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The magnetic susceptibility of soils and alluvial sediments from Gdańsk region (northern Poland)

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Volume magnetic susceptibility of soils and alluvial sediments from the eastern Pomeranian region near Gdańsk was investigated. Full set of geochemical analyses had been previously performed for all the samples studied. The results are presented in the form of the susceptibility maps of the topsoil horizon, the subsoil at the depth between 40 and 60 cm and the alluvial sediments. Additionally the differential susceptibility map between topsoil horizon and the subsoil at the depth 40–60 cm has been also constructed. A close correlation is observed between positive anomalies of differential susceptibility and urban areas. This is interpreted as surface anthropogenic pollution. Magnetic susceptibility values higher than 1200×10^{-6} SI units, observed in topsoil horizon, might reflect high contents of such elements as Ba, Co, Mg, Mn and Ni.

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INTRODUCTION

The search for quick and cheap methods for environmental monitoring, being alternative or complementary to the geochemical mapping, has become an important challenge for geophysics. Magnetometric methods has been successfully applied in environmental studies of soils and sediments. Magnetic susceptibility maps of soils were constructed for the area of England and Wales. They reveal susceptibility anomalies related to large industrial centres (Hay *et al.*, 1997). Similar maps of regional scale are prepared in Austria (Scholger, 1997) and Switzerland (Zergenyi *et al.*, 1998).

This study presents the record of the low frequency magnetic susceptibility of soil, subsoil and alluvial sediments from the Vistula mouth area. The results of magnetic measurements were directly compared to geochemical spectra, which enabled to establish the correlation between higher contents of some elements and magnetic susceptibility values of investigated samples. Geochemical data base used in this study was adopted from *Geochemical Atlas of Poland* (Lis and Pasieczna, 1995), which significantly lowered the total costs of investigations.

METHODS AND SAMPLING

Magnetic susceptibility (k) is a measure of the ease with which a material can be magnetised. Positive values of k are directly related to the content of ferro- and paramagnetic particles in the sediment sample. Negative values of k indicate influence of diamagnetic minerals. Magnetic susceptibility of topsoil might be of either natural (geogenic or pedogenic) or anthropogenic origin. The latter arises from accumulation of industrial dust, rich in strongly magnetic minerals. In this case easy measurable magnetic susceptibility might reflect an amount of industrial dust influx into soils (e.g. Heller *et al.*, 1998). It has also been proved that fuel burning, cement production as well as metallurgical and other processes are the sources of magnetic particles released to the atmosphere as aerosols (e.g. Strzyszcz *et al.*, 1996). These dusts usually contain a significant amount of heavy metals. It was revealed twenty years ago (Hullet *et al.*, 1980) that most metals which occur in coal in the form of sulphides (Pb, Zn, Cd, V, Cr, Co, Ni and Cu), are present in ashes together with magnetic minerals.

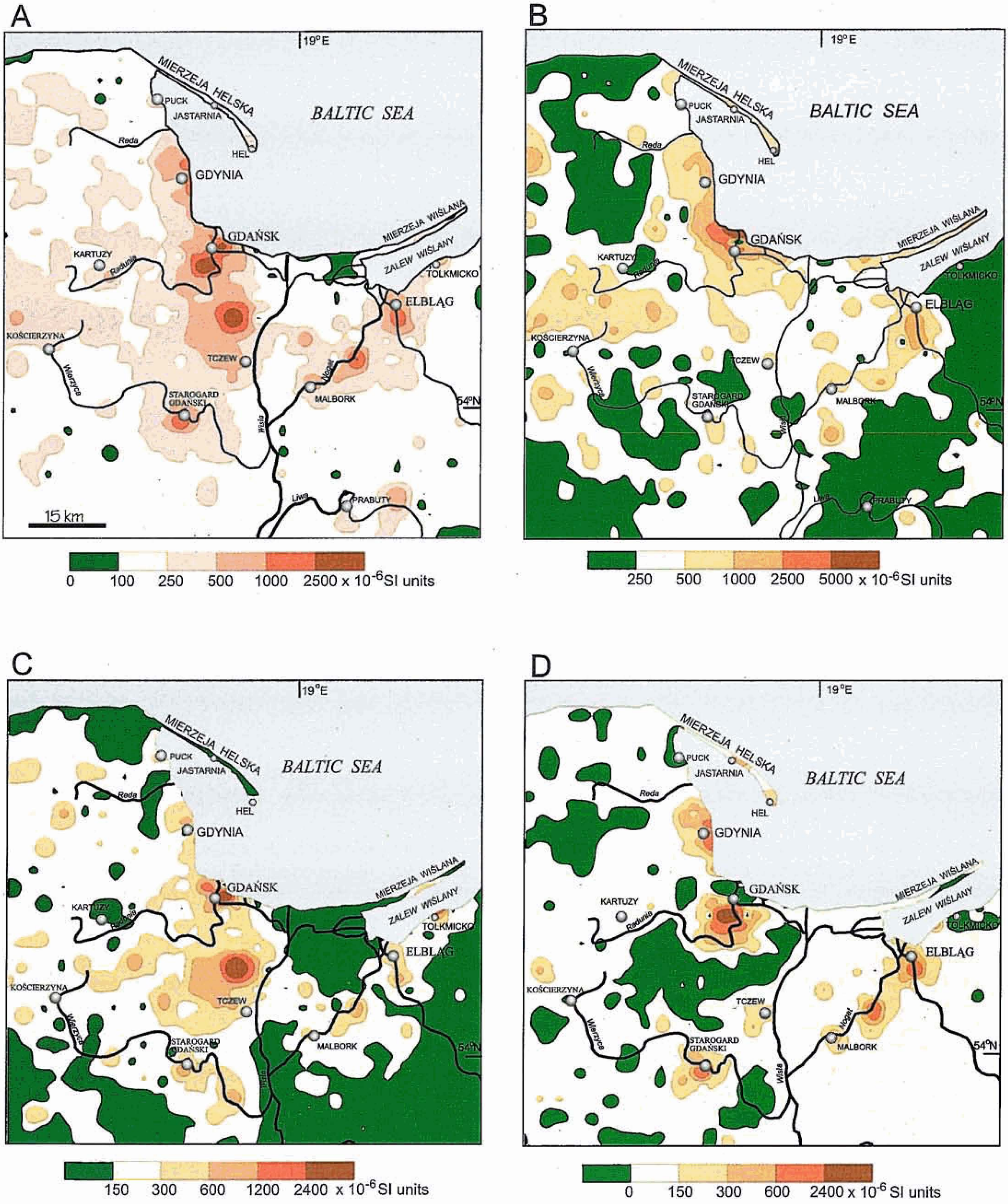

Fig. 1. **A**. Magnetic susceptibility map of topsoils from the Gdańsk region; **B**. Magnetic susceptibility map of alluvial sediments from the Gdańsk region; **C**. Magnetic susceptibility map of subsoils (at the depth of 40–60 cm) from Gdańsk region; **D**. Map of differential magnetic susceptibility between topsoil horizon and subsoil at the depth of 40–60 cm

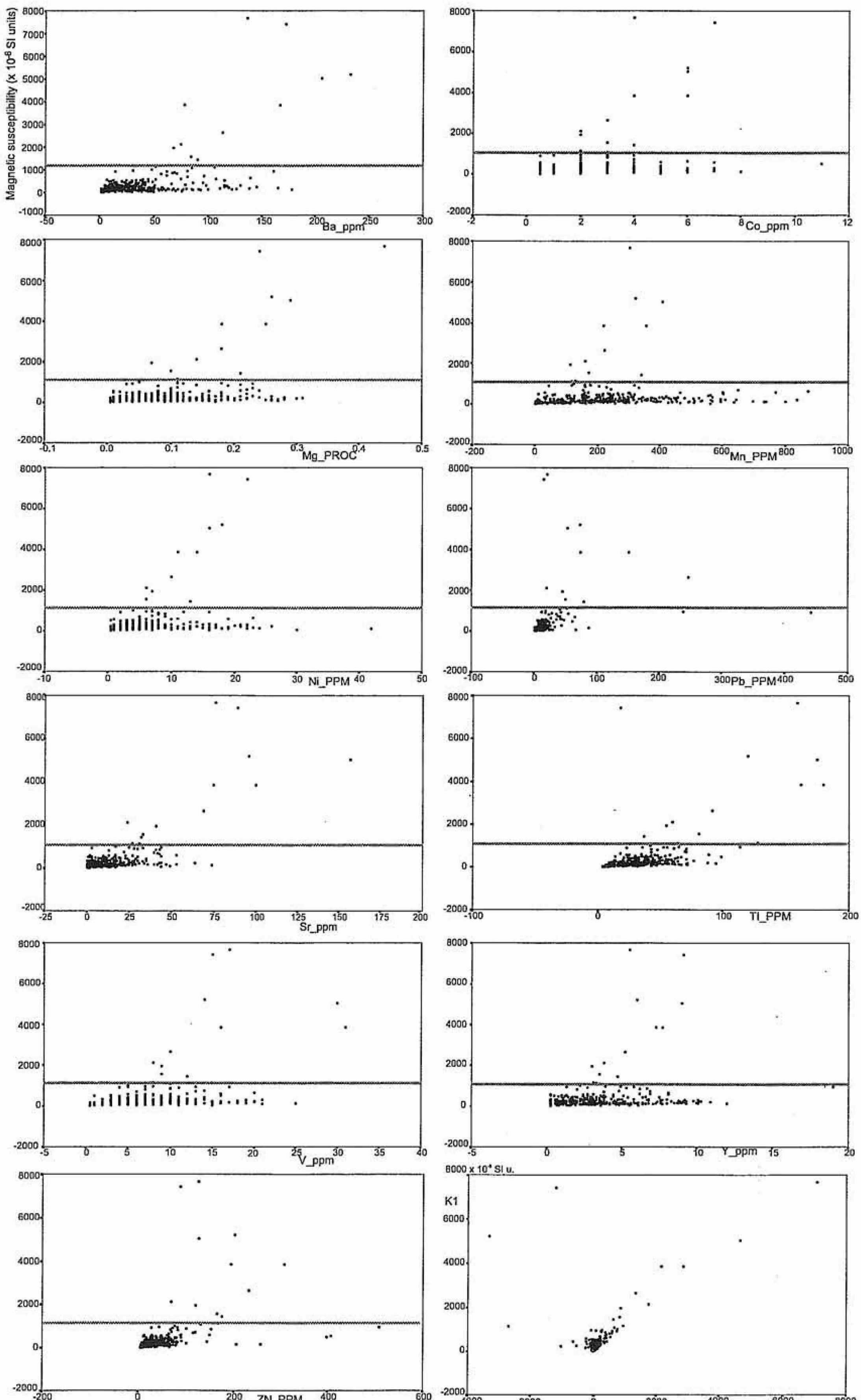

Fig. 2. Magnetic susceptibility of topsoils from Gdańsk region versus concentration of selected elements

The last plot shows the magnetic susceptibility of topsoil (K1) versus differential magnetic susceptibility between topsoil and subsoil at the depth of 40–60 cm (K1–K2); magnetic susceptibility measurements and geochemical analyses were carried out on the same sample set

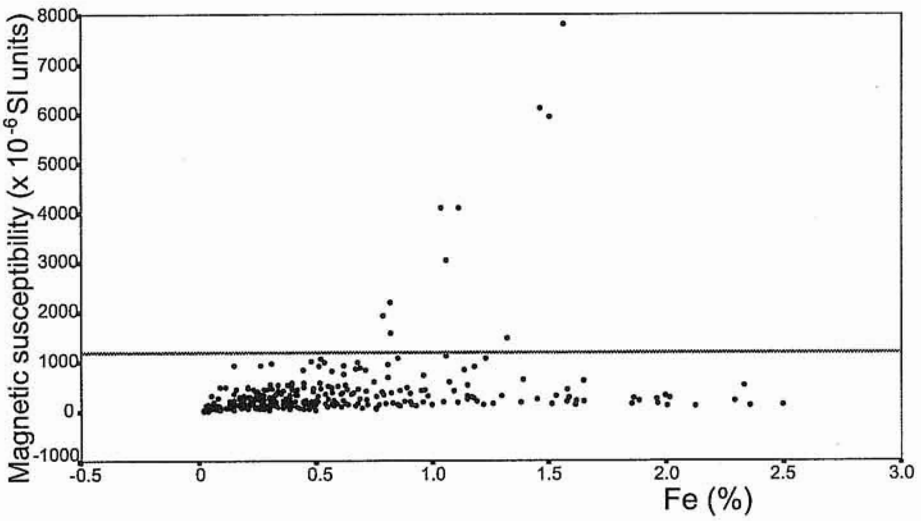

Fig. 3. Magnetic susceptibility of Gdańsk region versus percentage concentration of iron

The area of investigation is situated between 18 and 19.6° long. E, and between 53.7 and 54.8° lat. N. Its central part is the Vistula delta. Magnetic susceptibility measurements were performed for 1750 samples, which had been collected and used for the *Geochemical Atlas of Poland* (Lis and Pasieczna, 1995). About 600 samples was taken from the accumulation topsoil horizon. The same amount of samples was collected in the same points from the depth interval 40–60 cm. The rest of samples was taken from recent alluvial sediments. The soil sampling places were selected accordingly to the prevailing kinds of cultivation. If the forests prevailed in the area, the samples were taken from the forest soils. All the samples, after drying, were sieved to obtain the fraction finer than 1 mm. Volume magnetic susceptibility was measured with the *KLY2* kappa bridge produced by AGICO (Brno).

MAGNETIC SUSCEPTIBILITY OF THE TOPSOIL HORIZON

Magnetic susceptibility of the topsoil horizon amounted from 6 x 10^{-6} SI units in some samples from the northwestern part of the investigated area to 7680 x 10^{-6} in the sample from Gdańsk agglomeration. Anomalously high values of magnetic susceptibility occur in the belt extending south-north, from Starogard Gdański, through Tczew, Gdańsk and Gdynia (Fig. 1A). Relatively high values of magnetic susceptibility were encountered also along the Nogat river, from Malbork to Elbląg and Tolkmicko at Zalew Wiślany. Two more anomalous points are located at the Mierzeja Helska near the cities Jastarnia and Hel.

MAGNETIC SUSCEPTIBILITY OF THE RECENT ALLUVIAL SEDIMENTS

The magnetic susceptibility map of alluvial sediments reveals several positive anomalies, which correlate well with anomalies observed in the topsoil susceptibility map. Anomalously high values of susceptibility of alluvial sediments are noted in the area of Gdańsk agglomeration and between Malbork and Elbląg (Fig. 1B). High values of magnetic susceptibility are observed also at Mierzeja Wiślana and Mierzeja Helska. Origin of these anomalies is difficult to interpret without more detailed investigations. They might result either from extensive pollution of the areas or from the concentration of heavy minerals in the beach sands.

MAGNETIC SUSCEPTIBILITY OF SUBSOILS AT THE DEPTH OF 40–60 CM

Magnetic susceptibility of the ground at the depth 40–60 cm varied between 3 x 10^{-6} and 8523 x 10^{-6} SI units. Positive anomalies observed in the investigated horizon are localised mostly in the same places as those occurring in the topsoil horizon (see Figs. 1A and C). However, the amplitude of the anomalies is generally smaller (near Gdynia and Elbląg) with two exceptions (the seaside part of the Gdańsk agglomeration and Tolkmicko area). Anomaly of the Jastarnia (Mierzeja Helska) is not manifested at the map.

DIFFERENTIAL MAGNETIC SUSCEPTIBILITY BETWEEN TOPSOIL HORIZON AND SUBSOIL AT THE DEPTH OF 40–60 CM

Well defined positive anomalies in the differential susceptibility map are concentrated in the area of Gdynia, southern part of Gdańsk, Starogard Gdański, Tczew, Malbork, Elbląg, Jastarnia and Hel (Fig. 1D). Their close correlation with urban areas indicates that differential susceptibility map most reliably defines the regions of environmental pollution. Large positive anomaly between Gdańsk and Tczew is no more visible at the map. In this sector the basement susceptibility is even greater than the topsoil susceptibility, which might indicate geogenic origin of this anomaly.

MAGNETIC SUSCEPTIBILITY VS. CONTENTS OF SELECTED ELEMENTS

Positive correlation is observed between magnetic susceptibility of topsoil and such elements as Ba, Co, Mg, Mn and Ni (Fig. 2). The correlation is definite for magnetic susceptibility values higher than 1200 x 10^{-6} SI units. A positive correlation might be inferred also for Sr, Ti, V and Y, it is however, not as evident as in the former case. Quite another type of correlation might be observed in the case of Zn and Pb. Up to 1500 x 10^{-6} SI units a weak positive correlation is observed, while in the higher susceptibility range an opposite, negative correlation seems apparent.

Topsoil magnetic susceptibilities correlate well with differential susceptibility values (Fig. 2), which means that in most cases positive anomalies on the surface are not accompanied by susceptibility increase at the depth 40–60 cm (except an anomaly between Tczew and Gdańsk).

CONCLUSIONS

1. Volume magnetic susceptibilities higher than 1200 x 10^{-6} SI units might reflect high contents of some elements (e.g. Ba, Co, Mg, Mn and Ni) in the topsoil horizon.

2. Close correlation of distinct positive anomalies of differential magnetic susceptibility with urbanised regions indicates that differential susceptibility map displays the geochemical anomalies of anthropogenic origin, related to environmental pollution.

3. Anomalies in the magnetic susceptibility map of topsoil horizon are resultant effects of anthropogenic and geogenic origin. Negative anomalies of differential magnetic susceptibility might indicate to its dominant geogenic component.

4. Differential magnetic susceptibility map might be a useful tool for preliminary detection of heavy metal pollution in soils. The method is cheap and quick, especially when measuring magnetic susceptibility directly in the field.

REFERENCES

HAY K. L., DEARING J. A., BABAN S. M. J. and LOVELAND P. J. (1997) — A preliminary attempt to identify atmospherically derived pollution particles in English topsoils from magnetic susceptibility measurements. Phys. Chem. Earth, **22**: 207–210.

HELLER F., STRZYSZCZ Z. and MAGIERA T. (1998) — Magnetic record of industrial pollution in Polish forest soils. J. Geophys. Res., **103** (B8): 17 767–17 774.

HULLET L. D., WEINBERGER A. J., NORTHCUTT K. J. and FERGUSON M. (1980) — Chemical species in fly ash from coal-burning power plant. Science, **210**: 1356–1358.

LIS J. and PASIECZNA A. (1995) — Geochemical Atlas of Poland. Państw. Inst. Geol. Warszawa.

SCHOLGER R. (1997) — Magnetic susceptibility as a tool for mapping of heavy metal contamination of sediments and soils. Case studies from Styria, Austria. Ann. Geophys., **1** (15): C105.

STRZYSZCZ Z., MAGIERA T. and HELLER F. (1996) — The influence of industrial immisions on the magnetic susceptibility of soils in Upper Silesia. Stud. Geophys. Geodet., **40**: 276–286.

ZERGENYI R. S., HIRT A. M., LANCI L., LOWRIE W. and LUSCHER P. (1998) — Magnetic mapping of soils in Alpine Area. Ann. Geophys., **1** (16): C219.