaceous-Paleogene (K-Pg) boundaries in the Nanxiong Basin based on evidences from volcanic activity and paleoclimatic evolution, Science China-Earth Sciences, 64(4), 631-641, doi:10.1007/s11430-020-9736-0.

Extraterrestrial and Planetary Magnetism

AlHantoobi, A., J. Buz, J. G. O'Rourke, B. Langlais, and C. S. Edwards (2021), Compositional Enhancement of Crustal Magnetization on Mars, Geophysical Research Letters, 48(6), doi:10.1029/2020gl090379.
Hou, M. Q., et al. (2021), Superionic iron oxide-hydroxide in Earth's deep mantle, Nature Geoscience, 14(3), 174-+, doi:10.1038/s41561-021-00696-2.
Matsumoto, T., T. Noguchi, Y. Tobimatsu, D. Harries, F. Langenhorst, A. Miyake, and H. Hidaka (2021), Space weathering of iron sulfides in the lunar surface environment, Geochimica Et Cosmochimica Acta, 299, 69-84, doi:10.1016/j.gca.2021.02.013.
Maurel, C., J. F. J. Bryson, J. Shah, R. V. Chopdekar, L. T. Elkins-Tanton, C. A. Raymond, and B. P. Weiss (2021), A Long-Lived Planetesimal Dynamo Powered by Core Crystallization, Geophysical Research Letters, 48(6), doi:10.1029/2020gl091917.
Nakada, R., G. Tanabe, I. Kajitani, T. Usui, M. Shidare, and T. Yokoyama (2021), EXAFS Determination of Clay Minerals in Martian Meteorite Allan Hills 84001 and Its Implication for the Noachian Aqueous Environment, Minerals, 11(2), doi:10.3390/min11020176.

Fundamental Rock Magnetism and direct Applications

Berndt, T. A., L. Chang, G. A. Paterson, and C. Q. Cao (2021), Experimental test of the cooling rate effect on blocking temperatures in stepwise thermal demagnetization, Geophysical Journal International, 224(2), 1117-1127, doi:10.1093/gji/ggaa514.
Didenko, A. N., V. A. Rashidov, G. P. Markov, M. S. Trusenko, V. V. Petrova, and L. P. Anikin (2021), Petromagnetic and Geochemical Descriptions of Volcanics Discharged by Alaid Volcano, Kuril Islands, in 2015-2016, Journal of Volcanology and Seismology, 15(1), 1-18, doi:10.1134/s0742046321010097.
Ge, K. P., W. Williams, L. Nagy, and L. Tauxe (2021), Models of Maghematization: Observational Evidence in Support of a Magnetic Unstable Zone, Geochemistry Geophysics Geosystems, 22(3), doi:10.1029/2020gc009504.
He, K., X. Y. Zhao, Y. X. Pan, X. Zhao, H. F. Qin, and T. W. Zhang (2020), Benchmarking Component Analysis of Remanent Magnetization Curves With a Synthetic Mixture Series: Insight Into the Reliability of Unmixing Natural Samples, Journal of Geophysical Research-Solid Earth, 125(10), doi:10.1029/2020jb020105.
Hirt, A. M., and P. F. Liu (2021), Estimating the Relative

Concentration of Superparamagnetic and Stable Single Domain Particles in Geological, Biological, and Synthetic Materials, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.586913.

Hu, P. X., H. Oda, X. Zhao, R. J. Harrison, D. Heslop, T. Sato, A. R. Muxworthy, and A. P. Roberts (2021), Assessment of Magnetic Techniques for Understanding Complex Mixtures of Magnetite and Hematite: The Inuyama Red Chert, Journal of Geophysical Research-Solid Earth, 126(1), doi:10.1029/2020jb019518.

Jackson, M. J., and B. Moskowitz (2021), On the distribution of Verwey transition temperatures in natural magnetites, Geophysical Journal International, 224(2), 1314-1325, doi:10.1093/gji/ggaa516.

Pastore, Z., S. A. McEnroe, N. S. Church, and H. Oda (2021), Mapping and Modeling Sources of Natural Remanent Magnetization in the Microcline-Sillimanite Gneiss, Northwest Adirondack Mountains: Implications for Crustal Magnetism, Geochemistry Geophysics Geosystems, 22(3), doi:10.1029/2020gc009580.

Rosa, D., A. Sandrin, T. F. D. Nielsen, and H. Vesturklett (2020), Petrography, geochemistry and magnetic susceptibility of the Isortoq Fe-Ti-V deposit, Isortoq Giant Dykes, South Greenland, Geus Bulletin, 44, doi:10.34194/geusb.v44.4626.

Tang, H. F., Z. G. Zhao, Z. W. Tian, B. L. Lu, W. Tang, K. L. He, C. X. Zhu, and P. J. Wang (2021), Characteristics of the Density and Magnetic Susceptibility of Rocks in Northern Borneo and their Constraints on the Lithologic Identification of the Mesozoic Rocks in the Southern South China Sea, Acta Geologica Sinica-English Edition, 95(1), 280-293, doi:10.1111/1755-6724.14633.

Zhang, Q., E. Appel, H. Stanjek, J. M. Byrne, C. Berthold, J. Sorwat, W. Rosler, and T. Seemann (2021), Humidity related magnetite alteration in an experimental setup, Geophysical Journal International, 224(1), 69-85, doi:10.1093/gji/ggaa394.

Geomagnetism, Paleointensity and Records of the Geomagnetic Field

Alken, P., A. Chulliat, and M. Nair (2021), NOAA/NCEI and University of Colorado candidate models for IGRF-13, Earth Planets and Space, 73(1), doi:10.1186/s40623-020-01313-z.

Asefaw, H., L. Tauxe, A. A. P. Koppers, and H. Staudigel (2021), Four-Dimensional Paleomagnetic Dataset: Plio-Pleistocene Paleodirection and Paleointensity Results From the Erebus Volcanic Province, Antarctica, Journal of Geophysical Research-Solid Earth, 126(2), doi:10.1029/2020jb020834.

Beguin, A., A. Pimentel, and L. V. de Groot (2021), Full-Vector Paleosecular Variation Curve for the Azores: Enabling Reliable Paleomagnetic Dating for the Past 2 kyr, Journal of Geophysical Research-Solid Earth, 126(2), doi:10.1029/2020jb019745.

Calvo-Rathert, M., M. F. Bogalo, J. Morales, A. Goguitchaichvili, V. A. Lebedev, G. Vashakidze, N. Garcia-Redondo, and E. Herrero-Bervera (2021), An Integrated Paleomagnetic, Multimethod-Paleointensity, and Radiometric Study on Cretaceous and Paleogene Lavas From the Lesser Caucasus: Geomagnetic and Tectonic Implications, Journal of Geophysical Research-Solid Earth, 126(2), doi:10.1029/2020jb020019.

Caminha-Maciel, G., and M. Ernesto (2020), Kinematics of the virtual geomagnetic poles during Brunhes-Matuyama times, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 193-204, doi:10.1144/sp497-2019-80.

Di Chiara, A. (2020), Palaeosecular variations of the geomagnetic field in Africa during the Holocene: a review, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 127-141, doi:10.1144/sp497-2019-51.

Di Chiara, A., E. Herrero-Bervera, and E. Tema (2020), Geomagnetic field variations in the past: an introduction, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 1-8, doi:10.1144/sp497-2020-78.

Dobretsov, N. L., D. V. Metelkin, and A. N. Vasilevskiya (2021), Typical Characteristics of the Earth's Magnetic and Gravity Fields Related to Global and Regional Tectonics, Russian Geology and Geophysics, 62(1), 6-24, doi:10.2113/rgg20204261.

Gogorza, C. S. G., M. A. Irurzun, G. Heider, A. Goguitchaichvili, G. Ojeda, J. Chiesa, and C. Greco (2021), Dating of Holocene fluvial deposits in the southern Sierras Pampeanas (Argentina) by matching paleomagnetic secular variation to a geomagnetic field model, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.102996.

Gonzalez-Lopez, A., S. A. Campuzano, A. Molina-Cardin, F. J. Pavon-Carrasco, A. De Santis, and M. L. Osete (2021), Characteristic periods of the paleosecular variation of the Earth?s magnetic field during the Holocene from global paleoreconstructions, Physics of the Earth and Planetary Interiors, 312, doi:10.1016/j.pepi.2021.106656.

Herrero-Bervera, E., and I. Snowball (2020), Integrated high-resolution PSV, RPI and C-14 study of IODP-347 Site M0060 (Anholt Loch, Baltic Sea) for the last c. 14 ka, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 179-192, doi:10.1144/sp497-2019-147.

Lakshmi, B. V., K. Deenadayalan, and P. B. Gawali (2020), A test of the pseudo-Thellier technique for determining relative palaeointensity in the Tirna Basin, Osmanabad, Maharashtra, India, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 143-158, doi:10.1144/sp497-2019-77.

Levashova, N. M., I. V. Golovanova, D. V. Rudko, K. N. Danukalov, S. V. Rudko, S. R. Yu, and J. G. Meert (2021), Late Ediacaran magnetic field hyperactivity: Quantifying the reversal frequency in the Zigan Formation, Southern Urals, Russia, Gondwana Research, 94, 133-142, doi:10.1016/j.gr.2021.02.018.

Li, C. G., Y. Zheng, M. D. Wang, Z. Sun, C. S. Jin, and J. Z. Hou (2021), Refined dating using palaeomagnetic secular variations on a lake sediment core from Guozha Co, northwestern Tibetan Plateau, Quaternary Geochronology, 62, doi:10.1016/j.quageo.2020.101146.

Lopez-Loera, H., G. Cifuentes-Nava, A. Goguitchaichvili, M. Cervantes, D. S. Velazquez, J. Rosas-Elguera, J. Morales, H. Delgado-Granados, and J. Urrutia-Fucugauchi (2021), An integrated magnetic survey on lava flows associated to the Paricutin volcano (Western Mexico), Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.103075.

Lund, S. P., M. Schwartz, and L. Keigwin (2021), On the relationship between excursions and paleomagnetic secular variation - Records from MIS 5, North Atlantic Ocean, Physics of the Earth and Planetary Interiors, 310, doi:10.1016/j.pepi.2020.106615.

Lund, S., L. Benson, and R. Negrini (2021), Timing of Sierra Nevadan stadial/interstadial variations from 15 to 56 ka, Quaternary International, 583, 31-38, doi:10.1016/j.quaint.2021.02.007.

Lurcock, P., et al. (2020), A 4500 year record of palaeomagnetic secular variation and relative palaeointensity from the Tyrrhenian Sea, in Geomagnetic Field Variations in the Past: New Data, Applications and Recent Advances, edited by E. Tema, A. DiChiara and E. HerreroBervera, pp. 159-178, doi:10.1144/sp497-2019-255.

Meduri, D. G., A. J. Biggin, C. J. Davies, R. K. Bono, C. J. Sprain, and J. Wicht (2021), Numerical Dynamo Simulations Reproduce Paleomagnetic Field Behavior, Geophysical Research Letters, 48(5), doi:10.1029/2020gl090544.

Nowaczyk, N. R. (2021), Redeposition experiments with natural sediments from the SE Black Sea in magnetic fields between about 2 and 114 mu T, Geophysical Journal International, 224(1), 271-289, doi:10.1093/gji/ggaa455.

Nowaczyk, N. R., J. B. Liu, and H. W. Arz (2021), Records of the Laschamps geomagnetic polarity excursion from Black Sea sediments: magnetite versus greigite, discrete sample versus U-channel data, Geophysical Journal International, 224(2), 1080-1096, doi:10.1093/gji/ggaa506.

Tauxe, L., C. N. Santos, B. Cych, X. Zhao, A. P. Roberts, L. Nagy, and W. Williams (2021), Understanding Nonideal Paleointensity Recording in Igneous Rocks: Insights From Aging Experiments on Lava Samples and the Causes and Consequences of "Fragile" Curvature in Arai Plots, Geochemistry Geophysics Geosystems, 22(1), doi:10.1029/2020gc009423.

Troyano, M., Y. Gallet, A. Genevey, V. Pavlov, A. Fournier, F. Lagroix, M. Niyazova, and D. Mirzaakhmedov (2021), Analyzing the geomagnetic axial dipole field moment over the historical period from new archeointensity results at Bukhara (Uzbekistan, Central Asia), Physics of the Earth and Planetary Interiors, 310, doi:10.1016/j.pepi.2020.106633.

Wang, H. P., and D. V. Kent (2021), RESET: A Method to Monitor Thermoremanent Alteration in Thellier-Series Paleointensity Experiments, Geophysical Research Letters, 48(5), doi:10.1029/2020gl091617.

Xu, D. K., et al. (2021), Application of multiple dating techniques to the Holocene sediments of Angrenjin Co in the southern Tibetan Plateau, Quaternary Geochronology, 62, doi:10.1016/j.quageo.2020.101148.

Instruments and Techniques

Nurindrawati, F., and J. J. Sun (2020), Predicting Magnetization Directions Using Convolutional Neural Networks, Journal of Geophysical Research-Solid Earth, 125(10), doi:10.1029/2020jb019675.

Watson, E. J., G. M. Turner, T. A. Little, and E. J. Piispa (2021), Using paleomagnetism to test rolling hinge behaviour of an active continental low angle normal fault, Papua New Guinea, Earth and Planetary Science Letters, 558, doi:10.1016/j.epsl.2021.116745.

Magnetic Fabrics and Anisotropy

da Silva, O. B., and M. I. B. Raposo (2020), Emplacement of the Anta Granite from Rio de Janeiro State (SE, Brazil); determined by magnetic fabrics, Brazilian Journal of Geology, 50(4), doi:10.1590/2317-4889202020200007.

Febbo, M. B., R. N. Tomezzoli, J. M. Calvagno, G. Arzadun, L. C. Gallo, and N. N. Cesaretti (2021), Anisotropy of magnetic susceptibility analysis in Tunas Formation cores (Permian), Claromec?o Basin, Buenos Aires, Argentina: Its relation to depositional and post-depositional conditions, Journal of South American Earth Sciences, 107, doi:10.1016/j.jsames.2020.103144.

Garza, R. S. M., J. W. Geissman, T. P. Alonso, J. A. Gomez, and T. Wawrzyniec (2021), Structural Setting, Paleomagnetism, and Magnetic Fabric of Miocene Plutons in a Transpressional Sinistral Shear Zone, Tonala, Chiapas, Mexico: Evidence of Shortening During Magma Emplacement, Tectonics, 40(2), doi:10.1029/2020tc006559.

Goswami, S., S. Lahiri, and M. A. Mamtani (2021), Paleostress variation during the same regional deformation in the Eastern Dharwar Craton (southern India), Journal of Structural Geology, 143, doi:10.1016/j.jsg.2020.104268.

Hrouda, F., J. Jezek, and M. Chadima (2021), On the origin of apparently negative minimum susceptibility of hematite single crystals calculated from low-field anisotropy of magnetic susceptibility, Geophysical Journal International, 224(3), 1905-1917, doi:10.1093/gji/ggaa546.

Kapawar, M. R., V. Mamilla, and S. J. Sangode (2021), Anisotropy of magnetic susceptibility study to locate the feeder zone and lava flow directions of the Rajmahal Traps (India): Implications to Kerguelen mantle plume interaction with Indian Plate, Physics of the Earth and Planetary Interiors, 313, doi:10.1016/j.pepi.2021.106692.

Pinotti, L., et al. (2021), Geological and geophysical methods relevant to decipher the structure and emplacement of granites: Insights from the Calmayo pluton (Eastern Sierras Pampeanas, Argentina), Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.103021.

Quiroga, R., et al. (2021), Spatio-temporal variation of the strain field in the southern Central Andes broken-foreland (27 degrees 30 ' S) during the Late Cenozoic, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.102981.

Schofisch, T., H. Koyi, and B. Almqvist (2021), Influence of decollement friction on anisotropy of magnetic susceptibility in a fold-and-thrust belt model, Journal of Structural Geology, 144, doi:10.1016/j.jsg.2020.104274.

Yan, C. L., L. S. Shu, Y. Chen, M. Faure, Z. H. Feng, and M. G. Zhai (2021), The construction mechanism of the Neoproterozoic S-type Sanfang-Yuanbaoshan granitic plutons in the Jiangnan Orogenic Belt, South China: Insights from geological observation, geochronology, AMS and Bouguer gravity modeling, Precambrian Research, 354, doi:10.1016/j.precamres.2020.106054.

Mineral Physics, Chemistry, Mineralogy and Petrology

Hiraga, R., O. D. M. Gomes, and R. Neumann (2021), Maghemite in Brazilian Iron Ores: Quantification of the Magnetite-Maghemite Isomorphic Series by X-ray Diffraction and the Rietveld Method, and Confirmation by Independent Methods, Minerals, 11(4), doi:10.3390/min11040346.

Hou, T., R. Botcharnikov, E. Moulas, T. Just, J. Berndt, J. Koepke, Z. C. Zhang, M. Wang, Z. P. Yang, and F. Holtz (2020), Kinetics of Fe-Ti Oxide Re-equilibration in Magmatic Systems: Implications for Thermo-oxybarometry, Journal of Petrology, 61(11-12), doi:10.1093/petrology/egaa116.

Tominaga, M., E. Ortiz, J. F. Einsle, N. F. R. Vento, M. O. Schrenk, I. Buisman, I. S. Ezad, and D. Cardace (2021), Tracking Subsurface Active Weathering Processes in Serpentinite, Geophysical Research Letters, 48(6), doi:10.1029/2020gl088472.

Paleomagnetism

Antonio, P. Y. J., et al. (2021), New constraints for paleogeographic reconstructions at ca. 1.88 Ga from geochronology and paleomagnetism of the Carajas dyke swarm (eastern

Amazonia), Precambrian Research, 353, doi:10.1016/j.precamres.2020.106039.

Antonio, P. Y. J., et al. (2021), West Africa in Rodinia: High quality paleomagnetic pole from the similar to 860 Ma Manso dyke swarm (Ghana), Gondwana Research, 94, 28-43, doi:10.1016/j.gr.2021.02.010.

Ayarza, P., J. J. Villalain, J. R. M. Catalan, F. A. Lobato, M. D. Oreja, P. Calvin, C. Recio, M. S. Barrios, and E. G. Martin (2021), Characterizing the Source of the Eastern Galicia Magnetic Anomaly (NW Spain): The Role of Extension in the Origin of Magnetization at the Central Iberian Arc, Tectonics, 40(3), doi:10.1029/2020tc006120.

Brown, L., B. S. Singer, and M. Barquero-Molina (2021), Paleomagnetism and Ar-40/Ar-39 chronology of ignimbrites and lava flows, Central Volcanic Zone, Northern Chile, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.103037.

Chang, L., et al. (2021), Detrital remanent magnetization of single-crystal silicates with magnetic inclusions: constraints from deposition experiments, Geophysical Journal International, 224(3), 2001-2015, doi:10.1093/gji/ggaa559.

Choe, H., and J. Dyment (2021), The fate of marine magnetic anomaly in subduction zones: A global appraisal, Earth and Planetary Science Letters, 561, doi:10.1016/j.epsl.2021.116787.

Domeier, M., E. Font, N. Youbi, J. Davies, S. Nemkin, R. Van der Voo, M. Perrot, M. Benabbou, M. A. Boumehdi, and T. H. Torsvik (2021), On the Early Permian shape of Pangea from paleomagnetism at its core, Gondwana Research, 90, 171-198, doi:10.1016/j.gr.2020.11.005.

Dopico, C. I. M., P. Y. J. Antonio, A. E. Rapalini, M. G. L. de Luchi, and C. G. Vidal (2021), Reconciling Patagonia with Gondwana in early Paleozoic? Paleomagnetism of the Valcheta granites, NE North Patagonian Massif, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.102970.

Ernesto, M., L. A. Zaffani, and G. Caminha-Maciel (2021), New paleomagnetic data from the Parana Magmatic Province: Brief emplacement time and tectonism, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.102869.

Franceschinis, P. R., S. Y. Fazzito, A. E. Rapalini, M. P. Escayola, S. E. Geuna, and C. R. Piceda (2021), Permian remagnetization of the Early Cambrian Guachos Formation, Eastern Cordillera, Argentina, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.102887.

Gallo, L. C., A. D. Farjat, R. N. Tomezzoli, J. M. Calvagno, and R. M. Hernandez (2021), Sedimentary evolution of a Permo-Carboniferous succession in southern Bolivia: Responses to icehouse-greenhouse transition from a probabilistic assessment of paleolatitudes, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.102923.

Geuna, S. E., L. D. Escosteguy, B. D. Appella, L. Pinotti, F. D'Eramo, and M. Hollanda (2021), The geodynamic evolution of the Famatinian orogen from the paleomagnetic record of El Hongo trondhjemite (Early Paleozoic, Sierras Pampeanas de C ' ordoba, Argentina), Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.103059.

Hencz, M., T. Biro, Z. Cseri, D. Karatson, E. Marton, K. Nemeth, A. Szakacs, Z. Pecskay, and I. J. Kovacs (2021), A Lower Miocene pyroclastic-fall deposit from the Bukk Foreland Volcanic Area, Northern Hungary: Clues for an eastward-located source, Geologica Carpathica, 72(1), 26-47, doi:10.31577/GeolCarp.72.1.3.

Kent, D. V., P. E. Olsen, G. Muttoni, and M. Et-Touhami (2021), A Late Permian paleopole from the Ikakern Formation (Argana basin, Morocco) and the con fi guration of Pangea, Gondwana Research, 92, 266-278, doi:10.1016/j.gr.2021.01.002.

Kirscher, U., R. N. Mitchell, Y. B. Liu, A. R. Nordsvan, G. M. Cox, S. A. Pisarevsky, C. Wang, L. Wu, J. B. Murphy, and Z. X. Li (2021), Paleomagnetic constraints on the duration of the Australia-Laurentia connection in the core of the Nuna supercontinent, Geology, 49(2), 174-179, doi:10.1130/g47823.1.

Liu, C. Y., G. A. Paterson, S. H. Li, Y. X. Pan, and R. X. Zhu (2021), Remagnetization of Permian Emeishan basalts: Constraints on the timing of native copper mineralization in northeast Yunnan Province, China, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.590939.

Mendes, B. D. L., D. Pastor-Galan, M. J. Dekkers, and W. Krijgsman (2021), Avalonia, get bent! - Paleomagnetism from SW Iberia confirms the Greater Cantabrian Orocline, Geoscience Frontiers, 12(2), 805-825, doi:10.1016/j.gsf.2020.07.013.

Merdith, A. S., et al. (2021), Extending full-plate tectonic models into deep time: Linking the Neoproterozoic and the Phanerozoic, Earth-Science Reviews, 214, doi:10.1016/j.earscirev.2020.103477.

Poblete, F., et al. (2021), Towards interactive global paleogeographic maps, new reconstructions at 60, 40 and 20 Ma, Earth-Science Reviews, 214, doi:10.1016/j.earscirev.2021.103508.

Puigdomenech, C., S. Alarcon, V. R. Gonzalez, P. Rossel, D. Orts, and C. Zaffarana (2021), Tectonic rotations in central Chile: New insights on the southern limit of the Maipo Orocline, Journal of South American Earth Sciences, 106, doi:10.1016/j.jsames.2020.103012.

Song, D. F., W. J. Xiao, B. F. Windley, and C. M. Han (2021), Provenance and tectonic setting of late Paleozoic sedimentary rocks from the Alxa Tectonic Belt (NW China): Implications for accretionary tectonics of the southern Central Asian Orogenic Belt, Geological Society of America Bulletin, 133(1-2), 253-276, doi:10.1130/b35652.1.

Swanson-Hysell, N. L., S. A. Hoaglund, J. L. Crowley, M. D. Schmitz, Y. M. Zhang, and J. D. Miller (2021), Rapid emplacement of massive Duluth Complex intrusions within the North American Midcontinent Rift, Geology, 49(2), 185-189, doi:10.1130/g47873.1.

Titus, S. J., and J. R. Davis (2021), Problems With Net Tectonic Rotation for Dikes and Suggestions for Alternative Approaches, Geochemistry Geophysics Geosystems, 22(1), doi:10.1029/2020gc009395.

Tong, Y. B., Z. Y. Yang, J. L. Pei, H. Wang, Z. H. Wu, and J. F. Li (2021), Crustal Clockwise Rotation of the Southeastern Edge of the Tibetan Plateau Since the Late Oligocene, Journal of Geophysical Research-Solid Earth, 126(1), doi:10.1029/2020jb020153.

Wu, L., J. B. Murphy, C. Quesada, Z. X. Li, J. W. F. Waldron, S. Williams, S. Pisarevsky, and W. J. Collins (2021), The amalgamation of Pangea: Paleomagnetic and geological observations revisited, Geological Society of America Bulletin, 133(3-4), 625-646, doi:10.1130/b35633.1.

Zhao, P., E. Appel, and B. Xu (2020), An Inclination Shallowing-Corrected Early Triassic Paleomagnetic Pole for the North China Craton: Implication for the Mesozoic Geography of Proto-Asia, Journal of Geophysical Research-Solid Earth, 125(10), doi:10.1029/2020jb019489.

Stratigraphy

Abubakre, A. O., and M. O. de Kock (2021), Magnetostratigraphic constraints for Early Permian rocks of the southwestern Karoo Basin, South Africa, Gondwana Research,

90, 220-240, doi:10.1016/j.gr.2020.11.009.
Cantalejo, B., K. T. Pickering, C. McNiocaill, P. Bown, K. Johansen, and M. Grant (2021a), A revised age-model for the Eocene deep-marine siliciclastic systems, Ainsa Basin, Spanish Pyrenees, Journal of the Geological Society, 178(1), doi:10.1144/jgs2019-131.
Cantalejo, B., K. T. Pickering, K. G. Miller, and C. M. Niocaill (2021b), Chasing the 400 kyr pacing of deep-marine sandy submarine fans: Middle Eocene Ainsa Basin, Spanish Pyrenees, Journal of the Geological Society, 178(1), doi:10.1144/jgs2019-173.
Goguitchaichvili, A., B. Gomez, M. C. Rathert, V. Lebedev, M. Cervantes, G. Vashakidze, J. Sologashvili, and J. Morales (2021), Noise across Olduvai Subchron: Paleomagnetic study of a Pliocene lava succession from Javakheti Highland (Georgia, Lesser Caucasus), Physics of the Earth and Planetary Interiors, 311, doi:10.1016/j.pepi.2020.106641.
Grygar, T. M., K. Mach, M. Koubova, M. Martinez, K. Hron, and K. Facevicova (2021), Beginning of the Miocene Climatic Optimum in Central Europe in sediment archive of the Most Basin, Czech Republic, Bulletin of Geosciences, 96(1), 61-81, doi:10.3140/bull.geosci.1794.
Guan, C., et al. (2021), Paleomagnetic and Chronologic Data Bearing on the Permian/Triassic Boundary Position of Qamdo in the Eastern Qiantang Terrane: Implications for the Closure of the Paleo-Tethys, Geophysical Research Letters, 48(6), doi:10.1029/2020gl092059.
Hlavatskyi, D. V., and V. G. Bakhmutov (2020), Magnetostratigraphy and magnetic susceptibility of the best developed Pleistocene loess-palaeosol sequences of Ukraine: implications for correlation and proposed chronostratigraphic models, Geological Quarterly, 64(3), 723-753, doi:10.7306/gq.1544.
Hounslow, M. W., S. E. Harris, K. Wojcik, J. Nawrocki, K. T. Ratcliffe, N. H. Woodcock, and P. Montgomery (2021a), A geomagnetic polarity stratigraphy for the Middle and Upper Ordovician, Palaeogeography Palaeoclimatology Palaeoecology, 567, doi:10.1016/j.palaeo.2021.110225.
Hounslow, M. W., S. E. Harris, K. Wojcik, J. Nawrocki, N. H. Woodcock, K. T. Ratcliffe, and P. Montgomery (2021b), Geomagnetic polarity during the early Silurian: The first magnetostratigraphy of the Llandovery, Palaeogeography Palaeoclimatology Palaeoecology, 567, doi:10.1016/j.palaeo.2021.110245.
Jovane, L., K. P. Kodama, and L. A. Hinnov (2021), Editorial: Multi-Disciplinary Applications in Magnetic Chronostratigraphy, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.634790.
Kazansky, A. Y., V. Y. Vodovozov, A. Y. Gladenkov, Y. B. Gladenkov, and V. M. Trubikhin (2021), Magnetostratigraphy of West Kamchatka Marine Cenozoic Key Section (Kvachina Bay), Stratigraphy and Geological Correlation, 29(1), 104-119, doi:10.1134/s0869593821010044.
Lise-Pronovost, A., M. S. Fletcher, Q. Simon, Z. Jacobs, P. S. Gadd, D. Hestop, A. I. R. Herries, Y. Yokoyama, and A. Team (2021), Chronostratigraphy of a 270-ka sediment record from Lake Selina, Tasmania: Combining radiometric, geomagnetic and climatic dating, Quaternary Geochronology, 62, doi:10.1016/j.quageo.2021.101152.
Omar, H., A. C. Da Silva, and C. Yaich (2021), Linking the Variation of Sediment Accumulation Rate to Short Term Sea-Level Change Using Cyclostratigraphy: Case Study of the Lower Berriasian Hemipelagic Sediments in Central Tunisia (Southern Tethys), Frontiers in Earth Science, 9, doi:10.3389/feart.2021.638441.
Pawlak, J., H. Hercman, P. Sierpien, P. Pruner, M. Gasiorowski, A. Mihevc, N. Z. Hajna, P. Bosak, M. Blaszczyk, and B. Wach (2020), Estimation of the durations of breaks in deposition - speleothem case study, Geochronometria, 47(1), 154-170, doi:10.2478/geochr-2020-0022.
Scheidt, S., et al. (2021), Chronological Assessment of the Balta Alba Kurgan Loess-Paleosol Section (Romania) - A Comparative Study on Different Dating Methods for a Robust and Precise Age Model, Frontiers in Earth Science, 8, doi:10.3389/feart.2020.598448.
Stanford, S. D., B. D. Stone, J. C. Ridge, R. W. Witte, R. R. Pardi, and G. E. Reimer (2021), Chronology of Laurentide glaciation in New Jersey and the New York City area, United States, Quaternary Research, 99, 142-167, doi:10.1017/qua.2020.71.
Usui, Y., and T. Yamazaki (2021), Magnetostratigraphic evidence for post-depositional distortion of osmium isotopic records in pelagic clay and its implications for mineral flux estimates, Earth Planets and Space, 73(1), doi:10.1186/s40623-020-01338-4.
Wimbledon, W. A. P., V. Bakhmutov, E. Halasova, A. Svobodova, D. Rehakova, C. Frau, and L. G. Bulot (2020), Comments on the geology of the Crimean Peninsula and a reply to a recent publication on the Theodosia area by Arkadiev et al. (2019): "The calcareous nannofossils and magnetostratigraphic results from the Upper Tithonian-Berriasian of Feodosiya region (Eastern Crimea)", Geologica Carpathica, 71(6), 516-525, doi:10.31577/GeolCarp.71.6.3.

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ever, given circumstances, we thought best not to cap the conference in the first place, allowing as much participation from around the world as possible. Relatedly, and unlike the "big box meetings" we strive to differentiate ourselves from in format, we also did our best to accommodate all speakers and conveners by having the sessions run at different times throughout the day depending on who was presenting/convening and from where. Inevitably this resulted in some early morning or later in the evening presentations, but at least no one had to give a "red eye" talk.

To allow all participants to view the presentations and at least "follow the discussion", all talks and subsequent Q&A's were recorded and posted on the Institute for Rock Magnetism YouTube channel[PROVIDE LINK]. Viewers will find all sessions arranged as playlists, including one for the keynote talks and the "lightning talks" for the two poster sessions.

All in all, we IRMers all thought that the conference was a great success, with a final tally of 206 participants from 23 countries from 6 continents (Figure 1).

Day one

The meeting was kicked off bright and early on June 1st with a welcome by IRM director Bruce Moskowitz, followed by a technical overview of the meeting provided by the IRM's "new" lab manager, Maxwell Brown.

The first **Keynote Talk** was delivered by **Barbara Maher** (Lancaster University) on "*Environmental Magnetism: Bonanza not Bandwagon*".

The title of Barbara's talk makes a statement regarding the richness of iron minerals, both natural and anthropogenic, as a resource to research in many different fields, whether geology, mineralogy, biology, and chemistry. This wealth will allow the field of environmental magnetism and overlapping disciplines to further develop our fundamental understanding of climatic and environmental processes, the health impacts of particulate air pollution, and aiding the development of sustainable bio- and geotechnologies.

The first session on magnetic anisotropy featured four talks. **Andrea Biedermann** (Institute of Geological Sciences, University of Bern, Switzerland), opened with "*Characterizing Anisotropy of Ferromagnetic Grains: Methods and Challenges.*" Andrea's presentation focused on characterizing the anisotropy of ferromagnetic grains, providing an overview of the methodologies, and addressing the advantages and challenges of each technique in relation to the particular grains or minerals targeted. Andrea discussed the recent advancements in the characterization and interpretation of anisotropy, showing examples of how the increasingly detailed understanding of anisotropy can advance the interpretation of structural and paleomagnetic data.

Andrea's talk was followed by a double-header by **Kenneth Kodama** (Lehigh University, USA) and **Dario Bilardello** (Institute for Rock Magnetism, University of Minnesota, USA) titled "*The Anisotropy Correction for Inclination Shallowing - Historical Perspectives and Future Trends.*" Ken provided a historical overview of the application of the anisotropy correction for inclination shallowing, from the first laboratory compaction experiments to the establishment of the first direct relationship between the development of inclination shallowing, clay fabric, and magnetic remanence anisotropy. Ken described the inclination correction equations for magnetite and hematite, based on the necessary measurements of the remanent anisotropy carried by the characteristic remanence carrying grains and their individual particle anisotropy, and provided "historical" examples of the development of research in inclination shallowing and applications. Ken also discussed the comparison of the anisotropy-based correction to the elongation/inclination (E/I) correction technique.

Dario picked up from where Ken left off and expanded on hematite anisotropy measurement techniques, aimed at better isolating the fabric of interest, and methods to estimate the particle anisotropy. He further discussed the propagation of the (negligible) added uncertainty introduced by the inclination correction and, in this light, further addressed the comparison of inclination correction techniques, including simplified corrections based on mean shallowing (f) factors. Additionally, Dario presented theoretical and laboratory advancements on the effects of inclination corrections on relative paleointensity (RPI) estimates, by performing full-vector corrections that bring in better agreement the RPIs obtained from data acquired in same field intensities but varying inclinations.

Next up was **Stuart Gilder** (Ludwig-Maximilians-Universität München, Germany) who presented on "*Estimating relative paleointensity from remenance anisotropy.*" In sediments containing prolate magnetic particles carrying shape anisotropy, the NRM is sometimes observed to be subparallel to the field direction, but the magnetic fabric is bedding parallel, implying an imperfect alignment of particles. Increasing the applied field intensity, however, increases particle alignment, resulting in the maximum anisotropy axes to also parallel the field direction. Following this concept, it is therefore possible to theoretically use magnetic anisotropy, particularly of remanence, to quantify relative paleointensity. Stuart demonstrated this idea utilizing magnetotactic containing mud redeposited in fields ranging between ~0.3 and 70 mT, discussing anisotropy measurement schemes and protocols to calculate the remanent tensors. Stuart also discussed a number of caveats involving both anisotropy determinations and paleointensity estimates alike.

The session was closed by **David Finn** (University of Leicester, UK) who talked about "*Switching Field Angular Dependence Speaks Volumes about the Measurement of Laboratory Imparted Remanences.*" The basis of David's talk was the observation by Karen Norgaard Madsen that for non-saturating alternating fields (AF) two orthogonal AFs would not produce equal and opposite GRMs as suggested by Stephenson. The explanation for this observation was that the total number of particles activated by an AF varies with the applied field direction, owing to their switching field angular dependence, leading to large errors arising from the use of non-saturating AFs for the measurement of coercivity distribution, relative paleointensity, and ARM anisotropy. David demonstrated that a typical set of partially activating (non-saturating) ARMs are not suitable for tensor analysis owing to the switching field angular dependence, independently of the linearity between the biasing field strength and resultant magnetization. Consequently, the applicability of the ARM method is limited by the peak field intensities obtainable in most laboratories that do not reach AF saturation, requiring more powerful AF demagnetizers. One such device is the Schillinger's magnetic core design, which allows for an easy design of a fully automated measurement setup capable of applying AFs/ARMs in any arbitrary orientation with peak fields greater than 500 mT. David also discussed the advantages of partially activating ARMs to detect higher-order anisotropy shapes than second-order tensors, which may be exploited for the separation of complex composite fabrics (requiring, however, complete measurement automation and the field orientation flexibility provided by Schillinger's design.

Day two

The second day of the meeting commenced with the first **Poster Session**, featuring presentations on "*Anisotropy and Applications*", "*Environmental Magnetism and Proxies*", and "*Assorted Topics*". We invite you to view our webpage and our YouTube channel to learn more about these presentations.

Following, the second topical session on Environmental Magnetism was opened by **Dave Heslop** (Australian National University, Australia) who presented on "*Magnetic Unmixing of Natural Magnetic Mineral Assemblages — Challenges to Approximating Reality.*" Given the importance of magnetic minerals in the environment and their sensitivity to natural processes, they are inevitably identified and quantified using a variety of techniques to assist drawing of inferences concerning past environmental changes. The challenge is to identify and quantify different magnetic mineral subpopulations in a given material, and numerical unmixing techniques, which decompose magnetic remanence curves using collections of basis functions, have contributed significantly to this endeavor. David discussed at length the nonuniqueness of available techniques and the non-possibility of fully quantifying model uncertainties. To this end, he presented an automated Bayesian framework for unmixing remanence curves to aid quantification of magnetic mineral subpopulations, which, incorporating prior knowledge on the sought distributions of coercivities to the unmixing model, enables full estimation of the uncertainties, in turn allowing more robust environmental inferences. Last but not least, David discussed the limitations of unmixing techniques.

Next, **Sarah Slotznick** (Dartmouth College, USA) gave a talk on "*Deep-time" Environmental Magnetism: Untangling Redox Conditions, Diagenesis, and Metamorphism.*" Sarah discussed paleoenvironmental reconstructions of Precambrian Earth History, with a particular attention to redox state and oxygen levels due to their importance for biogeochemical processes, highlighting the suitability of rock-magnetic techniques to identify and quantify redox-sensitive iron mineralogy non-destructively, and at lower abundances than traditional methods (e.g., optical petrography, X-ray diffraction, geochemical extractions, etc.) Sarah described the challenges faced when working with Precambrian-age sedimentary rocks, and predominantly the necessity of separating the primary iron oxides that preserve information about the ancient environment, from the secondary ones resulting from subsequent alteration during diagenesis/ metamorphism. Beyond paleomagnetic dating, which has only recently been applied to Precambrian sedimentary rocks, new methodologies are sought for absolute quantification of various magnetic minerals in mixed-phase assemblages, particularly for hematite, goethite, and magnetic iron sulfides for which "best practices are still in development. Furthering of "deep-time" environmental magnetism creates opportunities to combine data with geochemical/spectroscopic information and to model the system. The continued development of magnetic microscopy techniques holds incredible promise for the future of the field.

Zhaoxia Jiang (Ocean University of China), closed the session with a presentation on "*The influence of Al on the magnetic properties and diffuse reflectance spectroscopy of hematite.*" Zhaoxia described how the existing magnetic and color reflectance property framework for understanding hematite is based largely on stoichiometric hematite. However, cation substitution, predominantly by Al, occurs widely in single crystal and polycrystalline natural hematite, which will alter many physical properties of hematite, leading to ambiguity in geological interpretation if substitutions are not quantified/ assumption of stoichiometry is made. Zhaoxia elaborated on the influence of cation substitution on the magnetic and color spectral properties of hematite, and on the identification and quantification of hematite contents in soils and sediments.

Day three

The third day of the meeting was devoted to Speleothem research and featured the second **Keynote Talk** delivered by **R. Lawrence "Larry" Edwards** (University of Minnesota, USA): "U-Th Dating of Cave Deposits." Larry provided a very detailed account of the evolution of the Uranium-Thorium (U-Th) or ^{230}Th dating techniques, to which he contributed greatly. It is well-suited to the dating of cave calcite and aragonite (speleothems) with the right set of characteristics: carbonate that is a few to 100 years old can be dated to a precision of one year, whereas 2σ uncertainties for carbonate increase from ±10 years, ±300 years, ±800 years, ±3 ka, ±8 ka, ±15 ka, and ±40 ka for carbonate deposited 10 ka, 130 ka, 200 ka, 300 ka, 400 ka, 500 ka, and 600 ka, respectively. The low natural concentrations of ^{230}Th and ^{234}U, ^{230}Th technically limited dating in terms of precision and sample-size requirements. The first ^{230}Th dates were determined by alpha-counting, however the sensitivity of the method was increased by 4 orders of magnitude with the development of mass spectrometric techniques by Edwards et al. (1987), and subsequently by another order of magnitude with the use of inductively-coupled plasma ionization techniques (Cheng et al., 2013). Applications related to ^{230}Th dating of speleothems dating jumped forward with the development of mass spectrometric techniques, evolving into today's vibrant field. Particularly significant contributions have been and continue to be made to fields of climate and environmental change and to archeology and cultural change. This approach has led to the calibration of the full ^{14}C timescale, a goal of the scientific community for 7 decades, and that is in part related to the geomagnetic field's modulation of ^{14}C-producing cosmic rays. In addition, this approach has been used to constrain the timing of the Laschamp Excursion and to establish the chronology for environmental magnetism studies.

The day's session was opened by **Yu-Min Chou** (Southern University of Science and Technology, China) who presented on "*A Challenge of Paleomagnetism Research - Speleothem Magnetism.*" For rapid geomagnetic field variations there is a gap in geomagnetic field behavior at the of 10^1-10^3 years scale owing to the non continuous nature of most natural materials: lava flows are non continuous records "by definition" and sediments are affected by blocking depths, bioturbation and other "pDRM" processes in general, compaction-induced shallowing, or other processes that hinder continuous and/or smooth recording of the magnetic field. Speleothems can bypass these processes, providing continuous records that can be absolutely dated (U-Th). Similarly to other sedimentary records, however, both primary detrital (e.g., magnetite/ titanomagnetite) or secondary authigenic (e.g., goethite) minerals may be present, resulting in uncertainties on the exact speleothem acquisition mechanisms and allowing acquisition of directional data, but generating problems for paleointensity estimates. Speleothem magnetic research first began ~40 years ago, but only with more recent instrumental advances substantial advances have been made, e.g., identification and dating of the Laschamp event, the South Atlantic anomaly recurrence or ultra-rapid (~100 years) reversals. In his talk Yu-Min described in great depth the challenges of performing speleothem magnetism, from finding suitable samples (considering weathering, flooding and other processes affecting the magnetic carriers in speleothems), how to orient, cut and prepare samples appropriately (including strategies for identifying the layers to be measured), the issues with dating (Uranium concentrations for U-Th dating and identification of hiatuses in the speleothem layers), and finally discussing best practices and instrumentation for performing high quality magnetic analyses.

Yuval Burtsyn (Hebrew University of Jerusalem, Israel) talked about "*Holocene palaeohydrological variations in the Eastern Mediterranean inferred from magnetic and isotopic properties of speleothems from Soreq Cave, Israel.*" Yuval started by introducing IRM variability as a proxy for glacial-interglacial conditions, however showing that while from mid latitude US and Chinese records high IRM values correlated with wet summers, in a study from tropical areas higher IRMs correlated with dry climate instead. Yuval addressed this apparent contradiction by comparing multiple proxy records, including isotopic proxies, obtained from Holocene speleothems growing under different hydrologic conditions within the same cave to infer paleoclimate and soil/vegetation dynamics: SEM imaging for magnetic mineral characterization identified pedogenic magnetite as well as extraterrestrial spheroids, which provided a direct link to the soil from which the magnetic material was supposedly derived. Moreover, unmixing experiments from speleothem and soil samples above confirmed that the magnetic components in the speleothem were derived from the soil and transported into the cave from the karst system. Regarding the isotopic proxies, Yuval showed that while delta ^{14}C and IRM proxies correlated, the δ^{18}O did not, as a consequence of the δ^{18}O representing shorter, decadal, variations whereas δ^{14}C represent longer time scales and are also related to the detrital flux of material into the cave. Yuval discussed how the IRM_{mass} values appear to reflect concentration variations, showing differences among sites that reflect drip-site specific variations, and representing the nature of the non-linear karstic systems. On the other hand, the IRM_{flux}, the IRM concentration normalized by the speleothem growth time, correlates more favorably among different sites, probably constituting a better overall proxy for different hydrologic conditions. Yuval then used this proxy, together with δ^{14}C and δ^{18}O values to resolve questions regarding how wet the conditions were throughout the speleothem deposition, noting that there is no simple correlation of IRM_{flux} with precipitation over geologic time even within the same site.

Elena Zanella (University of Turin, Italy) gave a presentation titled "*Speleothem Magnetism's Contribution to Paleoenvironmental Changes: the Rio Martino and its Many Applications.*" Elena presented on two multi-proxy high-resolution records from flowstones of the Rio Martino cave, in the northwestern Italian Alps. The first record included combined geochemical and magnetic properties directed to study the evolution of the Alpine Critical Zone during the Holocene, whereas the second record covered the first part of the Penultimate Glacial (early MIS 6) and constrains the interstadial conditions over the Southern Alps. The talk provided an interesting example of paleoclimate variability that can be extracted from speleothems by linking rock magnetic properties to changes in detrital input driven by regional and global climate, in terms of proxies related to composition, concentration, and grain-size of the detrital and pedogenetic magnetic phases. Elena, however, cautioned on how high efficiencies in remanence acquisition may implicate complex processes for which interpretations are not readily available, and for which integration with other proxies (e.g., stable isotopes, growth rate, trace elements, and facies analysis) become essential to perform paleoenvironmental reconstructions.

The final talk of the day was by **Roger Fu** (Harvard, USA), who talked about "*High-Resolution Speleothem Mapping Using the QDM.*" Because the well-dated, high-resolution rock-magnetic speleothem records have shown that multiple mechanisms of magnetic particle enrichment occur, understanding the paleoclimate implications of a speleothem record requires confident knowledge of the enrichment process in each specimen. Roger discussed how high spatial resolution mapping of speleothems, particularly using the quantum diamond microscope (QDM), helps identify the origin of magnetic particles, informing paleoclimate interpretations. Roger's talk covered different approaches such as benchmarking against instrumental records, resolving interlaminar shifts in rock magnetic properties, and correlating magnetic properties to textural and petrographic observations.

Day four

The final day of the conference was centered around Instrumentation Advances and Methods. **Ramon Egli** (Central Institute for Meteorology and Geodynamics, Austria) kicked off with "F*ORC & Co: Recent Advances, Pitfalls, and Future Developments.*" FORC diagrams are an increasingly popular characterization tool for visualizing mixtures of magnetic domain states and distributions of coercivities in two dimensions, despite their measurement times, use of complex and non-standardized measurement protocols and processing routines, on top of non-straightforward interpretations. The many recent advances in instrumentation and processing techniques, as well as forward FORC modeling have allowed better understanding of fundamental properties of natural magnetic minerals, promoting a better definition of specific magnetic components, and their numerical unmixing. However, the interpretation of magnetic measurements remains intrinsically ambiguous. In his talk, Ramon took the viewers on a journey through the "FORC cabinet of curiosities" including a number of FORC signatures ranging from the more common to the bizarre, using these to highlight the nature of magnetization processes that can be accessed through this type of measurement, and their relationship to other magnetic characterization tools.

Clara Maurel (Massachusetts Institute of Technology, USA), talked about "*Bridging the Gap Between Spacecraft Magnetometry Investigations and Laboratory Experiments Using Iron Meteorites.*" While many studies have found meteorites to be magnetized and carry a record of their parent body's magnetic field, no asteroid has been found to contain reliable evidence of a remanent magnetization, despite representing the same planetesimal population. It has been hypothesized that the discrepancy occurs because magnetization decreases with sample size, and therefore would be inherently undetectable at the asteroid scale. Clara tested this hypothesis by combining measurements of iron meteorites at multiple size scales ranging from millimeter to meter. The study demonstrated that the magnetization need not be reduced to zero with increasing size, but rather may asymptote at a non-zero value, apparently invalidating the proposed hypothesis. However, the detection of a magnetization in larger bodies might be hindered by other processes.

David Schuler (Applied Physics Systems, USA) presented on developments on "*Optically Pumped Magnetometers for Rock Measurements.*" David presented the recent advancements in adapting the optically pumped magnetometer (OPM) for rock and u-channel measurements performed at Applied Physics Systems. David discussed the already existing instrument, as well as the new implementations that are currently being worked on, including plans for future development. Challenges faced by the team include optimal magnetic shielding, sample handling and positioning, and the adaptation of the magnetometer for u-channel measurements. The OPM measures field intensity rather than moment, therefore comparing data with the SQUID magnetometers presents further challenges. Regardless, David showed a suite of data from different lithologies acquired on both the OPM and the 2G system which compared favorably in terms of both intensity and direction. Last but not least, David is interested in feedback in terms of what implementations the community would like to see, and is always available for comments and suggestions.

Finally, the last talk of the conference was given by **Michael Grappone** (University of Liverpool, UK), who showed his results on "*Improving the Productivity of Paleomagnetic Laboratories: On-going Advancements and Challenges in Paleomagnetic Instrumentation.*" Michael presented an overview of available paleomagnetic equipment that is currently available and discussed the pros and cons of each: the playing field is typically subdivided into more affordable but labor intensive instrumentation versus fully automated but more spendy systems. However, these technical discrepancies must also face the demand for the increasing statistical rigor that is demanded of the scientific community. In this context, and discussing the automated options, Michael presented his own development of a home-made automated RF liquid nitrogen SQUID Superconducting Magnetometer for the Automated Recording of Thermal remanence (SMARTr) capable of in situ thermal demagnetization and measurement. Michael presented a comparison of data acquired on the SMRTr to that generated by a 2G instrument equipped with a RAPID system showing that over the same time interval the SMARTr system can measure 15 specimens compared to the 5 measured on a 2G, yet with larger uncertainties. However, Michael pointed out that the SMARTr prototype possessed a 2-SQUID geometry, and therefore the data shown represented the worst-case scenario. On the other, "technically simpler" side, Michael showed examples of the new magneto-impedance sensors used by Kodama (2017) and the Optically Pumped sensor utilized by the new Applied Physics Systems' system. Michael also showed newer applications of fluxgate systems. Last but not least, Michael presented an instrumentation overview specific to paleointensity data.

The second **Poster Session** offered the final opportunity for participants to mingle and view poster presentations on "*Advances in Instrumentation and Methods*", "*Paleointensity*", and "*Speleothems and Holocene Field Variations*." Once again, more details on these presentations can be found on our website and YouTube channel. We at the IRM are all looking forward to an in-person meeting in two years time, most probably in our beloved (and currently under renovation) location in Santa Fe, NM. Undoubtedly, however, the virtual experience has brought about advantages in overall global conference participation, and we are looking into incorporating a virtual component to our future conferences in an attempt to make our meetings more accessible. As always, please feel free to reach out for comments and suggestions, it was our pleasure in seeing and interacting with you!

References

Edwards, R.L., Chen, J.H. and Wasserburg, G.J. 1987. U-238, U-234, Th-230, Th-232 systematics and the precise measurement of time over the past 500,000 years. Earth Planet. Sci. Lett., 81, 175-192.

Cheng, H., Edwards, R.L., Shen, C.C., Polyak, V.J., Asmerom, Y., Woodhead, J., Hellstrom, J., Wang, Y.J., Kong, X.G., Spotl, C., Wang, X.F., and Alexander, E.C. 2013. Improvements in 230Th dating, 230Th and 234U half-life values, and U-Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. Earth Planet. Sci. Lett. 371, 82-91. doi.org/10.1016/j.epsl.2013.04.006

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; **Maxwell Brown, Peat Sølheid** and **Dario Bilardello**, Staff Scientists.

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