original scientific paper

UDC 902.3:550.38

MAGNETIC SUSCEPTIBILITY MEASUREMENTS IN DOLINAS

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ABSTRACT

On the basis of measurement of apparent magnetic susceptibility directly on the sections in dolinas, we can conclude that in the favourable conditions this method can be efficiently used as an additional method in the archaeological prospection in the karst, where other geophysical methods are less successful due to the specific natural conditions.

Key words: archaeology, arhaeological prospection, geophysics, karst, magnetic susceptibility, dolinas

GENERAL INTRODUCTION

The aim of the magnetic susceptibility measurements in dolinas was to detect, in a fast and reliable way, the layers containing burnt fragments (use of fire in the past) which, associated with the archaeological survey, would provide us with a better archaeological interpretation of the dolinas.

The use of magnetic measurements in archaeological prospecting is based on two principles (Clark, A. 1990, 99); in the first place, top soil usually has a higher magnetic susceptibility than the underlying layers and geological bedrock (this fact was explained in the early works of Le Borgne, E. 1955, 1960), and secondly, human activity increases the magnetic susceptibility of the soil. Magnetic properties of the soil are to a large extent determined by the concentration and the type of iron minerals it contains. During accumulation these tend to concentrate in the upper layers of the soil. In temperate and humid climates, goethite is the most common iron mineral found in soil, while in arid climates haematite prevails. An iron hydroxide, lepidocrocite is less common than goethite, and can usually be found in water saturated soil. During dehydration it can be converted into a much more magnetic maghaemite (Clark, A. 1990, 100). Maghaemite is particularly important in archaeological prospecting, as its presence is considered to be an indication of human occupation. Its crystal structure is the same as that of magnetite and is similarly strongly magnetic.

Numerous processes, some of them due to human activity, can increase the magnetic susceptibility of soil. Le Borgne (1955 and 1960) suggested that the transformation of haematite to maghaemite, with magnetite as an intermediate stage, was linked to the alteration of anaerobic (reducing) conditions in soil to aerobic (oxidizing) ones. The same transformation can occur through the burning of organic materials; in the reducing environment of a fireplace, haematite is first converted into magnetite, which subsequently, during the cooling of ion air, is deoxidized to maghaemite.

According to Tite and Mullins (1971), variations of the magnetic susceptibility on an archeological site are determined by the concentration of magnetic iron oxides in the soil, the duration of the use of fire at the site, and the reducing conditions created below the fire place. Consequently, a high magnetic susceptibility over a large area is typical for the sites that have been *intensely inhabited* for extended periods of time. Where the intensity and duration of settlement have not been extensive, only some archaeologically interesting structures, e.g. fireplaces, ceramic kilns, etc., can be located by means of the magnetic susceptibility measurements (Tite, M. S. and Mullins, C. E. 1971, 219).

For archaeological prospecting on prehistoric sites magnetometry is frequently used as an efficient mapping tool. If no recognizable structures are present, or if due to erosion (or other causes) the site has "changed" its location, or if magnetic responses of archaeological

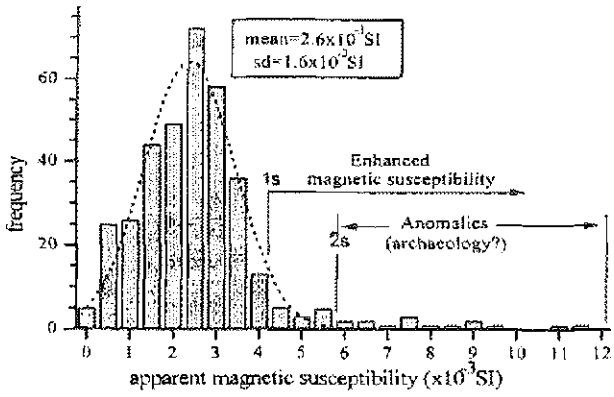

Fig. 1: Distribution of apparent magnetic susceptibility values for all surveyed dolinas.
Sl. 1: Razporeditev vrednosti navidezne magnetne susceptibilnosti za vse preučevane vrtače.

features are very weak, the application of such methods is limited. In these cases direct measurements of magnetic susceptibility can be useful. For example, detailed measurements of the magnetic susceptibility of small samples of clay can be used for characterizing such samples. The response of a sample to an applied magnetic field depends on its mineral constitution, as well as its thermal history; measurements of its magnetic susceptibility (magnetization per unit volume and unit magnetic field) at several magnetic field strengths are necessary to fully identify it (Dimc, F. et al. 1994, 226). Such a series of measurements are analysed on a sample by the standard Honda-Owen method (Chern, M. Y. et al. 1992, 418).

This method was applied for detecting changes in the magnetic susceptibility in areas with very weak magnetisation that appear on carbonatic flysch bedrock. Soil samples were first heated in an oxidizing atmosphere to the temperature of 650° and later cooled at room temperature in a reducing atmosphere. The average final magnetic susceptibility value was three times as great as the initial one (Dimc et al. 1994, 229). Using the same method, a high level of correlation between the magnetometry, geochemistry and surface survey (distribution of slag and pottery) was achieved in the Late Roman settlement Ajdovščina above Rodik in SW Slovenia (Mušič et al. 1995, 14). The method has proved to be exceptionally suitable also for detecting areas of burning in prehistoric sites in the Kras (Mušič et al 1994, 42).

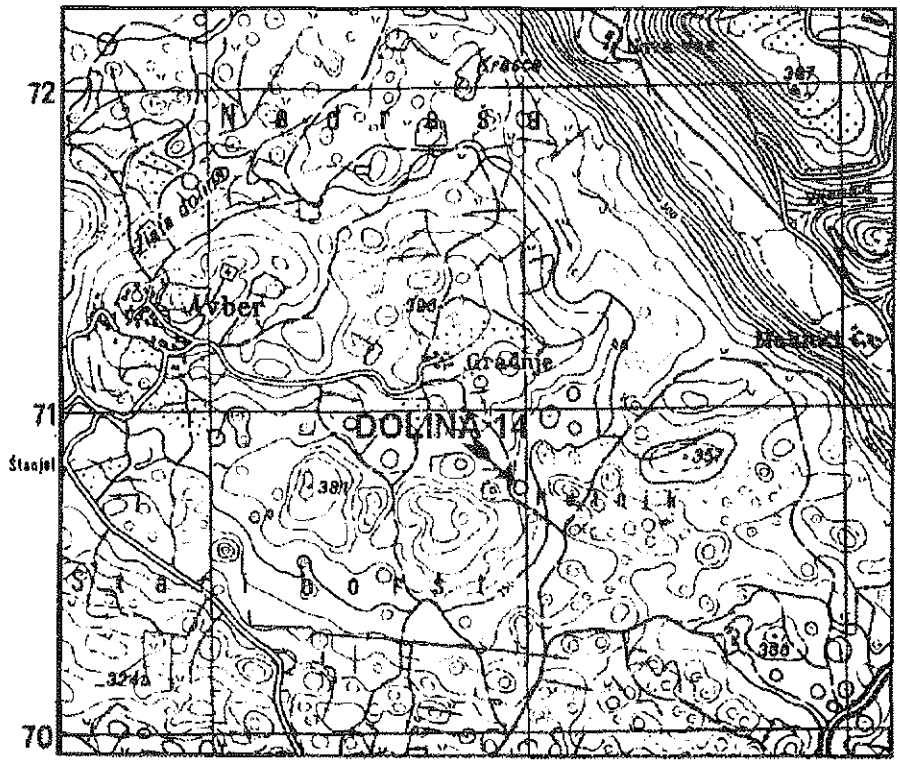

Fig. 2: Location map of dolina 14 near Avber.
Sl. 2: Položaj vrtače 14 pri Avberju.

APPLIED FIELD METHODOLOGY

Apparent magnetic susceptibility in dolinas was measured with Kappameter KT-5 field instrument (Geofyzika, Brno) (with a resolution of $1x10^{-5}$ SI). The fundamental part of the instrument is an LC oscillator of 10 kHz, the inductivity of which is embodied by a flat measuring coil situated at the active face of the instrument. The frequency of the oscillator is measured with the coil at some distance from the rock/soil ("free space" measurement) and then with the coil applied to the surface. From the frequency difference the apparent susceptibility is computed by the microcomputer and displayed (The instruction manual for Kappameter KT-5, Geofyzika, Brno).

This instrument allowed us to measure apparent magnetic susceptibility directly on the surface of the sections in dolinas. As magnetization in dolinas proved to be very high ($2.6x10^{-3}$ SI [= Sievert] on average) and as it was possible to detect the relative differences in magnetic susceptibility among the samples, we avoided the more precise but time consuming measurements on Manics DSM8 and interpretation according to the Honda-Owen method.

The position and number of the sections were selected for each dolina separately, according to their size, preservation of the sections, number of sherds discovered, etc. We measured the magnetic susceptibility of soils in parallel sections extending from the top to the bottom of each dolina. The distance between the measuring points was 20 cm.

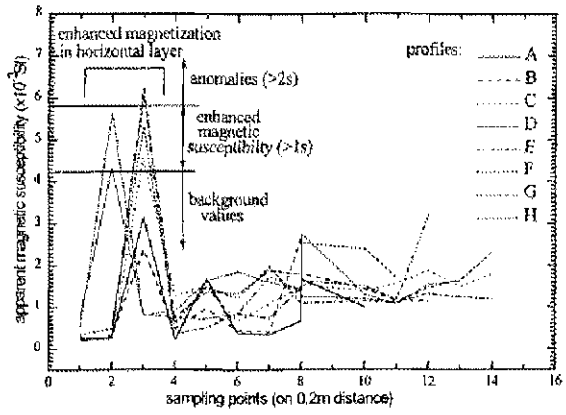

Fig. 3: Measured values of apparent magnetic susceptibility in eight parallel profiles in dolina 14 near Avber.

Sl. 3: Izmerjene vrednosti navidezne magnetne susceptibilnosti v osmih vzporednih profilih v vrtači 14 pri Avberju.

RESULTS OF THE MAGNETIC SUSCEPTIBILITY MEASUREMENTS

If we assume that all dolinas have soil of nearly similar structures (if we consider only type of iron minerals and their concentration), then the anomalies in magnetic susceptibility caused by the use of fire in the past will also appear in a nearly similar way.

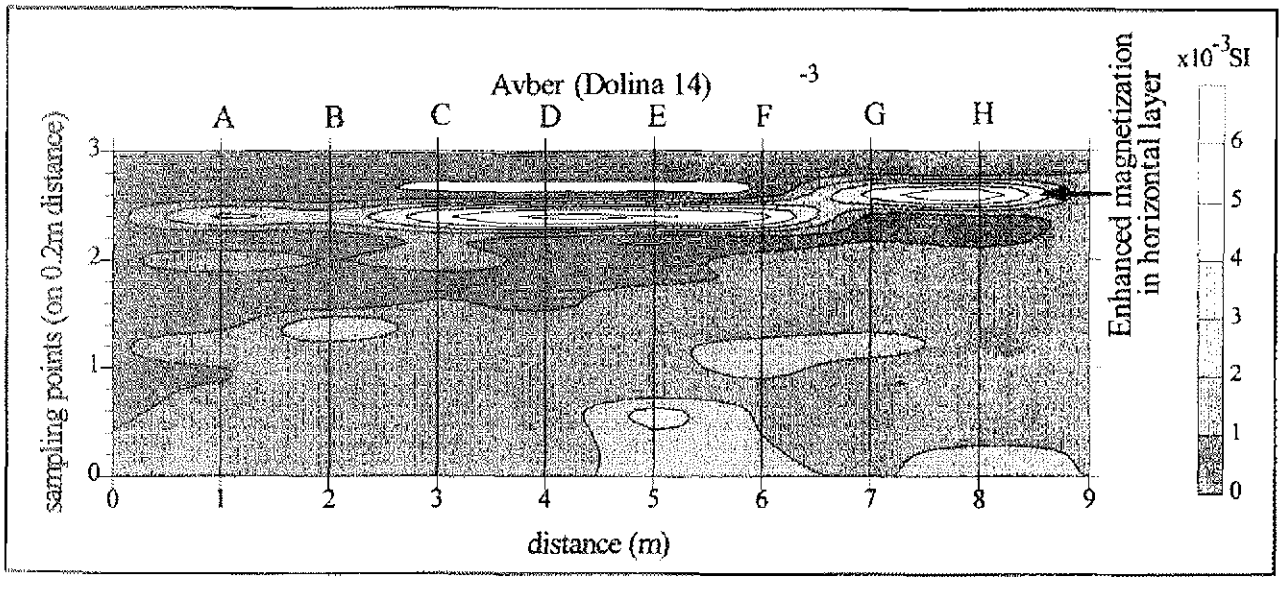

Fig. 4: Apparent magnetic susceptibility in section in dolina 14 near Avber. Thin horizontal layer with enhanced magnetization is clearly visible.

Sl. 4: Navidezna magnetna susceptibilnost v preseku vrtače v dolini 14 pri Avberju. Jasno je vidna tanka horizontalna plast s povišano magnetizacijo.

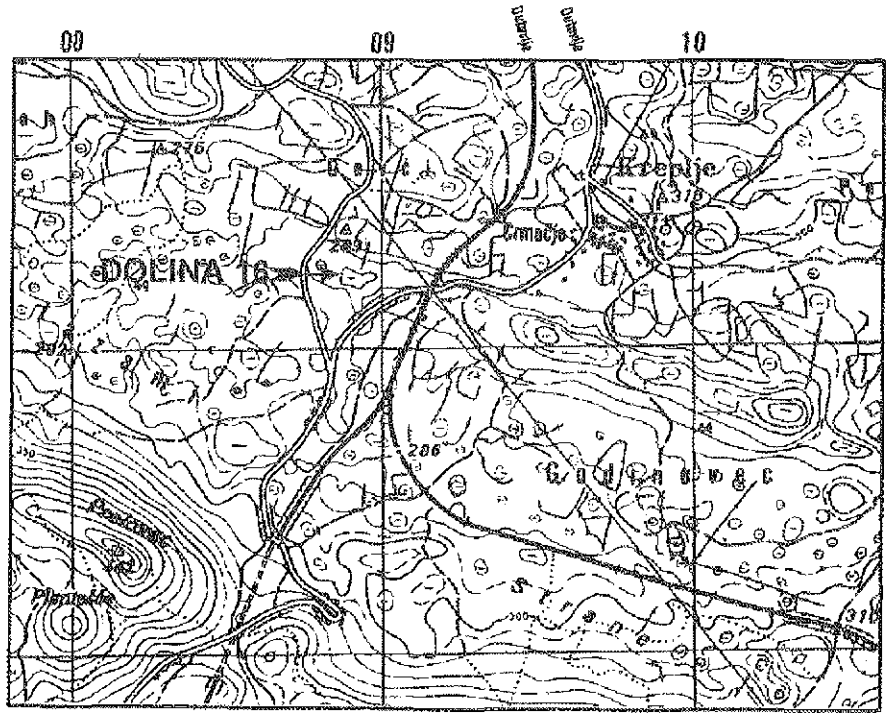

Fig. 5: Location map of dolina 16 near Kreplje.
Sl. 5: Položaj vrtače 16 pri Krepljah.

Fig. 1 displays the distribution of a few hundred readings taken from all dolinas. The frequencies, to a large degree, are very close to the normal gaussean curve. On the basis of all values of apparent magnetic susceptibility measured in different dolinas, with or without visible archaeological features, background values were estimated. The mean value of all measurements was 2.6×10^{-3} SI and the standard deviation 1.6×10^{-3} SI. Because of high variability, the calculated value of two or even one standard deviations (values higher than 5.8×10^{-3} SI and 4.2×10^{-3} SI respectively) was considered as the high anomalies. Values higher than one standard deviation were considered as enhanced magnetic susceptibility and values higher than two standard deviations as statistically significant anomalies (fig. 1). As it is visible from our results (fig. 3 and 8), both can be of archaeological interest.

Avber (Dolina 14) (fig. 2): Magnetic susceptibility was measured in eight sections at 1 m intervals (figs. 3 and 4, profiles A-H). Enhanced magnetic susceptibility was detected in a horizontal layer 10-20 cm thick and 60-80 cm under the present surface of the dolina bottom. According to this results we can assume that the enhanced magnetization is of an archaeological origin.

Kreplje (Dolina 16) (fig. 5): Magnetic susceptibility was measured in four sections in the western part of the dolina. It is significant that no values were detected here that would deviate from the mean values for all dolinas in a statistically significant way (figs. 6 and 7, profiles A-D). Slightly higher readings were detected in upper parts of the sections which can be interpreted by the effects of natural agents.

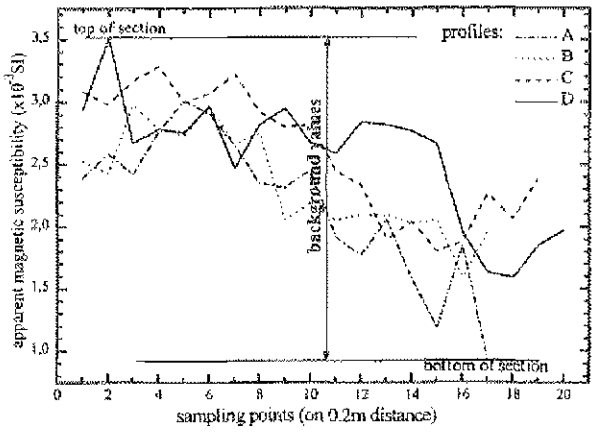

Fig. 6: Measured values of apparent magnetic susceptibility in four profiles in western section of dolina 16 near Kreplje. No statisticaly significant anomalies were observed.
Sl. 6: Izmerjene vrednosti navidezne magnetne susceptibilnosti v štirih profilih v zahodnem preseku vrtače 16 pri Krepljah. Ugotovljena ni bila nobena statistično značilna anomalija.

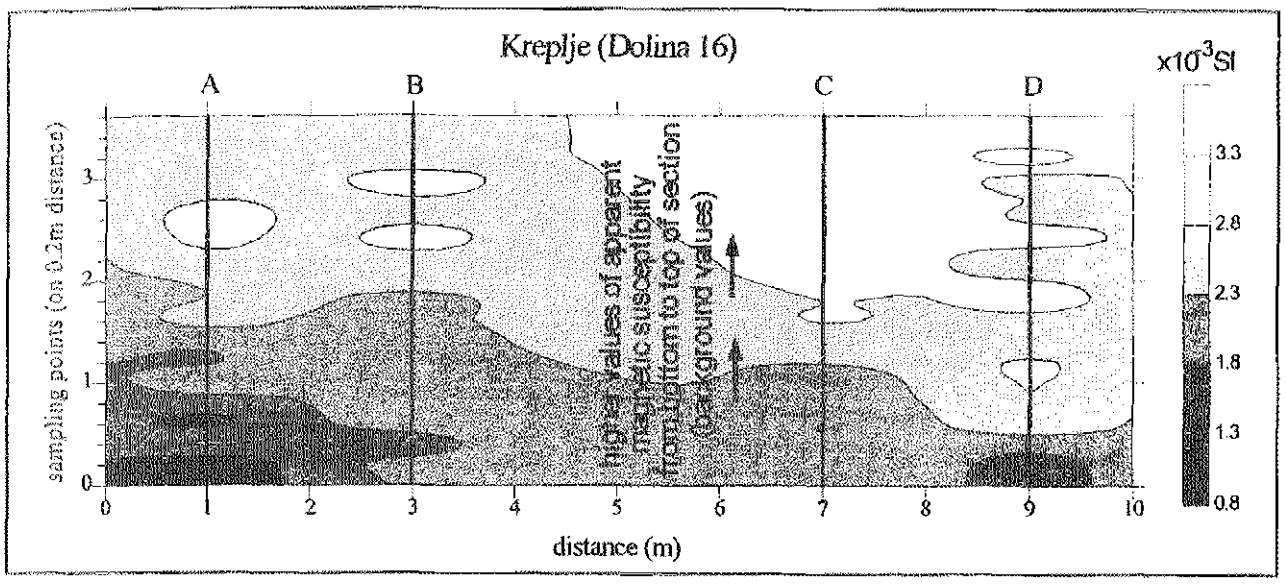

Fig. 7: Apparent magnetic susceptibility in western section of dolina 16 near Kreplje.
Sl. 7: Navidezna magnetna susceptibilnost v zahodnem preseku vrtače 16 pri Krepljah.

Four sections were also measured in the eastern part of the dolina (fig. 9, profiles A-D). We discovered statistically significant anomalies comparable with those in dolina 14; only that in dolina 16, the layer containing traces of burning was much more curved and the measured values were even higher. Measurements in section B were taken from this curved layer, while other sections (A, C, D) cut this layer in different directions. Higher values of magnetic susceptibility in A, C, and D sections were at places where these cut the section B.

We assume that the high magnetic susceptibility discovered in both dolinas are the result of the use of fire in the past. We can say that in both cases these areas were local phenomena and do not appear everywhere in the dolinas.

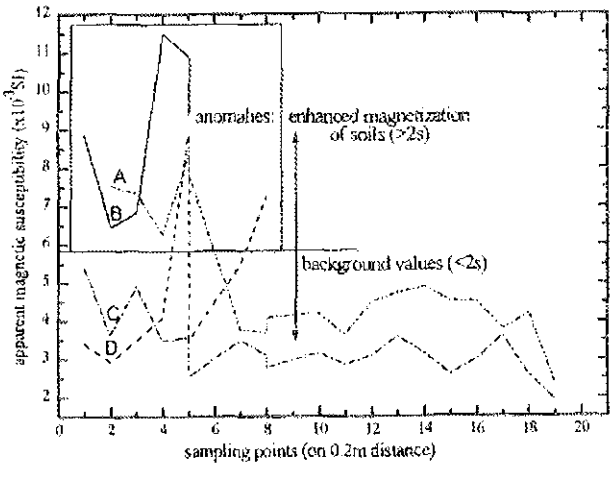

Fig. 8: Measured values of apparent magnetic susceptibility in four profiles in eastern section of dolina 16 near Kreplje. Statistically significant anomalies of enhanced magnetic susceptibility were detected in thin irregular layer.
Sl. 8: Izmerjene vrednosti navidezne magnetne susceptibilnosti v štirih profilih v vzhodnem delu vrtače 16 pri Krepljah. Statistično značilno povišane vrednosti magnetne susceptibilnosti so bile ugotovljene v tanki pviti plasti.

MERITVE MAGNETNE SUSCEPTIBILNOSTI V VRTAČAH

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POVZETEK

V prispevku povzemam rezultate prospekcije na Krasu, pri kateri smo ugotavljali ustreznost meritev navidezne magnetne susceptibilnosti za detekcijo arheoloških, predvsem prazgodovinskih kulturnih plasti. Prospekcija z metodo magnetne susceptibilnosti temelji na dejstvu, da pride pri visokih temperaturah (intenzivna uporaba ognja) do konverzije šibkomagnetnih železovih mineralov v tleh v bolj magnetne oblike. Te razlike smo ugotavljali z meritvami navidezne magnetne susceptibilnosti neposredno na površini profilov v vrtačah. Pri interpretaciji anomalnih območij v vsaki vrtači smo upoštevali kontrast proti neposredni okolici, višino izmerjenih vrednosti glede na vrednosti v vseh vrtačah in obliko ter položaj anomalnega območja v vrtači. Ugotovili smo, da kot značilne lahko upoštevamo tiste vrednosti, ki so višje od enega standardnega odklona za celotno populacijo vzorcev. Rezultate raziskave podajamo na dveh različnih primerih iz vrtač pri Avberju (vrtača 14) in Krepljah (vrtača 16), kjer smo ugotovili anomalije v magnetni susceptibilnosti, ki so po našem mnenju arheološkega izvora. V prvem primeru se je anomalno območje pokazalo v obliki približno horizontalne plasti, ki se na robovih izklinja. V drugem primeru pa smo določili anomalno območje na osnovi statistične primerjave izmerjenih vrednosti s tistimi, ki smo jih ugotovili na drugih profilih v isti vrtači, in s statističnimi parametri za vse meritve.

Ključne besede: arheologija, arheološka prospekcija, geofizika, kras, magnetna susceptibilnost, vrtače

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