Pedological description and magnetic susceptibility of the natural soil nearby the test site of the Croatian mine action centre (CROMAC) in Benkovac, Croatia

H. Preetz & J. Igel

Hannover, November 2006

Leibniz Institute for Applied Geosciences (GGA)
Stilleweg 2
30165 Hannover, Germany
www.gga-hannover.de

Pedological description and magnetic susceptibility of the natural soil nearby the test site of the Croatian mine action centre (CROMAC) in Benkovac, Croatia

Pedological description with estimated specifications

Soil type (WRB 2006[1]):	Leptic Cambisol (calcaric, eutric, skeletic, rhodic)
Soil depth:	35 cm (on average)
Texture:	Clay to silty clay
Humus content:	1 - 2 %
Soil colour:	reddish brown and brownish grey
Lime content:	5 %
Stone content:	60 - 80 % (limestone with slightly rounded angles)
Rock outcrop on surface:	80 - 90 %
Parent material:	Tertiary limestone

Fig. 1: Soil profile in a pit

[1] World reference base for soil resources 2006 - a framework for international classification, correlation and communication.- World soil resources reports: http://www.fao.org/ag/agl/agll/wrb/doc/wrb2006final.pdf

Fig. 2: View of the soil surface

Fig. 3: View of the test area. The peg in the foreground represents the coordinate 0/0. The line of the sight is along y (cp. fig. 4)

Geophysical field measurements

Among the amount of the magnetic susceptibility, the spatial distribution of this parameter is one important factor which can adversely affect a metal detector.

As shown in the description and the pictures before, the soil has a very high content of limestones. We know from several laboratory measurements that the susceptibility of the fine grained material of this soil type in this region is pretty high whereas the one of the limestones is very low (see end of the report). With this combination a high variability of the parameter has to be expected.

On the test area shown in fig. 3, measurements of the magnetic susceptibility have been carried out due to the determination of the spatial variability of this parameter. Therefore an area of 100 m² has been levelled and measurements were conducted with the MS2D search loop sensor from Bartington Instruments[2]. The distance of the profiles is 1 m with a measuring point spacing of 10 cm. The measuring grid is depicted in the following figure and a plot of the spatial distribution is illustrated in fig. 5.

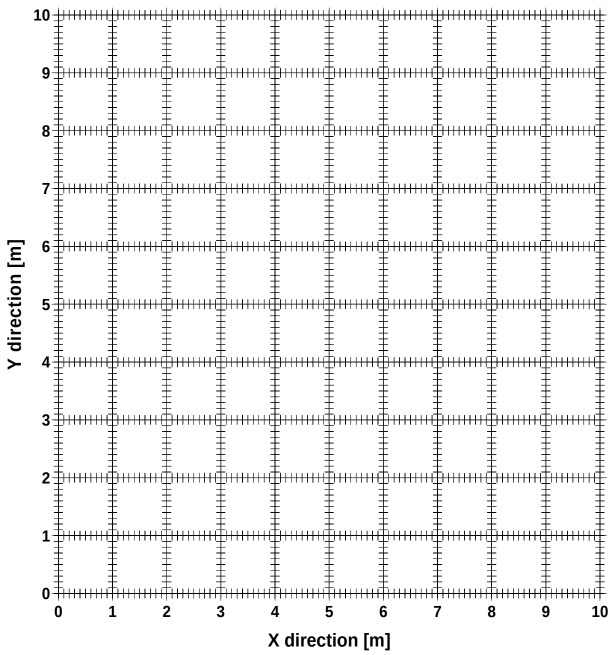

Fig. 4: The measuring grid of the susceptibility consisting of 2222 measuring points.

[2] DEARING, J. (1999): Environmental magnetic susceptibility - Using the Bartington MS2 system.- 2. ed., Kenilworth, England.

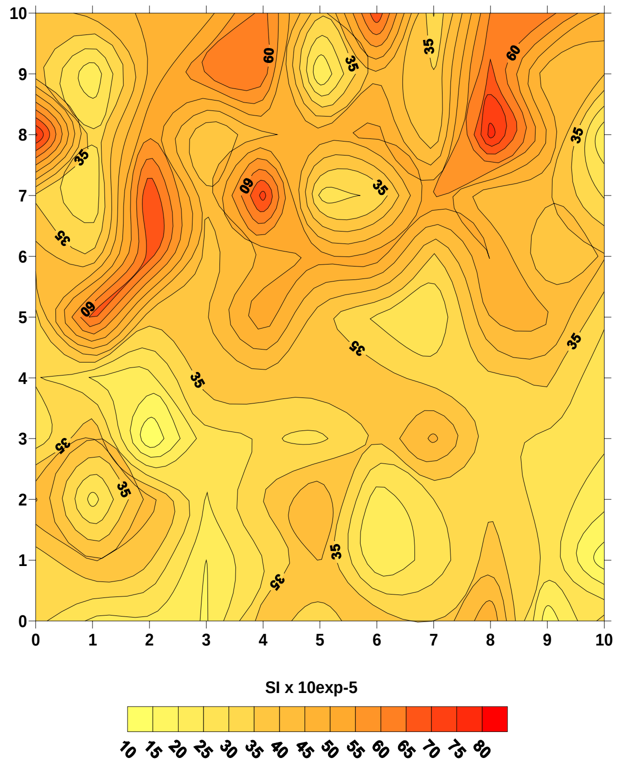

Fig. 5: Plot of the magnetic susceptibility showing the spatial distribution of the parameter.

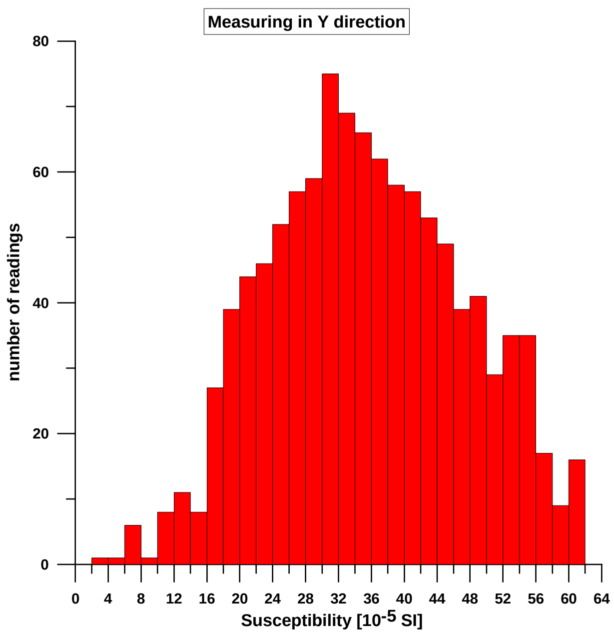

Fig. 6: Histogram of the measured values in Y direction. The mean value is 37.7 * 10^{-5} SI units, the median is 36 and the coefficient of variation is 53 %.

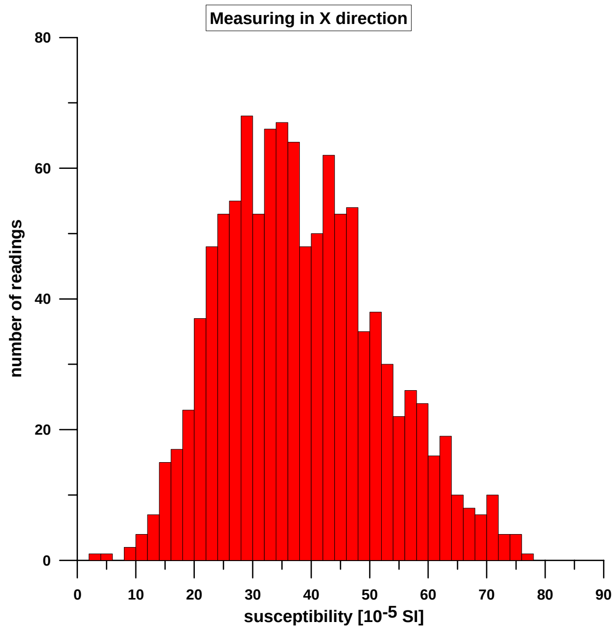

Fig. 7: Histogram of the measured values in X direction. The mean value is 39.4 * 10^{-5} SI units, the median is 38 and the coefficient of variation is 36 %.

Comparing the two measuring directions, the first statistical approach shows that the mean values as much as the median is nearly similar in both directions. Whereas the variance in Y direction is much higher than along X.

Further information about the spatial variability shall be illustrated by the variograms:

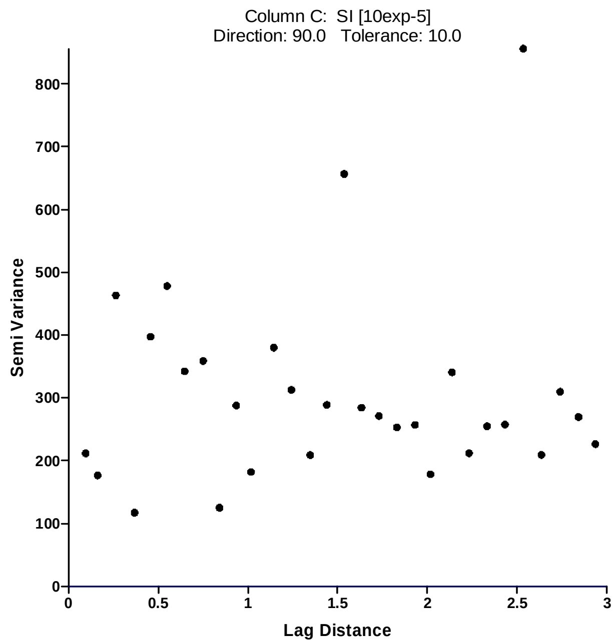

Fig. 8: Variogram of the magnetic susceptibility in Y direction

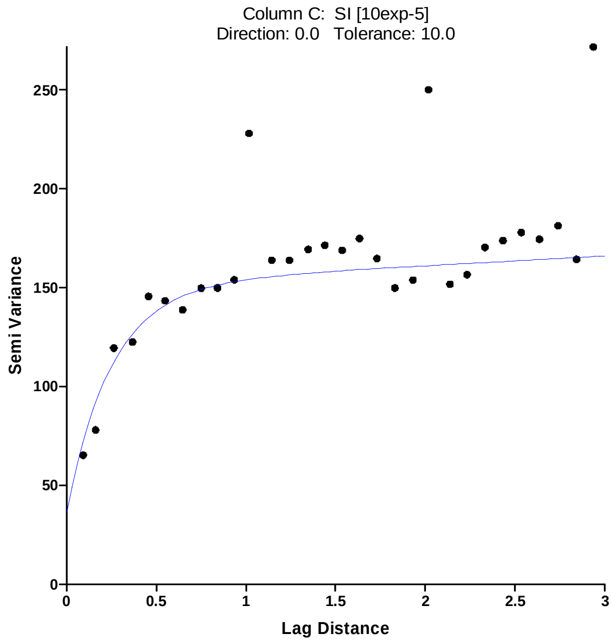

Fig. 9: Variogram of the magnetic susceptibility in X direction

The variograms in fig. 8 and 9 are displaying different spatial distributions. The readings in Y direction do not have a spatial correlation. They are just oscillating in the range of the variance and no model can be fitted to these values. Whereas a spatial correlation of the measurements in X direction is clearly visible. The correlation length is approx. 0.5 m. This is the distance within the readings are similar to each other.

The reasons for the distinct anisotropy may be in the pattern of the fracture system of the limestone close to the soil surface. The weathering of the limestone is the highest in the fracture zone and the joint filling of these spaces consist of the fine grained soil material which is protected against the erosion at this position. The susceptibility is much higher in the soil material than the adjacent limestone.

Geophysical laboratory measurements

To give a review about the magnetic properties of the soil in Benkovac concerning the functionality of metal detectors the results of the analysis of the frequency dependent complex magnetic susceptibility of a soil sample are appended. The measurement had been carried out in 2005 and the object matter was a sample from a test lane in Benkovac used for metal detector tests. This soil sample is from the same area and has the same properties as those soils on our measuring field.

The real and imaginary part of the susceptibility at 12 different frequencies (50 Hz - 10 kHz) was determined with a Magnon VFSM susceptibility bridge[3]. The magnetic field strength was 161 A/m.

As shown in fig. 10 and table 1 the soil has frequency dependence of 11 % over 10 decades which is a strong evidence for the presence of a superparamagnetic compound of the magnetic minerals. The absolute values of the frequency dependence can be read in table 1 as well. Moreover, the susceptibility of the soil sample measured in the laboratory is nearly ten times

[3] www.magnon.de

higher than the mean of the field measurements. This is because the sample consisted only of pure soil without any limestones which are reducing the susceptibility of the field measurement considerably. As mentioned above the limestone content in the topsoil is up to 90 % (fig. 2). Therefore the susceptibility of the field measurement with the Bartington loop MS2D is at about 10 % of the laboratory measurement of the pure soil.

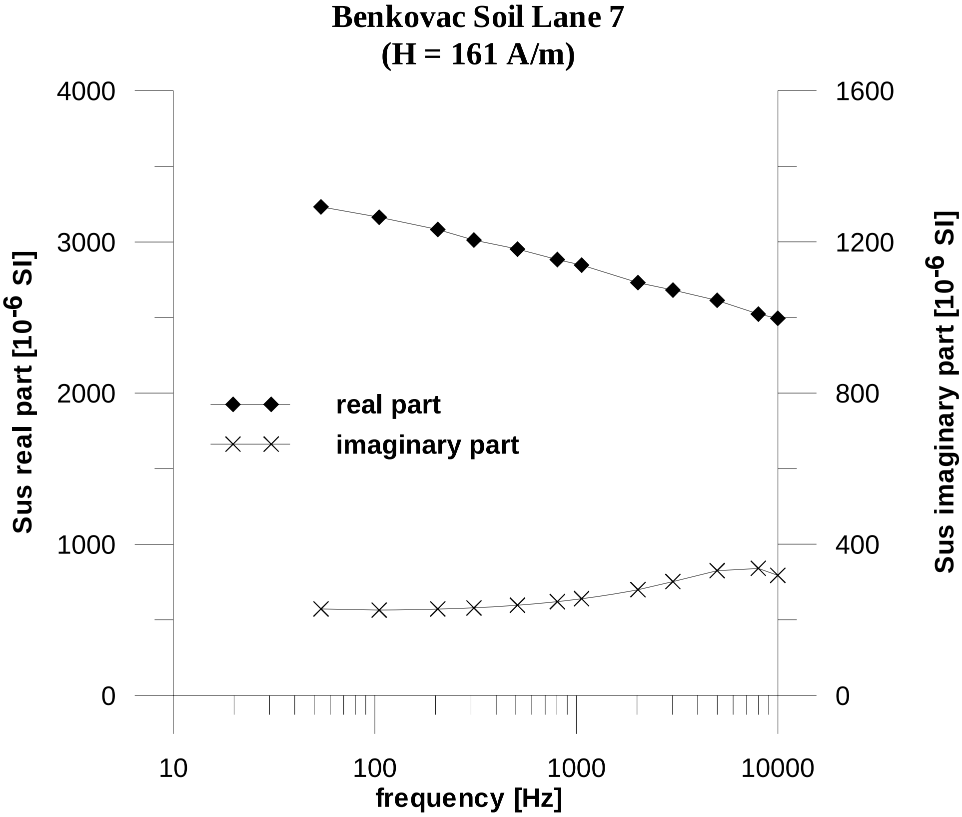

Fig. 10: Frequency dependent complex magnetic susceptibility of soil sample "Benkovac Soil / Lane 7 / Lane B".

Table 1: Frequency dependent complex magnetic susceptibility of soil sample "Benkovac Soil / Lane 7 / Lane B".

Sample	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ" [10exp-6 SI]
Benkov. L. 7/B	54	161	3231.3	229.0
Benkov. L. 7/B	105	161	3163.1	226.0
Benkov. L. 7/B	205	161	3082.0	229.0
Benkov. L. 7/B	310	161	3012.3	231.5
Benkov. L. 7/B	510	161	2952.3	238.8
Benkov. L. 7/B	804	161	2882.7	248.3
Benkov. L. 7/B	1060	161	2846.8	256.2
Benkov. L. 7/B	2020	161	2730.4	280.1
Benkov. L. 7/B	3013	161	2681.5	301.3
Benkov. L. 7/B	4993	161	2613.8	330.2
Benkov. L. 7/B	7991	161	2522.9	336.4
Benkov. L. 7/B	9991	161	2494.1	317.9