MAGNETOMETRY ON THE GEOGLYPHS OF PALPA AND NASCA (PERU)

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***Key words*:** *magnetic prospection, horizontal gradiometer, geoglyphs, Nasca, Peru*

The geoglyphs of Palpa and Nasca in southern Peru are considered one of the greatest mysteries of archaeology (*Aveni 1990*). Thousands of lines, cleared fields and figures were carved on flat plateaus in the desert, the so-called pampas, during the Paracas and Nasca cultures (800 BC - 650 AD). Ever since the first report of Peruvian archaeologist Toribio Mejía Xesspe in 1927, serious archaeological investigations have by far been outnumbered by unscientific interpretations. The geoglyphs of Palpa, in the northern Nasca basin, have been studied in detail with archaeological methods since 1997 by the Nasca - Palpa Project (*Reindel/Grün 2006*) supported by the German Federal Ministry of Education and Research (BMBF). In the framework of this project, we conducted in 2003 the first prospection with geophysical methods in the pampa (*Fassbinder/Reindel 2005*). During the following field seasons we chose four geoglyph sites in the vicinity of Palpa that had previously been documented in the framework of the same project through a combined field survey and analysis of high resolution aerial images (*Lambers 2006*). A reference data set was thus available for these sites. As the geoglyphs of Palpa and Nasca are part of a UNESCO World Heritage site, geophysical prospection is the only none-destructive technique of site exploration apart from aerial archaeology, and the only tool to detect and map possible unknown features beneath the lines and trapezoids.

So far, magnetometry has rarely been used for archaeological prospection in South America. As the magnetic inclination in Palpa is less than 15° and the intensity of the total Earth's magnetic field hardly exceeds 24.000 Nanotesla,

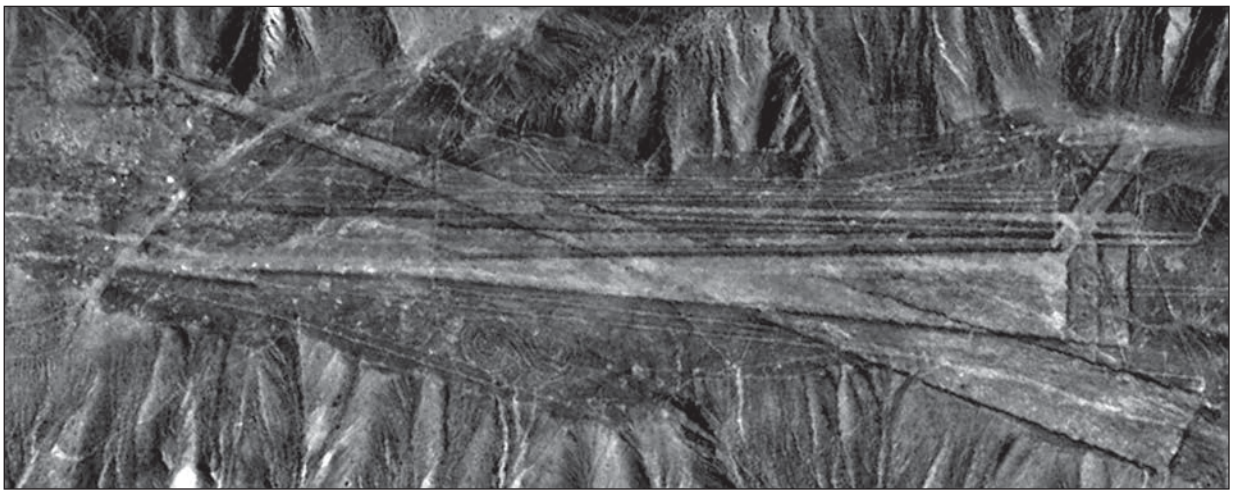

Fig. 1. Orthophoto (resolution: 25 cm) of geoglyphs on site PAP 51A north of Palpa. The complex is composed of lines, spirals and trapezoids constructed over several centuries. Orthoimage courtesy of Institute of Geodesy and Photogrammetry, ETH Zurich.

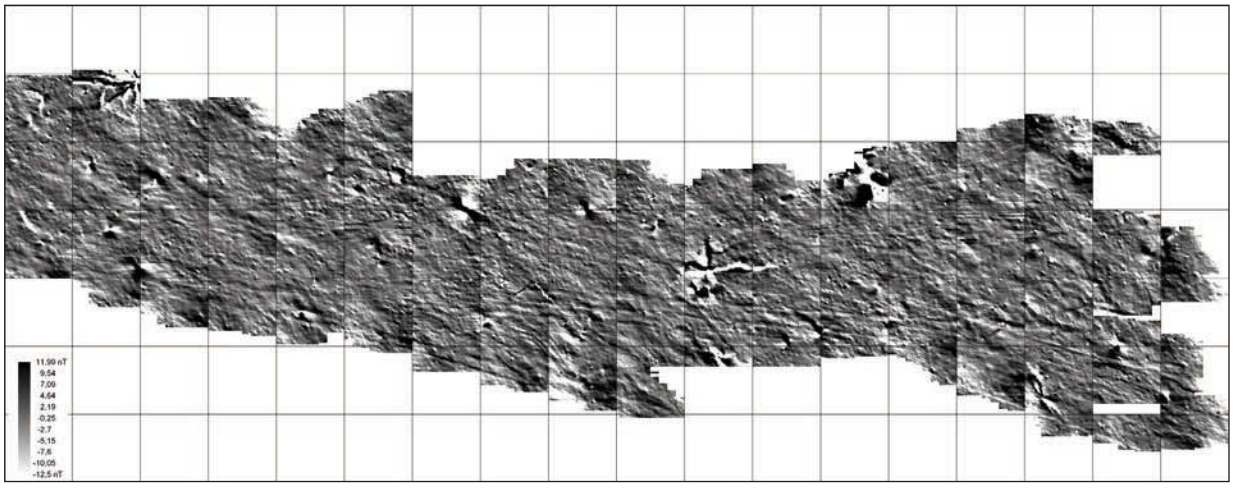

Fig. 2. Magnetogram of geoglyphs on site PAP 51A north of Palpa. Smartmag SM4G - Special in duo-sensor configuration, total field mode. Earth's magnetic field ca. 24 000 Nanotesla, dynamics +/-12.00 nT in 256 grey values from black to white, grid size 40x40 m, sampling density 50x12.5 cm, interpolated by Graduated Shade view based technique.

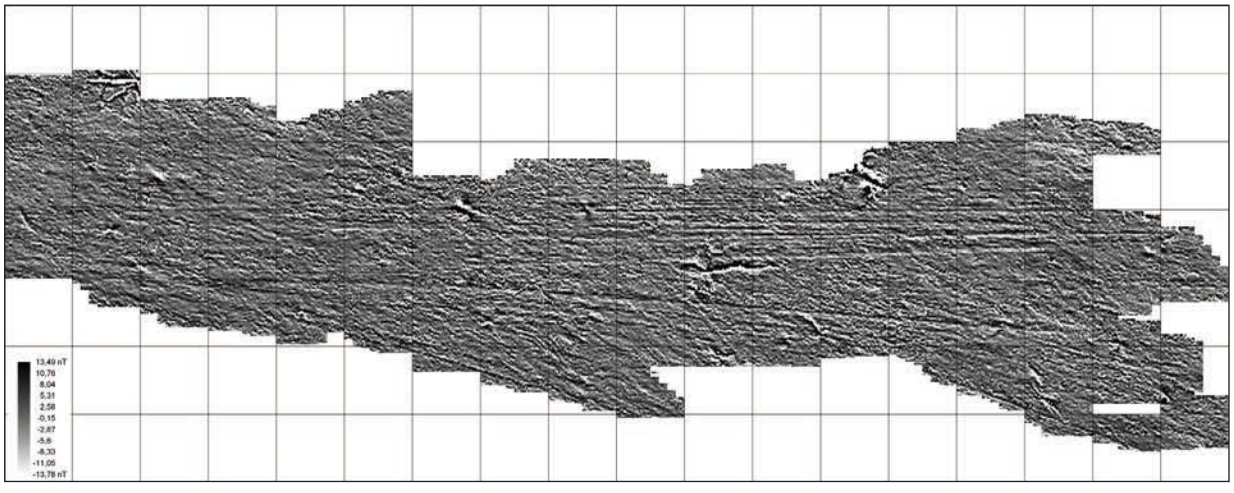

Fig. 3. Magnetogram of geoglyphs on site PAP 51A north of Palpa. Smartmag SM4G - Special in duo-sensor configuration, horizontal gradiometer mode. Earth's magnetic field ca. 24 000 Nanotesla, dynamics +/-13.00 nT in 256 grey values from black to white, grid size 40x40 m, sampling density 100x12.5 cm, interpolated by Graduated Shade view based technique

the highly sensitive total field caesium magnetometer (Scintrex Smartmag SM 4G-Special) to be used during fieldwork needed to be adapted to these conditions. In addition, geochemical processes forming iron oxides in soil, which usually cause clear magnetic anomalies, could not be expected because of the lack of precipitation. On the contrary, due to the flat inclination of the Earth's magnetic field, simple anomalies created more complicated patterns, which were difficult to interpret. To overcome this problem and to enhance the visibility of magnetic data, two sensors were arranged for the first time in a horizontal gradiometer configuration. The application of the magnetometer in such an arrangement, in combination with magnetic total field data, allowed to enhance the visibility of archaeological features in a region close to the magnetic equator. This enabled us to trace old lineal geoglyphs that had been obliterated during the construction of the larger trapezoids on the same site even in Nasca times.

A wooden frame, on which the probes were fixed, ensured a constant distance between magnetometer probes and topsoil. In this configuration two sensors were carried over the site in a zigzag mode, 30 cm above the ground. The sampling speed of the magnetometer (10 readings per second) allowed a 40 m profile of the grid (40x40 m) to be measured in less than 30 seconds. A band pass filter in the hardware of the magnetometer processor was used to eliminate the natural micro-pulsations of the Earth's magnetic field. The slower changes in the daily variation of the geomagnetic field were reduced to the mean value of the 40 m sampling profile and alternatively to the mean value of all data of a 40 m grid (*Fassbinder/Irlinger 1999*). For data processing the magnetometer readings were imported to Geoplot 3.00 (Geoscan Research) and Surfer (Golden Software) and converted into greyscale values ranging from 0 = white to 255 = black. The horizontal gradient was processed by ArcheoSurveyor (DW Consulting).

Here we report the results of magnetic prospection on four large trapezoids on the pampas to the north, east, and south of Palpa. The magnetograms of the total field measurements are dominated by remanent magnetization of lightning strikes, which clearly demonstrate a climate change in the past (*Eitel et al. 2005*; *Mächtle et al. 2006*). As far as archaeological features are concerned, the most important result is the detection of a series of old lineal geoglyphs beneath trapezoids in large geoglyph complexes. Most of these complexes were in use during several centuries and grew considerably over time (*Lambers 2006*). New geoglyphs were frequently added and existing ones enlarged or remodelled. In this process, large trapezoids often covered older lines. During their construction the stones of the desert pavement between the existing lines were removed, rendering the older lines invisible on the surface. The magnetograms clearly revealed the course of several old lines on all four investigated sites.

The lineal geoglyphs are visible in the magnetograms due to their heavily compacted surface, which was caused by people frequently walking over them in the course of ritual activity taking place on geoglyph sites (*Lambers 2006*). This compactation destroyed the vesicular horizon of the exposed loess sediment. In contrast, the large trapezoids constructed later did not confine movement of people over them, so their surface is generally less compacted. This is why the older lines are visible in the magnetogram even though their cleared surface resembles that of the trapezoids.

Apart from the geoglyphs, there was no indication at any of the four sites of the presence of archaeological features not related to the geoglyphs, nor had they been used for habitation. Thus, from an archaeological point of view, it seemed unlikely to find any buried archaeological remains predating the construction of the geoglyphs. However, the magnetic measurements showed anomalies that may be interpreted as traces of buildings, postholes, pits or other man-made structures. The relation of these possible structures to the geoglyphs remains to be investigated.

Without destruction and excavation, magnetometry has thus proven to be a powerful archaeological method for studying geoglyph stratigraphy. These findings not only shed new light on the development of large geoglyph complexes over time but also on the understanding of the Paracas and Nasca cultures and the history of the region in general. Magnetometry is thus a welcome tool for Nasca archaeology to confront unsound theories proposed by amateur archaeologists with scientific data.

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