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Magnetic susceptibility as a versatile investigation tool in different geocontexts: from Palaeozoic rocks to Recent sediments. An overview of three case studies

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Based on measurements on different types of rocks and sediments, various applications of the magnetic susceptibility (MS) in geology, geophysics and geoecology are presented. These have originated from outcrops, quarries or exploration wells, and respectively, from deltaic, lagoonal or marine sedimentary environments. Temporally, it is covered an interval between ca 380 Ma and Recent, and spatially, from Southern Carpathians to Danube, and from western Dacic Basin to Danube Delta and Northwestern Black Sea.

The first case regards an application of the magnetic susceptibility in geology (RĂDAN & RĂDAN, 1980a). Starting from more than 50,000 MS values obtained for cores extracted from 37 exploration wells in the Iazuri – Vlădeasa area (Poiana Ruscă Mountains, Southern Carpathians), a series of magnetic susceptibility models were carried out for the Devonian epimetamorphic schists. The MS vertical variations were illustrated by diagrams associated with each bore hole and by vertical sections supported by 6 to 9 exploration wells, placed along 3 profiles (RĂDAN & RĂDAN, 1980b). On the other side, several susceptibility maps were drawn, in two versions (RĂDAN & RĂDAN, 1981). All these models gave useful information concerning the two complexes of rocks of the "Ghelar series", which are characteristic for the Iazuri perysinclinal structure: the green tufogene schists (Middle Devonian) and the sericito-chlorito-quartzose schists (Upper Devonian). The magnetite bearing mineralisation distribution within the first complex is clearly outlined by means of the petromagnetic patterns. Besides, some tests for the magnetic susceptibility anisotropy of the epimetamorphic schists were performed (RĂDAN & RĂDAN, 1981). Finally, there are discussed the maps with susceptibility contours carried out at the lower, middle and upper levels of the main tuffogenous horizon of the tuffogenous greenschist complex (Middle Devonian), and also for the whole main horizon. The augmented Fe contents seem to be determined by the proximity of some important submarine volcanoes (MUREŞAN, 1973*).* The MS distribution pattern allows the identification of several supply palaeodirections of the volcanogenic material and of the associated iron minerals. The existence of a submarine volcanic activity in the vicinity of the Iazuri-Vlădeasa area, pointed out by petrographical methods (MUREŞAN, 1973), acquires thus a geophysical support, yielded by the magnetic susceptibility data.

The second case is dealing with the magnetic properties of the Pliocene coal bearing formations from the Western Dacic Basin (WDB), Southwestern Romania. Actually, it is a case history of the various signatures (*i.e*., geophysical, geological and geochemical) which were discovered in this area and that provide evidence of past "coal fires" (RĂDAN & RĂDAN, 2012). The rock magnetic signal that is characteristic for the "original" clays (not affected by coal fires), sampled in the WDB ("Jilţ Sud" and "Lupoaia" lignite quarries), is defined by a low amplitude. The initial magnetic susceptibility (k_{in}) exhibits values rarely exceeding $75 \times 10^{-6} \times 4\pi$ SI. During thermal demagnetisation works, as a result of some mineralogical transformations produced, we remarked an increasing of the magnetic susceptibility when temperatures higher than 300°C were applied (RĂDAN, 1998). The hematite appearance is possible, at the expense of the goethite or pyrite, but also the presence of the greigite is not excluded, in agreement with the first condition mentioned by KRS et al. (1990): the existence of the finely dispersed organic material and of some greater floristic and faunistic fragments, which favours a reducing environment. The presence of the vegetal material inside of several samples described as coaly clays, in one of them the gypsum being observed as well, stands for arguments for the possible appearance of the greigite. It can be added that during the palaeomagnetic stability tests, at the temperature steps of 300°C, 320°, 340°, 360°, 380° and 400°C it was easily established the sulfur release as volatile compounds, in fact a process taking place during the natural baking of the clays (S. RĂDAN, in RĂDAN, 1998). The rock magnetic signal, sent by the "baked clays", is changed in comparison with the signal received from the "original" clays. High and very high MS amplitudes were recorded for porcellanites and porcellanite-like clays: the k_{in} values range between $200 \times 10^{-6} \times 4\pi$ SI and $1500 \times 10^{-6} \times 4\pi$ SI, sometimes reaching $12800 \times 10^{-6} \times 4\pi$ SI. Besides, the enhancement of several

magnetic susceptibility anisotropy parameters was observed: e.g., the magnetic foliation (F) and the anisotropy degree (P) record values between 1.10 – 1.20, sometimes as high as 1.30 – 1.40, while for the thermally un-affected clays, a range of 1.03 – 1.05 was achieved for F and P. Instead, the features of the spatial distribution of the principal susceptibilities were generally preserved. So, the magnetic fabric is defined by similar characteristics with those obtained for the "original"/"fresh" clays. This remark is consistent with the data published by PERARNAU & TARLING (1985). The remanent magnetisation and the palaeogeomagnetic signatures are also comparatively analysed ("baked" *vs* "fresh" clays). The porcellanite deposits are able to produce significant magnetic anomalies; in the investigated area, amplitudes up to 1880 nT were measured.
The last case presented in the paper regards the use of the magnetic susceptibility as an investigation tool in aquatic sedimentary environments. A vast enviromagnetic archive of recent sediments from Danube Delta (DD), Razim (Razelm) – Sinoie Lagoonal Complex (RSLC), Black Sea Littoral Zone (BSLZ) and Northwestern Black Sea (NWBS) has been sampled over about 35 years (RĂDAN & RĂDAN, 2011). The most extended data bank belongs to the deltaic – lagoonal system (DD – RSLC) and is based on thousands of (sub)samples collected during the cruises carried out in the 1976 – 2011 period. To calibrate the modern sediments and to compare different magnetic fingerprints recovered from the various aquatic environments, a "magnetic susceptibility scale" (RĂDAN & RĂDAN, 2007) is used. The integrated magnetic susceptibility-lithological patterns associated with 10 deltaic lakes emphasize the allochthonous sedimentation, predominantly detrital in the lacustrine ecosystems that are directly influenced by the Danube River, comparing with the dominantly autochthonous sedimentation in the distal zones, where the organic component is mostly present. As regards the RSLC area, the MS data bank comprising around 1800 k values measured on bottom sediment samples (cores included) was systematized relating to 3 time periods in which the all four main lakes of the lagoonal complex were investigated: 1976 – 1978, 2002 – 2004 and 2007 – 2010. Based on the calibration of the lake sediments to the magnetic susceptibility scale, the data interpretation in a hydrodinamic context proved the sedimentogenetic capabilities of this versatile investigation tool. The quality of proxy environmental parameter of the magnetic susceptibility was even more demonstrated by a series of examples presented for the modern sediments sampled in four lakes of the Black Sea Littoral Zone, as well as in the Northwestern Black Sea. In conclusion, we remark that the validity of the VEROSUB & ROBERTS (1995) statement, *i.e.* "*many types of studies that are now classified as environmental magnetism have been in existence for some time*", is clearly proved by the enviromagnetic archives recovered from the modern sediments (RĂDAN & RĂDAN, 2011), sampled during 1976-2011 period, in various aquatic environments from the Danube – Danube Delta – Black Sea macro-system.

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Artikel/Article: Magnetic susceptibility as a versatile investigation tool in different geocontexts: from Palaeozoic rocks to Recent sediments. An overview of three case studies. 40-42