Lecture title: Magnetic methods in geological and environmental sciences

- ***COURSE SYLLABUS***

1.	**Course title:** Magnetic methods in geological and environmental sciences	
2.	**Lecturer:** *dr Dominika K. Niezabitowska-Śliwka & dr Sylwia K. Dytłow*	
3.	**Field, type and level of studies, year of study:** *rock magnetism and environmental magnetism, all years of study*	
4.	**Course character:** *monographic lecture*	
5.	**Teaching method:** *traditional*	
6.	**Language:**	*depending on the audience*
7.	**Course type and number of hours:** *Lecture (9 h), practice (16 h), Total: 25 h*	
8.	**Estimated load of student's independent work:**	*30 h*
9.	**Total workload and number of ECTS points:**	*55 h, 2 ECTS*
10.	**Short description and main focus of the course:** This doctoral course offers a comprehensive exploration of magnetic methods, bridging traditional applications in geological sciences with modern environmental diagnostics.	

Within the scope of geological sciences, magnetic techniques are utilized to investigate rock genesis, sedimentary dynamics, palaeoenvironmental changes, and magnetic field recording frameworks. Within the scope of environmental sciences, magnetic parameters serve as sensitive proxies for characterizing topsoils, atmospheric particulates, and road dust, with particular emphasis on identifying anthropogenic magnetic particles derived from vehicular wear and industrial emissions.

The course places equal emphasis on two complementary domain applications:

1. **Geological sciences:** Investigating rock and mineral magnetism, sedimentary processes, palaeoenvironmental reconstructions, natural soil dynamics and Earth's magnetic field recording.
2. **Environmental sciences:** Characterizing topsoils, atmospheric particulate matter, and street/road dust, with a focus on anthropogenic magnetic particles (AMPs) as indicators of traffic- and industry-related pollution.

A primary pillar of the course is multi-proxy analytical integration. Doctoral students examine the physical mechanisms of magnetism in matter, mastering parameters such as magnetic susceptibility, hysteresis properties, and thermomagnetic behavior. The course details how these magnetic proxies are combined with a comprehensive instrumental analytical suite. In geological contexts, the student will learn to apply magnetic proxies to facies analysis, sediment source tracing, and pedogenic processes, as well as to integrate magnetic mineral properties with magnetic field recording. In environmental contexts, the student will gain the ability to characterize road dust, urban topsoils, and airborne particulates, distinguishing technogenic magnetic signatures from natural mineral phases and evaluating their co-association with heavy metals, polycyclic aromatic hydrocarbons, and microplastics. Additionally, the role of multivariate statistical methodologies (PCA and HCA) will be introduced to show their potential in data interpretation.
The detailed program covers:

Lecture Program (9h):

1. **Fundamental Physics: Domain Theory, Hysteresis, and Magnetic Minerals (3 h)**

- Magnetic order: dia-, para-, ferro-, and ferrimagnetism.
- Domain theory: detailed analysis of magnetic domains.
- Energetics of magnetization and basic parameters: understanding the hysteresis loop and extracting fundamental parameters.
- Curie temperatures and the identification of magnetic mineralogy.

2. Remanence, Magnetic Anisotropy, and Magnetic Grain-Size Diagnostics (2 h)

- Isothermal and anhysteretic remanent magnetization and their role for grain size distribution
- Interpretation frameworks: Day- Dunlop plot, Tauxe plot, King plot, Dearing plot to define domain state boundaries and identify magnetic mixing.
- Anisotropy of magnetic susceptibility and its applications in geology and environmental sciences

3. Geological Sciences: From Genesis to Paleointensity (2 h)

- Rock magnetism and sedimentary dynamics: magnetic signatures of transport, depositional environments, and early diagenesis.
- Magnetostratigraphy: theoretical and practical basis of polarity reversal dating and constructing high resolution chronologies.

- Paleoenvironmental records: utilizing magnetic susceptibility and remanence to track paleoclimate cycles, sediment provenance, and variations in the paleointensity of the Earth magnetic field.

4. Environmental Sciences: AMPs and Anthropogenic Pollution (2 h)

- Anthropogenic magnetic particles: characterization of grains derived from vehicle exhaust, brake wear, and industrial combustion.
- Why magnetism: magnetic susceptibility as a cost effective, high resolution spatial proxy for traffic and industry related pollutants.
- Multi proxy integration: coupling magnetic signatures with heavy metal concentration, polycyclic aromatic hydrocarbon distributions, and microplastics.
- Source apportionment: using principal component analysis and hierarchical cluster analysis and diagnostic ratios.

Practice Program (16 hours)

1. **Laboratory Setup, Devices, and Sample Preparation Procedures (4 h)**
- Familiarization with laboratory devices.
- Overview of various sample types and designing custom preparation procedures for geological drill cores and environmental matrices.
- Selecting appropriate measurement types and establishing objectives for specific analytical goals.
2. **Data Acquisition, Raw Data Collection, and Processing (8 h)**
- Running practical measurements on diverse sample sets.
- Collecting raw data and performing mass normalization and recalculations.
- Data processing workflows to convert raw instrument signals into standardized magnetic parameters.
3. **Specialized Interpretation for Geological and Environmental Samples (4 h)**
- Applying specific diagnostic protocols to differentiate natural mineral assemblages from technogenic inputs.
- Interpreting dataset and constructing interpretation diagrams for real world sample sets.

11. References:

- Evans, M. E., & Heller, F. (2003). Environmental magnetism: principles and applications of enviromagnetics. Academic Press (Elsevier), New York.
- Tauxe, L. (2005). Lectures in paleomagnetism. Tauxe, L., 2005. Lectures in paleomagnetism. http://earthref.org/MAGIC/books/Tauxe/2005/.
- Tauxe, L. (1993). Sedimentary records of relative paleointensity of the geomagnetic field: Theory and practice, Rev. Geophys., 31(3), 319–354, doi:10.1029/93RG01771
- Thompson, R., & Oldfield, F. (1986). Environmental Magnetism. Springer Netherlands. https://doi.org/10.1007/978-94-011-8036-8
- O'Reilly W. (1984). Rock and Mineral Magnetism, Chapman and Hall, New York

12. Prerequisites:

none

13.	**Educational outcomes:**	**PQF level 8 codes:**
	Knowledge: Upon completion of the course, students have knowledge of the applications of magnetic methods in geology and environmental sciences and understand the physical mechanisms underlying magnetic properties of materials, including magnetic susceptibility, hysteresis, and thermomagnetic behavior. They understand the principles of measuring and analyzing magnetic properties of geological and environmental samples and the interpretation of magnetic data. They are familiar with the integration of magnetic methods with complementary laboratory techniques within a multi-proxy approach. Students also acquire knowledge of current research practices and international standards for evaluating, presenting, and communicating scientific results.	*P8S_WG*
	Practical Skills: Students know how to apply, combine, and interpret magnetic methods across both geology and environmental science. The course empowers them to practice laboratory work, analyze complex dataset, and creatively solve modern research problems. Students learn to use multi-proxy approaches and advanced analysis, allowing them to introduce fresh interdisciplinary perspectives and contribute novel elements to their field. Mastering complex methodological paths of versatile magnetic techniques gives doctoral candidates the technical independence to plan their own research path and spark innovative ideas. Grounded in global standards, the curriculum prepares them to share their findings and collaborate effectively.	*P8U_U*
	Social Skills: By engaging in hands-on data practical lectures and interactive classroom sessions, the course empowers doctoral students to critically evaluate the existing achievements, limitations, and paradigms of their academic discipline. Through practical data analysis, students learn to rigorously assess their own research contributions and identify how their combined geological and environmental findings advance the field. Furthermore, these interactive exercises highlight the direct real-world value of magnetic methods, showing students, how theoretical knowledge and multi-proxy data solve both complex cognitive challenges and practical environmental problems. Ultimately, the course bridges distinct scientific disciplines, enabling students to actively and creatively participate in the international research community.	*P8S_KK*
14.	**Evaluation of the educational outcomes:**	
	Part 1: Post-class preparation, literature reviews, and group discussions (30% of final grade Continuous assessment based on out-of-class workload and active academic engagement following each class session:	

	1. Short literature and homework reports: Following class session, the student must complete assigned reading of peer-reviewed scientific literature and submit a concise report (maximum of one A4 page) alongside practical data processing homework tasks. The report must critically synthesize key methodological approaches and findings from assigned readings. **2. Class opening discussions:** The first 10 minutes of class session are dedicated to a structured group discussion based on the assigned literature and homework tasks. Students are evaluated on their active participation, critical reasoning, and ability to articulate core physical and environmental magnetism concepts. **Part 2: Magnetic data interpretation and literature-based research report (70% of final grade)** A detailed independent research report (maximum of 4 A4 pages) based on raw, real-world magnetic measurement datasets. The report focuses on processing, plotting, and interpreting magnetic parameters, requiring the student to demonstrate proficiency in rock and environmental magnetism diagnostics: -The student must process raw measurement data to determine magnetic susceptibility, calculate hysteresis loop parameters and analyze thermomagnetic curves. The student is required to construct and interpret standard diagnostic biplots, specifically: Day–Dunlop plot, King plot and Dearing plot. -The student must synthesize the dataset to infer mineral phase transformations, particle origin (lithogenic vs. anthropogenic/pedogenic), or grain-size control. The findings must be critically contextualized through a literature review of contemporary peer-reviewed studies in geological or environmental sciences.
15.	**Criteria to complete the course:** *at least 60% attendance, final pass depends on the evaluation of the quality of the homework tasks and final report*
16.	**Contact with the lecturer:** *dniezabitowska@igf.edu.pl (dr D.N-Ś)* *skdytlow@igf.edu.pl (dr S.D.)*