Department of Magnetism

ABOUT

The main research directions in the Department of Magnetism include studies of the lithospheric structures using electromagnetic methods, research in the field of magnetohydrodynamics with applications to the dynamics of the Earth's interior, paleomagnetism and research in the field of environmental magnetism.

Paleomagnetic team took part in a wide range of activities in 2020. The environmental magnetism group working within NM1 task, continued the application of combined magnetic and non-magnetic methods to study the environment pollution. In particular, the scientific interests were focused on the study of traffic-related pollution, the quality of outdoor and indoor air, the pollution of river bank and soils. The collaborate efforts with other teams allowed for a multidisciplinary approach to resolve the questions concerning sources of pollution and evaluation of adverse health effects for children and adults related to exposure pathway of heavy metals. The monitoring service of the PM concentration and magnetic susceptibility to study temporary trends for three locations in Warsaw was also continued. The studies carried out within the NM2 task concerned mostly problems of paleogeographic and tectonic reconstructions. In particular, the investigations in the Carpathians (Poland and Slovakia) Africa (eastern Zimbabwe), in the area of Svalbard and in the south-western part of the East European Craton (Poland, Lithuania, Belarus) were continued. The research concerned paleogeographic positions of both large lithospheric plates as well as kinematics of smaller units, such as terranes, individual tectonic blocks or nappes. We investigated also Silurian gas-bearing shales from northern Poland focusing on problems concerning organic matter preservation. We investigated detail composition and the properties of magnetic minerals in shales in relation to variable depositional environment in the sedimentary basin.

The magnetic dynamo team within the NM3 has conducted research on scale selection phenomena in magnetohydrodynamic flows and convective heat transfer. The construction of three-dimensional models of the geoelectric structure for selected regions in Poland was also continued. A combined quantitative interpretation of the GCM and DC-R methods was used to solve the problem of flooding as an application of these methods in engineering geology. In addition, the studies of source effects which constitute a limit in the properties of natural source signals beyond which the magnetotelluric method does ceases work properly were continued. Throughout 2020 the absolute measurements and continuous recording of the Earth’s magnetic field in Belsk, Hel and Hornsund (Spitsbergen) observatories were conducted. All three observatories are members of the global INTERMAGNET network. A continuous recording of geomagnetic field changes with real-time data access has been carried out in the five permanent stations. Moreover, Schumann Resonance observations have been continued in Hornsund and Suwałki.

Furthermore, the Department of Magnetism is responsible for the Task 3 and Task 4 of the EPOS-PL project. In 2020, the works on the paleomagnetic and magnetotelluric database were continued. The EPOS+ project has also started, which will allow for the further expansion of our laboratories.

PERSONNEL

Head of the Department
Waldemar Jóźwiak
Associate Professor

Professors
Magdalena Kądziałko-Hofmokl
Marek Lewandowski
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Krzysztof Mizerski
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Krzysztof Nowożyński

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Head of Laboratory for Paleomagnetism and Environmental Studies
Tomasz Werner

Head of Belsk Observatory
Jan Reda

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Agata Bury | Poland | Anne Neska

Dorota Staneczek | Poland | Rafał Szaniawski

Wojciech Szkółka | Poland | Krzysztof Mizerski, Dariusz Baranowski

Paweł Jujeczko | Poland | Krzysztof Mizerski

MAIN RESEARCH PROJECTS

Diversity of technogenic magnetic particles in the soil environment depending on the emission sources and their role in transport of potentially toxic elements | B. Górka-Kostrubiec | National Science Centre (NCN) OPUS 12 | 2017-2020;

Magnetic properties of sediments applied for assessment of pollution level of heavy metals of Vistula River water within Warsaw | I. Szczepaniak-Wnuk | National Science Centre (NCN) Preludium 13 | 2018-2020;

EPOS – PL European Plate Observing System; Task 4 - CIBAL - Centre of Research Infrastructure of Analytical laboratories | T. Werner | Operational Program Smart Growth 2014-2020 | 2017-2021;

EPOS – PL European Plate Observing System; Task 3 - CIBOGM - Geomagnetic and Magnetotelluric Observations Research Infrastructure Center | W. Jóźwiak | Operational Program Smart Growth 2014-2020 | 2017--2021;

Własności magnetyczne łupków gazonośnych dolnego Paleozoiku z obszaru północnej Polski | D. Niezabitowska | National Science Center, Poland Etiuda 7 | 2019-2020;

Własności minerałów magnetycznych jako potencjalny wskaźnik zawartości materii organicznej | D. Niezabitowska | IG PAS Internal Grant for the Young Scientists | 2019-2020;

Buoyancy driven magnetic dynamo | K. Mizerski | National Science Center, Poland Sonata Bis | 2018-2021;

The role of lithospheric memory in the spatial and temporal localization of the intraplate deformation - investigating a deep structure of the Grójec Fault Zone based on potential field anomalies and seismic data | W. Jóźwiak | National Science Center, Poland Opus 13 | 2018-2021;

Diagramy FORC jako narzędzie do kompleksowej charakterystyki faz ferromagnetycznych | K. Dudzisz | National Science Center, Poland Miniatura 3 | 2019-2020;

Badania zasięgu zanieczyszczeń poeksploatacyjnych przy użyciu metod magnetycznych i anizotropii podatności magnetycznej na obszarze Sudetów | K. Dudzisz | IG PAS Internal Grant for the Young Scientists | 2019-2020;

INSTRUMENTS AND FACILITIES

Equipment for magnetic susceptibility measurements in the field

- MS2 susceptibility meter (Bartington, Great Britain) with sensors
- MS3 susceptibility meter (Bartington, Great Britain) with sensors

Equipment for PM dust collection (environmental magnetism studies)

- PNS15C/ PM dust samplers (Atmoservice, Poland) - 3 units
- PNS18T/ PM dust samplers (Atmoservice, Poland and Comde Derenda) - 3 units

Equipment for Magnetotelluric Survey and Magnetic Observations

- 2 Magnetotelluric broad-band stations Phoenix
- 8 Magnetotelluric low-frequency stations Geomag
- 6 Low-frequency magnetometers LEMI
- 4 PMP proton magnetometers
- 4 Proton Overhauser magnetometers
- 4 Torsion photoelectric magnetometers PSM
- 4 DIFLUX magnetometers for absolute measurements
- 13 NDL digital recorders
- 18 LB-480 digital recorders

Laboratory for paleomagnetism and environmental studies - list of the laboratory equipment:
Equipment for measurements of magnetic remanence with step-wise AF/TH demagnetization

- 755–1.65 2G Enterprises cryogenic magnetometer DC SQUID with AF degausser
- JR6a automated dual speed spinner magnetometer (Agico, Czech Republic)
- MMTDSC - Nonmagnetic furnace for thermal demagnetization Magnetic Measurements, Great Britain
- MMTD-80 Nonmagnetic furnace for thermal demagnetization by Magnetic Measurements, Great Britain
- MMTD1 Nonmagnetic furnace for thermal demagnetization by Magnetic Measurements, Great Britain

Equipment for acquisition of magnetic remanence

- LDA5/PAM1 Alternating Field Demagnetizer/ Anhysteretic and Pulse Magnetizer, Agico, Czech Republic
- LDA3a/AMU1a, Alternating Field Demagnetizer/ Anhysteretic Magnetizer, Agico, Czech Republic
- Two MMPM10 pulse magnetisers, Magnetic Measurements, Great Britain
- SI6 - Pulse magnetizer, Sapphire Instruments, Canada
- Two MMLFC low field cages, Magnetic Measurements, Great Britain

Equipment for magnetic susceptibility measurements

- KLY-5A/CS-4/CS-L Susceptibility bridge Agico, Czech Rep.
- MFK1-FA - Susceptibility bridge, Agico, Czech Rep.
- KLY-3/CS-3/CS-L - Susceptibility bridge, Agico, Czech Rep.
- KLY2 Susceptibility bridge, Geofyzika Brno, Czechoslovakia
- MS2 susceptibility meter (Bartington, Great Britain),
- MS3 susceptibility meter (Bartington, Great Britain)

Equipment for studies of magnetic hysteresis and Curie temperatures

- Micromag AGFM 2900-02 Alternating gradient force magnetometer, Princeton Measurements Corp., USA
- VSM Nuvo Vibrating Sample Magnetometer, Molspin Ltd, Gr. Britain
- AVFTB (Advanced Variable Field Translation Balance) Petersen Instruments, Magnetic Measurements, Great Britain) upgrade of the cooler unit (EPOS-PL)
- STEPS III apparatus for SIRM (T) experiments (TUS Electronics, Poland) - upgrade of the new electronics (EPOS-PL)

Mass balances

- The microbalance MYA 5.4.Y F (RADWAG, Poland) for mass determination of PM collected on filters used in dust samplers (EPOS-PL)

PALEOMAGNETIC AND MAGNETIC FABRIC DATA FROM LOWER TRIASSIC REDBEDS OF THE CENTRAL WESTERN CARPATHIANS: NEW CONSTRAINTS ON THE PALEOGEOGRAPHIC AND TECTONIC EVOLUTION OF THE CARPATHIAN REGION.

Rafał Szaniawski, Mirosław Ludwiniak (University of Warsaw), Stefano Mazzoli (University of Camerino), Jacek Szczygieł (University of Silesia), Leszek Jankowski (Polish Geological Institute).

In the Central Western Carpathians (CWC), most of the published paleomagnetic results from Permo-Mesozoic rocks document extensive remagnetizations and come from thin-skinned thrust units that have undergone multistage deformation. We present results from lower Triassic redbeds from the autochthonous cover overlying the basement that carry a primary magnetization. Petromagnetic results indicate that the dominant ferromagnetic carrier is hematite, while magnetic susceptibility and its anisotropy are controlled by both ferromagnetic and paramagnetic minerals. Magnetic fabrics document weak deformation related to Late Cretaceous shortening. The directions of the high unblocking temperature remanence components pass both reversal and fold tests, attesting to their primary nature. Paleomagnetic inclinations are flatter than expected from reference datasets, suggesting small latitudinal separation between the CWC and stable Europe. Paleomagnetic declinations are mostly clustered within individual mountain massifs, implying their tectonic coherence. They show only minor differences between the massifs, indicating a lack of significant vertical-axis tectonic rotations within the studied central parts of the CWC. The paleomagnetic declinations are therefore representative of the whole of the CWC in terms of regional paleogeographic interpretations, and imply moderate counterclockwise rotations (c. 26°) of the region with respect to stable Europe since the Early Triassic.

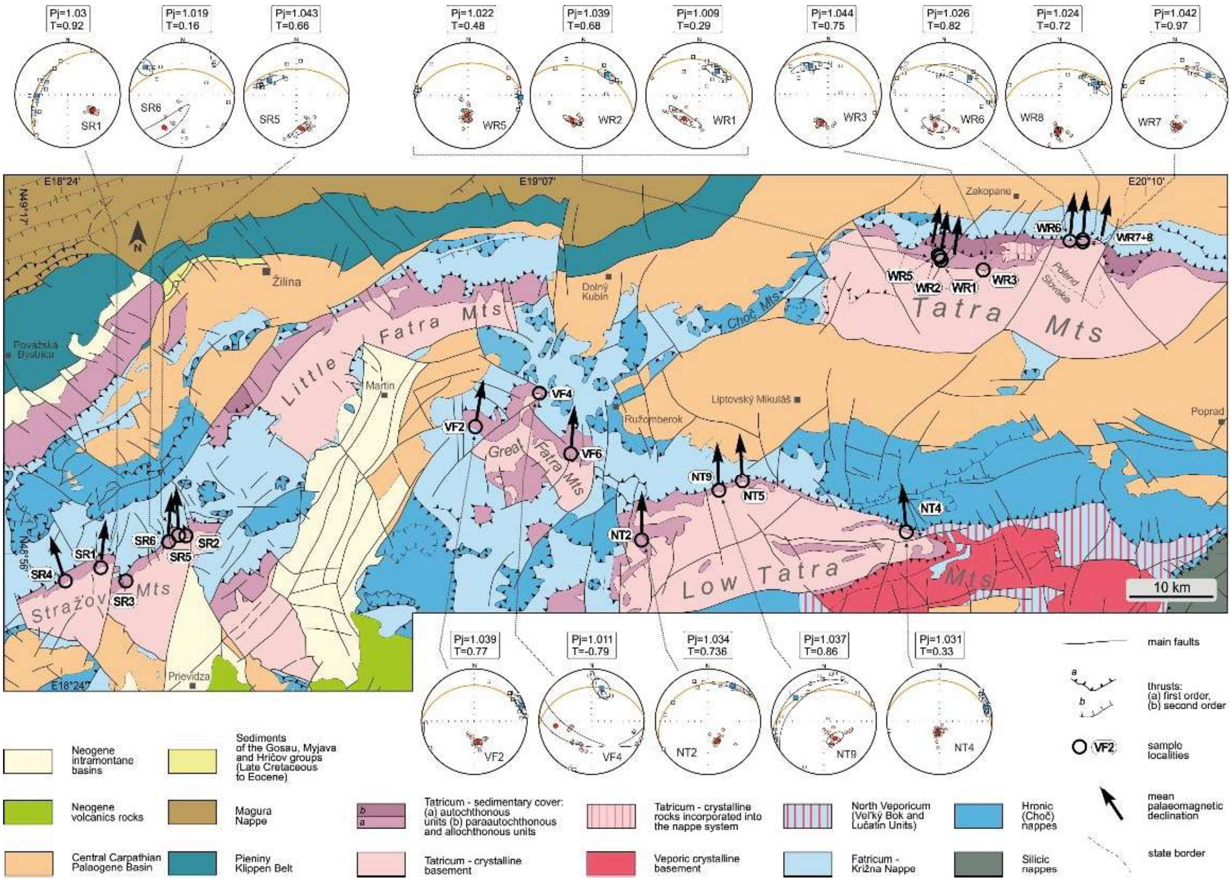


Fig. 1 Simplified geological map of the study area with marked location of sampling sites. Stereographic diagrams show AMS results (only for samples in which the susceptibility is higher than 30 × 10–6 SI volume); AMS principal axes are marked as red circles (Kmin) and blue squares (Kmax). Larger symbols representing site-mean principal axes are shown with their 95% confidence ellipses. Orange circles are mean bedding. T: shape parameter; Pj: corrected anisotropy degree.

RESEARCH ACTIVITY AND RESULTS

HYDROMAGNETIC DYNAMO IN NON-STATIONARY TURBULENCE

Krzysztof Mizerski

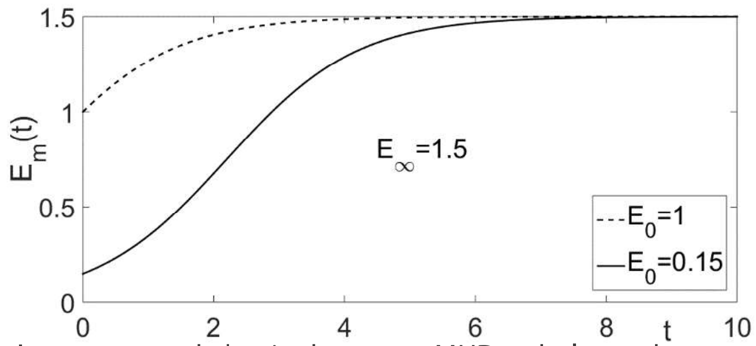
The turbulent hydromagnetic dynamo is a process of magnetic field generation by chaotic flow of an electrically conducting fluid (plasma, liquid iron etc.). It is responsible for generation of large-scale magnetic fields of astrophysical objects such as planets, stars, accretion discs, galaxies, galaxy clusters etc. In particular, the dynamical process of induction of large-scale fields by highly conducting plasma has been very difficult to understand, as very low resistivity is not capable of creating a phase shift between magnetic and kinetic components of waves, making their interaction ineffective for generation of a large-scale electromotive force (EMF). It has been demonstrated in Mizerski K.A. (2020, “Renormalization Group Analysis of the Turbulent Hydromagnetic Dynamo: The Effect of Nonstationarity”, Astroph. J. Suppl. Ser., 251(2):21) that when the typically invoked statistical stationarity of turbulence is relaxed, large-scale magnetic fields can be very effectively generated by low-resistivity plasma. The renormalization group technique was applied to extract the final expression for the mean EMF from the fully nonlinear dynamical equations (Navier-Stokes, induction equation) and the mean-field equations were solved for a force-free mode. Non-stationarity was shown to strongly enhance the process of large-scale EMF generation via wave interactions and the dynamo effect induced by non-stationarity was proved to be effective. The results were also used to demonstrate the influence of magnetic fields and non-stationarity on energy and helicity Fourier spectra of turbulent flows.

The analysis was focused on derivation of the full set of magnetohydrodynamic equations describing the dynamics of mean velocity and magnetic fields and the large-scale dynamo process in strong, fully nonlinear, non-stationary stirred turbulence. An important feature of the analysis performed was the inclusion of the effect of the Lorentz force on the flow, hitherto scarcely considered in the literature. We have applied the renormalization technique, which allowed to incorporate the effect of the nonlinear terms in the dynamical equations for turbulent fluctuations, in the limit of a small 'Rossby' number Ro<<1 , defined as a relative measure of the fluid's inertia with respect to the stirring force. The main results are listed below.

• The complete form of the mean EMF was obtained for strong, non-stationary turbulence. Both it's linear and nonlinear dependence on the large-scale magnetic field, the latter resulting from the action of the Lorentz force, were fully described.

• Of particular astrophysical interest is the limit of low viscosity and resistivity, which was thoroughly examined. In such a limit it was the non-stationarity of turbulence, i.e. the fully nonlinear interactions of waves (Fourier modes) with distinct frequencies, which were predominantly responsible for creation of the large-scale EMF, dominating the diffusively controlled mechanism. The latter, based on resistive phase shift between the kinetic and magnetic components of waves, is the only mechanism of large-scale EMF generation in stationary turbulence.

• Full energy evolution, including amplification and saturation, was found and studied for a force-free mode of the mean magnetic field. The value of the saturational energy was obtained.



Saturation of the magnetic energy of a force free mode for two cases: E∞/E0 =10 (solid line) and E∞ /E0 =1.5 (dashed line); in both cases the asymptotic energy value is E∞ =1.5 , but the initial energies differ

• It was reported, that in the strong MHD turbulence the energy spectra are substantially influenced by the helical component of the stirring force.

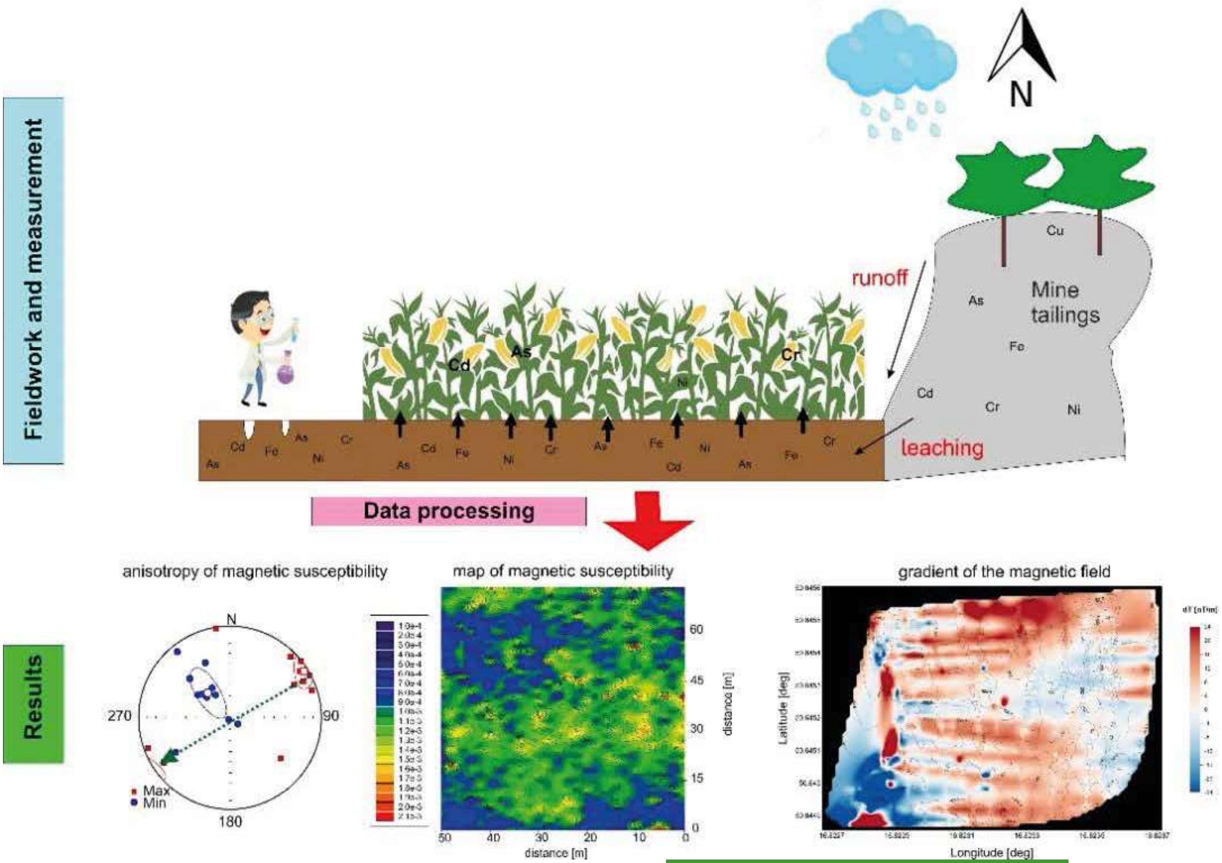
RESEARCH ACTIVITY AND RESULTS

ANISOTROPY OF OUT-OF-PHASE MAGNETIC SUSCEPTIBILITY AS A TOOL FOR TRACKING HEAVY METALS POLLUTION: A NEW APPROACH TO ENVIRONMENTAL MAGNETISM STUDY

Katarzyna Dudzisz, Szymon Oryński

The anisotropy of magnetic susceptibility (AMS) was successfully used to track deformation and flow directions in rocks and unconsolidated sediments. However, it has been very rarely applied to soils. In this study, AMS measurements together with in situ mappings of magnetic susceptibility and electromagnetic (EM) methods were employed to study soils around historical mining areas in the Sudetes Mountains (Poland). This place was selected in order to examine the spatial spread of contamination from the tailings, their potential sources and to test the potential use of the AMS to study migration pathways. These sites are diversified in terms of exploitation time and type of ore (Zloty Stok – gold and arsenic, Janowa Gora – iron and Szklary - nickel). They were selected in order to examine the spatial spread of contamination from mine tailings, their potential sources and to test the potential used of the AMS to study migration pathways.

The highest values of magnetic susceptibility (1-5x10-3 SI) are observed around nickel tailings, whereas the lowest values (60-120x10-6 SI) characterize the iron mining area. Preliminary results of GCM and magnetometry indicate the occurrence of overlapping anomalies in the studied area. Mapping of in situ magnetic susceptibility shows variability within particular sites. For Szklary, all methods indicate the presence of an elongated anomaly roughly NE-SW oriented. Although AMS axes of in-phase susceptibility are randomly distributed for all sites, magnetic fabric created by ferromagnetic minerals (out-of-phase, opAMS) indicate well-grouped maximum susceptibility axes mainly oriented NE-SW. There is a clear correlation between the mapped anomaly around nickel tailings (Szklary) and opAMS lineation. Outside the anomaly, opAMS directions are oriented SE-NW. For other sites, opAMS is also in line with results of EM methods. Taking these results, as well as landforms and hydrological conditions into account, it is suggested that magnetic minerals accompanying heavy metals migrate most likely with subsurface runoffs, and opAMS is capable of detecting changes in the direction of the pollution spread.



MEETINGS, WORKSHOP CONFERENCES and SYMPOSIA

M. Lewandowski, M. A. Kusiak, A. Nawrot, B. Barzycka, M. Laska, T. Werner, B. Luks | Dust over Svalbard: evidence for a recent , short distance transport | THE 4th WORKSHOP ON EFFECTS AND EXTREMES OF HIGH LATITUDE DUST | Islandia, Reykjavik | 13-14.02.2020 | oral

J. Reda | Report on definitive data timelines | INTERMAGNET Meeting | 13-15.07.2020 | oral

J. Reda | Progress on one-second data collection | INTERMAGNET Meeting | 13-15.07.2020 | oral

D. Niezabitowska, J. Roszkowska-Remin, R. Szaniawski | Magnetic Susceptibility Variations in Lower Paleozoic Shales of the Baltic Basin (Northern Poland) – A Helpful Tool for Regional Correlations and Decoding of Paleoenvironment Changes | Goldschmidt Virtual 2020 | 21-26.06.2020 | oral

K. Dudzisz, S. Oryński | Can anisotropy of out-of-phase magnetic susceptibility be used for tracking heavy metals pollution in soils: insights from mining areas in Sudetes Mountains, Poland | Magnetic Interactions 2020 | Southampton, UK | 9-10.01.2020 | poster

K. Dudzisz, S. Oryński, B. Górka – Kostrubiec, W. Klityński | Anisotropy of out-of-phase magnetic susceptibility as a tool for tracking heavy metals pollution: a new approach to environmental magnetism study | EGU General Assembly | 4-8.05.2020 | oral

K. Mizerski | Equations of hydrodynamics in geophysical problems | Faculty of Mathematics, Informatics and Mechanics, University of Warsaw | Warsaw, Poland | 02.-06.2020 | lecture

K. Mizerski | Applications of mathematics in astrophysical hydrodynamics | Faculty of Mathematics, Informatics and Mechanics, University of Warsaw | Warsaw, Poland | 12.2020 | seminar

D. Niezabitowska | The thermal and chemical evolution of sedimentary basin materials, and the effects on measurable magnetic properties | Institute for Rock Magnetism, University of Minnesota | Minnesota, Minneapolis, USA | 13.02.2020 | lecture

K. Dudzisz | Evaluating pollution distributions in soils around abandoned mining areas in the Sudetes Mountains, Poland: insights into the application of magnetic and electromagnetic methods | Institute of Applied Geosciences, Karlsruhe Institute of Technology | Karlsruhe, Germany | 23.01.2020 | Invited lecture

PUBLICATIONS

ARTICLES

Szczepaniak-Wnuk I., Górka-Kostrubiec B., Dytłow S., et al., 2020, Assessment of heavy metal pollution in Vistula river (Poland) sediments by using magnetic methods, Environmental Science and Pollution Research, 27, pp. 24129–24144.

Gumsley A., el al., **Michalski K.**, 2020, Caught between two continents: First identification of the Ediacaran Central Iapetus Magmatic Province in Western Svalbard with palaeogeographic implications during final Rodinia breakup, Precambrian Research, 341, 105622.

Górka-Kostrubiec B., et al., **Dudzisz K., Dytłow S.**, 2020, Integrated magnetic analyses for the discrimination of urban and industrial dusts, Minerals, 10(12), 1056.

Szaniawski R., et al., 2020, Paleomagnetic and magnetic fabric data from Lower Triassic redbeds of the Central Western Carpathians: new constraints on the paleogeographic and tectonic evolution of the Carpathian region, Journal of the Geological Society, 177, pp. 509-522.

Mizerski K. A., 2020, Renormalization Group Analysis of the Turbulent Hydromagnetic Dynamo: The Effect of Nonstationarity, The Astrophysical Journal. Supplement Series, 251 (2).

Lewandowski M., Kusiak M. A., **Werner T.**, Nawrot A., et al., Luks B., 2020, Seeking the Sources of Dust: Geochemical and Magnetic Studies on "Cryodust" in Glacial Cores from Southern Spitsbergen (Svalbard, Norway), Atmosphere, 11(12), 1325.

Ernst T., Nowożyński K., Jóźwiak W., 2020, The reduction of source effect for reliable estimation of geomagnetic transfer functions, Geophysical Journal International, 221 (1), pp. 415–430.

Caggio M, et al., **Mizerski K. A.**, 2020, Vertical heat transport at infinite Prandtl numer for micropolar fluid, ARCHIVES OF MECHANICS, 72 (6), pp. 525–553.

Del Corpo A., et al., **Reda J.**, 2020, An Empirical Model for the Dayside Magnetospheric Plasma Mass Density Derived From EMMA Magnetometer Network Observations, JOURNAL OF GEOPHYSICAL RESEARCH (SPACE PHYSICS), 125 (2), e2019JA027381.

Satolli S., et al., **Staneczek D.**, 2020, Magnetic fabric in carbonatic rocks from thrust shear zones: A study from the Northern Apennines (Italy), Tectonophysics, 791, 228573.