Corrections of Archaeological Magnetic Anomalies of the El Caño Pre-Columbian Site, Panama

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Resumen

Normalmente, los resultados de una prospección magnética se presentan bajo la forma de una imagen a escala de grises donde la tonalidad del gris es proporcional a la intensidad medida. Dicha imagen puede ser de gran utilidad en Arqueología ya que la misma podría revelar la presencia y/o ausencia de rasgos culturales enterrados a poca profundidad. No obstante, debido a diversos factores, las anomalías de interés pueden presentar cierto nivel de distorsión. Este trabajo presenta el resultado de las correcciones de los datos magnéticos obtenidos en un sitio arqueológico precolombino a través de procesos estadísticos y de compresión logarítmica. Con esto, fue posible atenuar los efectos de zig-zag y puntual.

Palabras clave: *Anomalías magnéticas, efecto zig-zag, efectos de borde*.

Abstract

Normally, the results of a magnetic prospection are presented under the form of an image on a scale of gray colors where the tones of the gray color is proportional to the measured parameter. Such image can be a great help in Archeology because it could reveal the presence and/or absence of cultural features buried at few depth. However, due to diverse factors, the most important anomalies could show certain level of distortion. This work presents the result of the magnetic data corrections

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obtained at an archaeological pre-columbian site through statistical processes and logarithmic compression. Because of this, it was possible to reduce the zigzag and spike effects.

Keywords: *Magnetic anomalies, zigzag effect, spike effect, El Caño, caesium magnetometer*.

Introduction

In geophysical prospection applied to the archeology, the electrical and magnetic methods correspond to the ones applied (Dabas *et al*., 1999; Tabbagh, 1992). However, the level of complexity in the magnetic prospection is higher than in the electrical one; this is the result of many factors such as the variation on the direction of the magnetic field and the temporary variation of it in all point of the space. This last type of variation is linked to the processes which give origin to the internal magnetic field; joined to this, we can find the periodical and no-periodical changes caused by external effects, and finally, the magnetic pulsations or variations of short period and small amplitude. Nevertheless, any method of observation of the magnetic field on the surface of the earth, will give values on not only information about the internal and external magnetic field but also about the most superficial layer of the earth's crust. For this reason, for getting information corresponding to the structures buried at a low depth, it is necessary to consider the temporary type corrections.

In magnetic prospection applied to the archeology, the problem turns more complex because for obtaining detailed information of the buried structures, it is necessary to handle our problem at a local level and not at a regional one. Besides, this involves the use of very sensitive devices with the capacity to measure small variations of the total magnetic field on the surface of the earth. It is true that during a work of magnetic prospection, the prospector is subjected to eventual errors of measurement, position or the system; this suggests the development of techniques which can reduce such errors and thus, to improve the visibility of the answers coming from the archaeological structures in relation to another type of answer of the subsoil: pedology, hydrology, farming activities and handling of soils (Tabbagh, 2000).

Level of complexity of the archaeological features

The soils are composed of a mixture of particles of rock which possesses certain physical properties in common with the original substances, but due to changes caused by the time, the plants, and the man, some of these properties tend to vary (Scollar *et al*., 1990).

The rests of cultural materials are the ones that because of their characteristics, survive in the time, in an indefinite form, even many centuries after their manufacturers have disappeared. There is a great diversity of cultural features of organic type (tissue or skin, bones, and wood) that disappear without leaving any trace. Also, there are others of inorganic type (certain type of rocks and the ceramic) which are inalterable, for example, the ceramic after its modeling and firing, experiments a physical-chemical type alteration that is irreversible and possesses important conditions of perdurability (Sánchez, 1988).

From the physical point of view, in these cultural features (volcanic or metamorphic rocks) the elemental particles which form them (electrons) experiment movements of orbital type around the atomic nucleus, this generates electric currents in the material, being at the same time the cause of a certain level of magnetism in such substance. This physical effect can be evaluated through a parameter known as magnetic moment **M**; it is as if these elemental particles corresponded to small magnets capable of orienting themselves in a given direction if the material is submerged in an external magnetic field **H**. If an archaeological feature or structure is subjected to a non-intense external magnetic field, then $\mathbf{M} \sim \mathbf{H}$; thus, $\mathbf{M} = k\,\mathbf{H}$, where k is known with the name of magnetic susceptibility and such parameter is crucial in the study of the magnetic properties of the matter, over all, in magnetic prospection. The magnetic response of an archaeological feature, rock or mineral is determined by the content and the susceptibilities of the magnetic materials that form them and it will reveal variations in function of the latitude of the prospection (Dabas *et al*., 1988).

When certain rocks and soils (the case of the ceramics) are subjected to high temperatures, the small magnets before mentioned, tend to line up with the terrestrial magnetic field. After the phase of cooling, such materials reflect a form of fossilization of the magnetism or magnetic field during a process of firing, increasing the value of the magnetic susceptibility. This process is known as thermoremanent magnetization, and it is characterized because of its stability in the time. This type of materials that is linked to this kind of magnetization is known as ferromagnetic substances (Dabas, 1989). Summarizing, the enrichment in ferromagnetic minerals like the magnetite and the maghemite in the archaeological structures is due to the use of the fire and the action of a magnetotactic bacteria in the organic residuals.

Taking into consideration what we have mentioned before, the study and analysis of the sub-soil magnetism through the measurement of the intensity (amplitude) of its magnetic field, it can give information in relation to the presence and/or absence of buried archaeological material.

Apart from it, there is evidence of a great magnetic contrast between the sediments of the canals and the non-disturbed soil. In other latitudes, the works of

(Fassbinder *et al*., 2005) have confirmed the existence of canal systems in a Babylonian city from approximately 4000 BC and also the geophysical investigations made in zones of Neolithic occupation (North of Europe) have revealed the existence of graves around the constructions proper of that epoch.

The levels of occupational organization of the pre-columbian cultural zones in Panama differs from those which were developed in other latitudes, as for example, the Mesoamerican or Inca. In Panama isthmus the archaeological prospections have given signals referring to rocky shelters and zones where were held some ceremonial activities which got together a great part of the Caciques (Indian chiefs) and their towns living in the neighborhood. Most of the material used for the construction of houses were perishable substances, however, in some sites were identified stone columns, burials, garbage dumps, roadways, and certain parapets and walls that can't be compared in dimension with those developed by the civilizations before mentioned.

What is generally common in these sites is the existence of ceramic rests or bowls which are a clear evidence of an environment occupied by the man in the past; such features are found scattered almost homogenously in a whole site under the humus until no more than 30 cm.

Treatment and display of archaeological magnetic data

The archaeological features are characterized by presenting certain type of complexity in the form and over all since a geometric perspective, which differs notably in relation to the geological prospection. In geophysical prospection applied to the Archaeology, the use of instruments of magnetic record of high resolution and automatic acquisition of data, lead to the development of diverse types of treatments aimed to correct some defects which are visible in the image obtained at the end of the work, such defects have been reported by (Scollar *et al*., 1986; Scollar *et al*., 1990; Eder-Hinterleitner *et al*., 1996; Ciminale and Loddo, 2001; Chianese *et al*., 2004).

Zigzag effect

One of the most common is the realization of measurements along parallel profiles and in a bidirectional mode (zigzag effect) and it means that the longitudes of the profiles are not always the same and as a result, the form of the main magnetic anomalies have a kind of distortion. It has been proposed the use of statistic algorithms which work on the even profiles and correlating these (in terms of positioning) with the odd ones.

Spike effect

This effect is closely related with the existence of precise anomalies product of errors of instrumental type or due to the presence of ferric objects scattered in an aleatory form on the surface of the soil (volcanic rocks or metals). From the instrumental point of view, the failure in one of the two sensors used in magnetic prospection can provoke extreme values (whether they be positive or negative) in the calculation of the magnetic, vertical gradient generating a distortion on the final image. This effect can be seen on the data of the magnetic vertical gradient from one of the recorded profiles with a caesium magnetometer on a pre-columbian archaeological site (Figure 1).

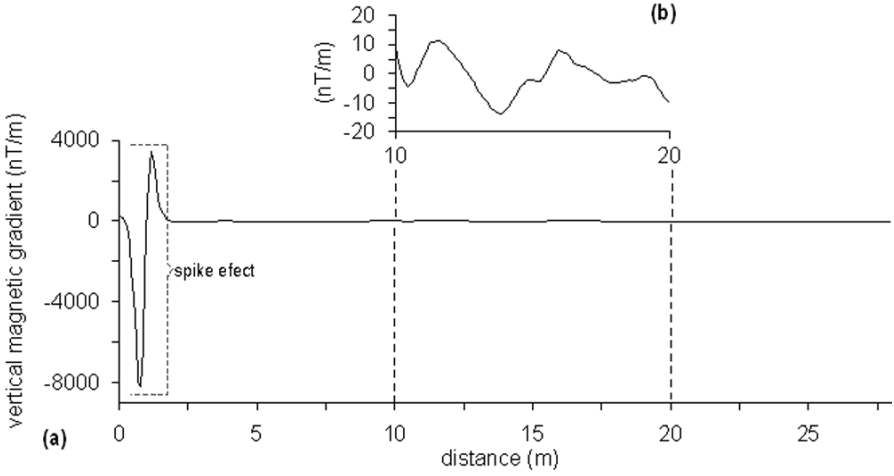

Figure 1. (a) Result of the Spike effect on the data of the vertical magnetic gradient along a profile of 28 m and (b) data of the same profile situated between the positions 10 and 20 m.

In the result of the picture 1 (a), the 89% of the data of the vertical magnetic gradient correspond to information of interest; however, only the 11% of the total of the magnetic data recorded at the beginning of this profile (0-3 m) and correspond to a great anomaly, contribute in a negative way in the detailed visualization of the information. This fact is observed in the picture 1 (b) where is only presented the magnetic data that exist between the 10 and 20 m along the same profile; it can be observed the clear difference between both representations. For this case, this anomaly is due to the effect of a basaltic column located on the surface of the site (spike effect). An algorithm of logarithmic compression can be used in order to attenuate such minimal or maximum values that distort the information, as the ones

from the figure 1 and that are not of interest for the archaeological prospection. We can say that:

$$f(x) = A\log(x/A+1), \quad for\ x > 0$$

and

$$f(x) = -A\log(1-x/A), \quad for\ x < 0$$

Where x corresponds to the values of the vertical magnetic gradient and A is a constant value between 2 and 20.

The case of the El Caño archaeological site

Instrument of magnetic prospection

The El Caño pre-columbian site, together with Sitio Conte and Cerro Cerrezuela are part of a ceremonial center that is characterized because of the presence of lines of columns, roadways, and terraces covered with stones. In order to detect some cultural features related to the pre-hispanic societies of that time, a magnetic prospection was developed at the El Caño archaeological site. It was used a caesium magnetometer type G-858 of Geometrics in mode gradiometer, with two sensors vertically disposed and separated in a distance of 1 m. This modality of prospection let to remove automatically the magnetic time variations (Bossuet *et al*., 2001; Chianese *et al*., 2004). The Figure 2 illustrates the disposition and functioning of the magnetic instrument along a profile.

Figure 2. Disposition of the caesium magnetometer in mode gradiometer and magnetic record along a profile.

The data were recorded in a bidirectional and continuing way along the diverse profiles and in a frequency of measurement of 5 records per second.

The Figure 3(a) shows a map of magnetic anomalies of one of the zones of interest (50 x 50 m). The grid was established for profiles of 50 m of longitude separated 1 m. The initial rank of values of the magnetic gradient (-50,36 and 67,01nT/m) was saturated to a rank between -15 and 15nT/m (figure 3(b)). In these maps it can be seen the two effects pointed previously: the rectangles 1 contain magnetic anomalies of interest completely distorted by the zigzag effect, while the rectangles 2 correspond to a precise and isolated anomalies, which are proper of the spike effect.

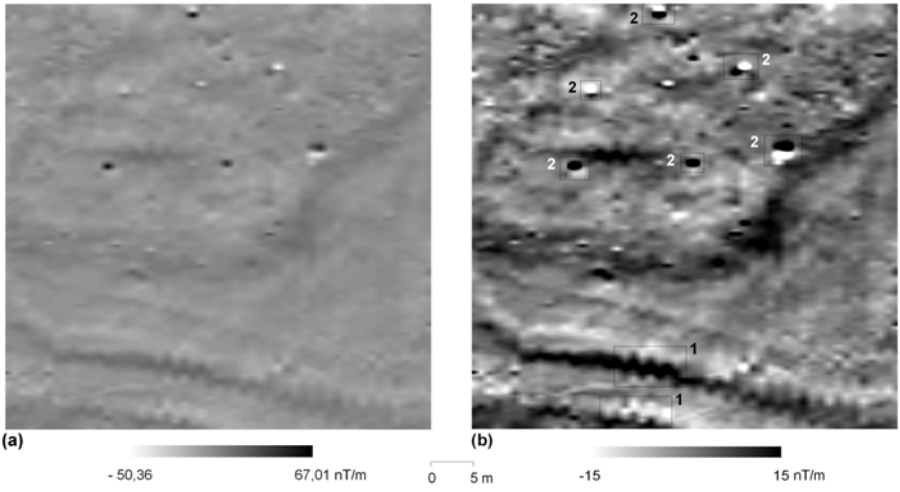

Figure 3. Magnetic map of the archaeological site El Caño for a rank of (a) -50,36 and 67,01 nT/m, and (b) -15 and 15 nT/m. The rectangles in (b) show the effects of zigzag and spikes.

Despite the distortions caused by the effects before mentioned in this image, is possible to identify some geometrics that could be related to cultural features proper of the pre-columbian societies established at the region.

Corrections of the magnetic anomalies

The sequence of the treatment of the magnetic data held in this work can be seen in the diagram of the Figure 4.

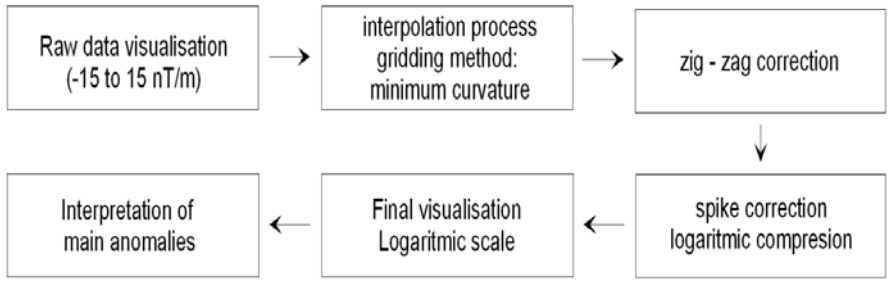

Figure 4. Diagram of sequence in the process of treatment of data.

The response of the application of the algorithms on the result of the Figure 3 for the correction of the zigzag and spike effect can be seen on the maps of the Figures 5(a) and 5(b), respectively.

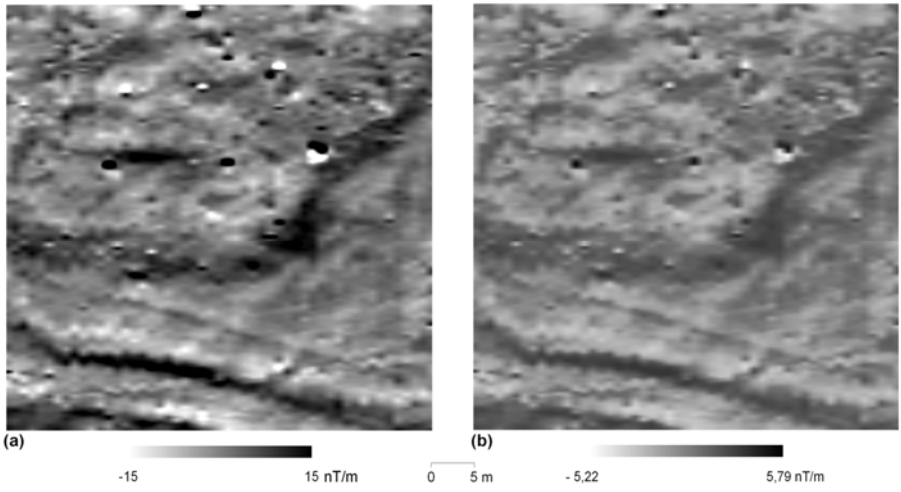

Figure 5. (a) Correction of the zigzag effect identified in the figure 3(b) and (b) correction of the spike effect observed in the figure 5(a).

As you can observe in the map of the Figure 5(a), the distortion of the anomalies in a form of broken lines that were identified in the rectangles of the Figure 3(b) have been attenuated (zigzag effect), while in a process of compression through a logarithm function was applied to the Map 5(a) getting the result of the Figure 5(b).

Finally, this last result can be presented in a logarithm scale through a map of contours; the result is presented in the Figure 6.

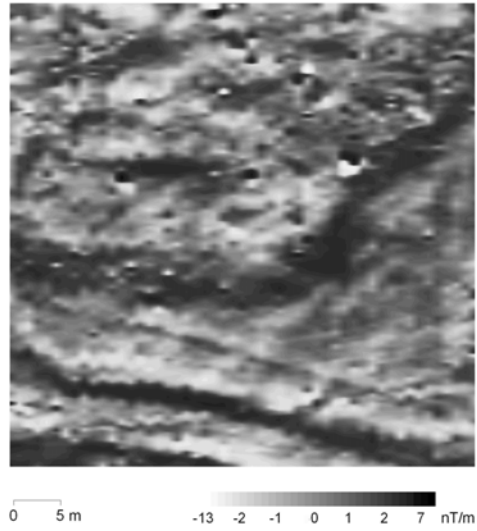

Figure 6. Final magnetic map obtained since the sequence of treatments described in this work.

With this map is possible to identify more clearly the anomalies related to possible archaeological features; the lining up located in the lower section of the map could be related to a kind of antique canal.

Conclusions

There are certain archaeological sites of pre-columbian type in the isthmus of Panama that present very particular characteristics, as for example, an architecture quasi-monumental (carved stones) and bowls that normally are found distributed on the whole zone of interest. However, many of these sites haven't escaped of the man intervention at present, for this reason is usual to find ferric materials on the surface or a very few depth (~ 5 cm). Due to their high magnetic content, these materials can be detected during a magnetic prospection, observing very strong and precise anomalies, and their magnetic contribution represents a problem at the time we visualize such anomalies which are of interest in archaeology; also, the volcanic rocks scattered in the soil can provoke similar results.

In the other hand, the problem of positioning along the defined profiles in bidirectional mode, can be a focus of distortion in the final image. The algorithms used in a sequential way on the data obtained in the archaeological site of pre-columbian type, have showed to be very useful in the restoration of the maps, offering to the archaeologist a new way of presenting the information.

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