Geomagnetics

Magnetic measurements deal with anomalies of the geomagnetic field, caused by contrasts of magnetization produce by magnetic rocks or soils rich in magnetic oxides. The magnetization of bodies contains shares of inductive and remnant magnetization. The inductive magnetization induced by the magnetic earth field depends on its actual strength and direction, as well as the susceptibility (χ) of rocks or soils. In contrast, the remnant magnetization is a long-term effect, quasi-constant and is independent of the recent geomagnetic field.

The effects of magnetic bodies, which can be surveyed on the surface of the earth, are dependent not only on their magnetization, form and size, but also on their depth since the magnetic field weakens with increasing distance. In archaeological investigations, various constructions such as kilns, ovens or fireplaces show increased remnant magnetism thus producing pronounced magnetic anomalies. The task of the interpretation is to separate the results of human activity from the geological variations in subsurface materials.

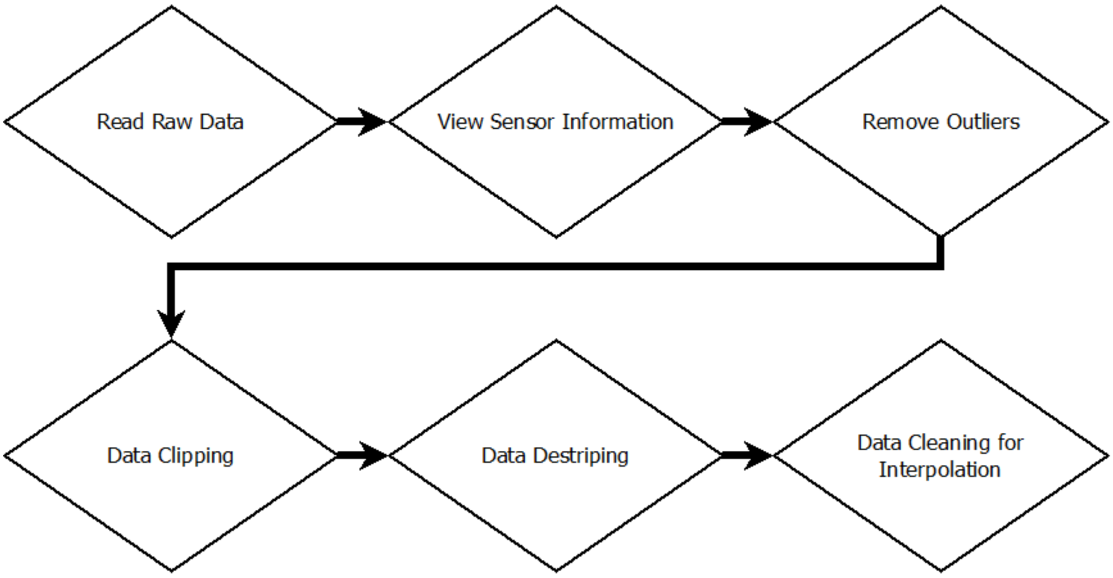
Subsurface targets with magnetic properties different from those of the surrounding soil matrix change the local magnetic field at some large or small degree. This kind of perturbation of the magnetic field is observed as an “anomaly” in the measurements. The disturbance of the upper layers of the soil due to anthropogenic causes can create observable magnetic anomalies.

Data Collection

Sensorik & Systemtechnologie (SENSYS) MX Compact Survey System was used for the geomagnetic data collection. SENSYS MX is a multi-channel measurement system, equipped with FGM600 magnetometers. The system is dependent on valid GPS information with the NMEA 0183 standard. Magnetometers are mounted on a non-magnetic carrier which can carry up to 16 sensors with 25cm separation. Yet, a numerous carrier-sensor combination is possible, depending on the needs of the geophysical survey. While the distance between sensors are fixed along the array (X-axis), measurements along the track (Y-axis) depends on the speed of survey as the sensors read magnetic data in fixed time intervals; a faster movement of array results in fewer readings and vice versa.

Data Processing and Workflow

SENSYS MX Compact system is capable of providing a satisfactory magnetic picture of an area of interest. However, further processing is required for a better interpretation of magnetic anomalies in the final dataset. To accomplish this, a series of functions are created in Matlab 2012a and Pyhton 3.2. ERDAS Imagine was used for data destriping with Fast Fourier Transformation (FFT).



Ground-penetrating Radar

Radar is the acronym for RAdio Detecting And Ranging. The Ground Penetrating Radar method has the same operation principle with the seismic reflection method. GPR can be used in a series of applications like the mapping of the bedrock depth, the determination of the stratum thickness and the aquifer depth, the location of physical and artificial cavities in the subsurface, cracks in the bedrock and the tracing of the changes in the rocks' composition. The method is specially used in archaeometry for the detection of buried antiquities.

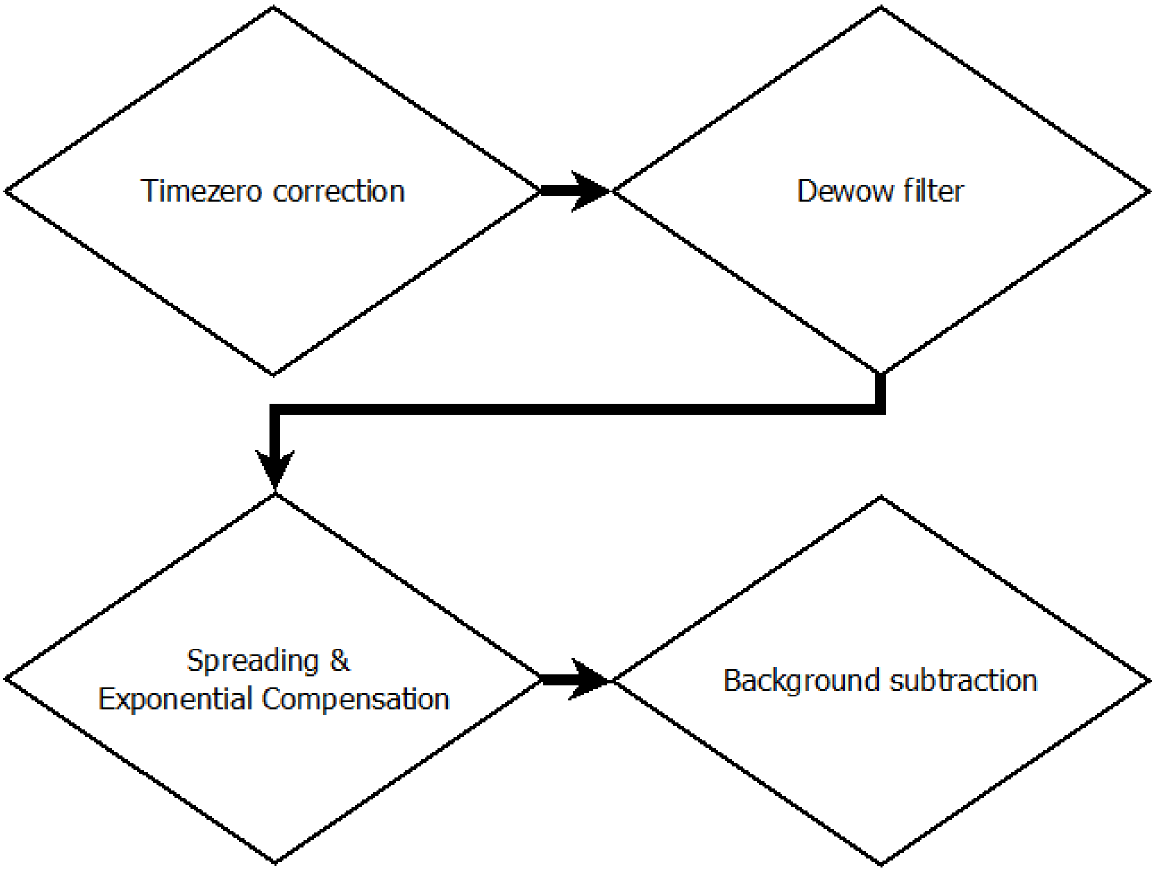
The Radar recordings (radiograms) are placed one beside the other so as to construct a section that simulates the real subsurface electrical section, producing information of the changes of the electrical properties with depth. Following this strategy a vertical depth section is created that simulates the true subsurface geoelectrical properties.

Data Collection

For GPR data collection, Noggin Plus-Smart Cart system by Sensors & Software was used with 250MHz antenna. For prospecting with GPR, grids were designated to delimit the areas of interest and data were collected in parallel transects along Y directions.

Data Processing and Workflow

The transects that were derived from the Noggin Plus GPR were processed using EKKO View Deluxe, GFP Edit4 and EKKO Mapper4 by Sensors and Software. The processed applied aimed to remove noise from the data and to enhance signal's information that will lead to subsoil's better representation. Processing was divided in two stages: the first dealing with application of correctional filters separately on every survey line, and the second dealing with the extraction of slices in accordance to depth (depth slices). The second stage of the process deals with the extraction of horizontal slices in accordance to depth. For this purpose GFP Edit was used to assign the correct coordinates (X, Y) of the processed survey lines. EKKO Mapper4 was responsible for creating the depth slices, namely horizontal slices with increasing depth. Each slice was averaging the signal within a 10cm width.



Electromagnetic Induction

Electromagnetic frequency domain instruments, with Slingram geometry, are of common use in archaeological prospection and in soil studies and offer the possibility to mapping simultaneously the electrical conductivity, the magnetic susceptibility and in some cases the magnetic viscosity.

To make the measurement an alternating primary field is transmitted by a coil, which induces eddy currents in conductive bodies. This one produces a secondary electromagnetic field measured by the receiver coil. The ratio of the primary and the secondary field give digits values of the instrument. The part of the primary field whose phase is rotated by 90 degrees is called the out-of-phase component. Changes of the in-phase and out-of-phase components allow conclusions to positions of conductive and magnetic bodies. ‘

Under the Low Induction Number approximation, measurement of the quadrature mode allows an estimation of the soil conductivity whereas measurements of the in-phase are relative to the magnetic susceptibility. In fact in conductive soil, in-phase part of the signal could be affected by the conductivity especially for high frequencies and low resistivity, whereas out-of-phase part of the signal could be affected by the imaginary part of a complex susceptibility, especially for soil with a high resistivity. We try in this study to extract and use these three parameters (electrical conductivity, magnetic susceptibility, and magnetic viscosity).

INTEREST OF EM in comparison of magnetic and electric survey:

- Information about the depth of the magnetic anomalies.
- Information about the conductivity, the magnetic susceptibility and the magnetic viscosity.
- The measurement doesn’t require any contact between the sensor and the ground surface.

Data Collection

The GEM2 is a broadband multi-frequency electromagnetic sensor. The sensor operates in a frequency band between 300 Hz to about 90 kHz. The instrument is carried at a height of 0.3 m above the ground surface. The acquisition frequency is 1 Hz so we take approximately 1 measurement every 1 meter along each profile.

The CMD is a single frequency electromagnetic sensor with multi-coils spacing, respectively 0.32, 0.71 and 1.18 meter. It allows measurement of both magnetic susceptibility and electrical conductivity for three depth of investigation.

Data Processing and Workflow

We use two kind of geolocalization. Both are in common use in geophysics. For the first one, we make a continuous acquisition along each profile and the software (WinGEM) will proceed to a homogeneous distribution of the measurement along this profile. For the second one, GPS data are simultaneously collected and stored by the control unit.

Both instruments allow measurement in HCP and VCP array. Usually we use the HCP array because it is more useful on the field. The both array allows measurement for different depth of investigation.