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Magnetic Exploration of the 0lmec Civilization

Magnetic surveys have been highly successful in locating Olmec monuments at the site of the oldest known civilization in Mesoamerica

The dream of all archaeologists has been an instrument that would allow them to "see" beneath the surface of the ground, even before excavation. Such an instrument has now been developed and successfully tested in the jungle country of southern Mesoamerica-that region of Mexico and Central America that was civilized before its conquest by the Spaniards.

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It is now known that the Olmec civilization, dating from approximately 1200 B.C. to 400 B.C., was the earliest of these native cultures (1). Most Olmec sites are concentrated in a relatively small heartland along the humid, fertile coastal lowlands of southern Veracruz and Tabasco, but some colonial Olmec centers have been found in the central Mexican highlands and in the state of Guerrero. The primary jungle sites are best known for their magnificently carved monuments, usually made from basalt and weighing up to forty tons. The most striking are the colossal heads-gigantic stone portraits of rulers who are depicted as thick-lipped, flat-faced personages wearing what appear to be helmets. In both the monumental carvings and the finely worked objects of jade and serpentine, the dominant themes seem to be religious symbolization of gods, represented by a combination of the jaguar and the human infant.

Of the four largest Olmec sites in the heartland, the oldest (2) now appears to be San Lorenzo, located on a side branch of the Coatzacoalcos River in southern Veracruz (Fig. 1). This center, discovered in 1945 by Matthew W. Stirling (3), of the Smithsonian Institution, quickly proved to have the finest and largest Olmec monuments of all. During the two years that he explored San Lorenzo, the carvings were typically discovered either at the bottom of deep ravines cutting into the site or on their slopes. None was found in its original position, and Stirling concluded that they had been pushed over the side by non-Olmec invaders at some unknown time.

Intrigued by the possibilities of throwing new light upon this ancient civilization, Coe (4) began in 1966 a long-term investigation of San Lorenzo, under the auspices of Yale University and the Instituto Nacional de Antropologia e Historia in Mexico, financed by the National Science Foundation. The first line of inquiry was into the nature of the site itself, which had never been mapped. It was discovered that San Lorenzo was a flat plateau about a kilometer and a quarter long in the north-south direction, with ravines extending from it on the northwest, west, and south sides. Rather than being formed by erosion, the ravines were man-made, resulting from the construction of enclosing ridges, obviously planned. Pairs of them proved to have mirror symmetry, such as a mound on one side being neatly matched by one on the opposite ridge.

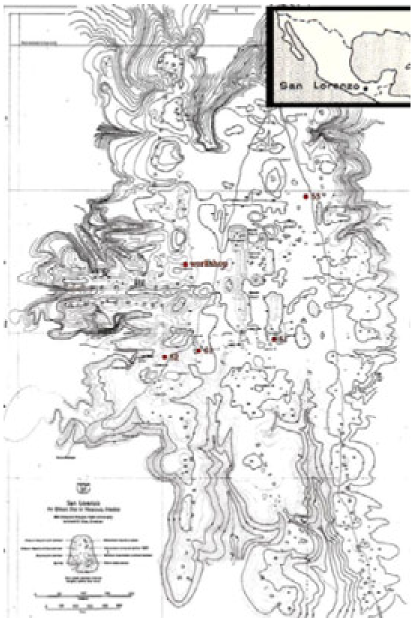

Figure 1. (prev page) This greatly reduced map of San Lorenzo in southern Veracruz, Mexico, shows the general outline of the plateau with the ridges and ravines. Note the symmetry of the ridges on the south and west sides of the plateau. The monuments indicated by small circles on the map were found before the magnetometer survey. The colored circles show the

location of Monuments 51, 52, 53, and 61, which are among the more important objects discovered during the survey.

Our second discovery, made through ceramic stratigraphy and radiocarbon dating, was that about 900 B.C. a major act of destruction took place at San Lorenzo. Every single piece of carved stone had been mutilated and then dragged onto specially prepared floors built on the ridges, which were completely covered by a fill composed of soil, gravel, and other debris. The monuments that Stirling discovered centuries later in the ravines had simply come to light through the gradual erosion of this fill.

Figure 2. View of the Tuxtla Mountains from San Lorenzo, Mexico. Basalt rock from these mountains was transported approximately 70 kilometers to San Lorenzo, where it was carved into monuments.

The discovery of this pattern of buried sculptures was purely accidental, a piece of luck that occasionally turns up on every expedition. The possibility immediately suggested itself that a great number of other Olmec carvings might still lie under the soil of San Lorenzo. How could these be found? Having had experience in the use of magnetometers for archaeological exploration, Froelich Rainey, Director of the University of Pennsylvania's Applied Science Center for Archaeology, suggested using such instruments at San Lorenzo.

Several geophysical techniques based on magnetic, electrical, seismic, or gravimetric methods have been used in archaeological prospecting (5). Magnetic surveying has proved to be by far the most practical and useful. Although not a common tool in archaeological kits, magnetometers have been utilized during the past decade at various sites around the Mediterranean (where they helped in finding ancient Sybaris, 6), in England, and in North America.

Magnetic anomalies at archaeological sites

The magnetic anomalies of significance in archaeological exploration are caused by the contrasting properties of the cultural feature and the soil, water, or rocks covering it (7). The amount of the very common mineral magnetite in the feature as well as its mechanical and thermal history usually determine the size of the disturbance, or anomaly, in the earth's magnetic field, which is actually measured by the magnetometer. Various rocks, soils, and objects foreign to the site possess different magnetic properties owing to the widely varying amounts of magnetite and whether or not the magnetic elements of the magnetite grains of the feature are aligned, i.e. the relative proportions of induced and remanent (permanent) magnetism. Buried rocks, walls, artifacts of various types, tombs, trenches, and other such features are all detectable under the right circumstances.

The most prominent magnetic anomalies are usually caused by natural materials that have undergone heating. Clay objects that have been subjected to high temperature, such as bricks, tiles, pottery, and firepits, attain a remanent magnetism as a consequence of the alignment of their magnetically susceptible elements with the earth's magnetic field during the process of cooling, Such remanent magnetism is also a property of rocks that have been heated in nature, especially volcanic or igneous rocks. Almost all the San Lorenzo monuments were carved from such rock - basalt - which is not native to the area but which was laboriously brought in from the Tuxtla Mountains, some 70 kilometers to the northwest (Fig. 2).

Figure 3. Surveying the San Lorenzo site with the magnetometer.

First of all, we had to determine whether or not magnetic surveying would aid the exploration of San Lorenzo, since most sites are, in fact, unsuitable for this technique. In February 1968, Rainey assessed conditions there and obtained samples of the monuments and of the fill in which they are principally buried. The induced and remanent magnetization of the monuments proved to be 2 X 10-1 and 4 X 10-4 emu, respectively, contrasted with a total magnetization of the fill of less than 3 X 10-1 emu. Thus, there was enough difference between the magnetism of the objects and the surrounding fill to make San Lorenzo an ideal site for the effective use of magnetic surveying. Further, there are no deeper-lying rock strata at the site to interfere with the observed anomalies; in fact, because there are no "natural" rocks, all anomalies would be significant. Finally, San Lorenzo is happily remote from any recent man-made implements, vehicular traffic, other iron and steel interference, and electric power lines.

Figure 4. This figure, over one meter high, represents the rain god (Monument 52) and is one of the finest of all Olmec sculptures. It was found as a result of the preliminary magnetometer survey.

Magnetic surveying

The following month we brought a portable cesium magnetometer to San Lorenzo (Fig. 3). This instrument has a sensitivity of 0.1 gamma (10-6 oersted) and can be operated in either a "search" or "survey" mode (7, 8). As a search device, it was used to take occasional readings visually or audibly, noting more the location of the anomaly than its amplitude. This mode is useful for rapid reconnaissance, for obtaining an overview of site conditions, and for tracing long anomalies (such as a wall). We chose initially to traverse San Lorenzo on horseback, particularly in the high grass and some dense forest areas. The local saddles were made of wood, and there were no steel horseshoes to interfere with the instrument. Almost immediately, we located an anomaly and estimated the depth of what turned out on excavation to be one of the finest of all Olmec sculptures-a rain god with typical half-human, half-jaguar features (Fig. 4), lying at the predicted depth of 2'/2 meters at the head of a buried drain system. Several more monuments were found in this manner, and archaeologists were as mystified as the local workmen at the uncanny ability of the magnetometer to "see" buried objects.

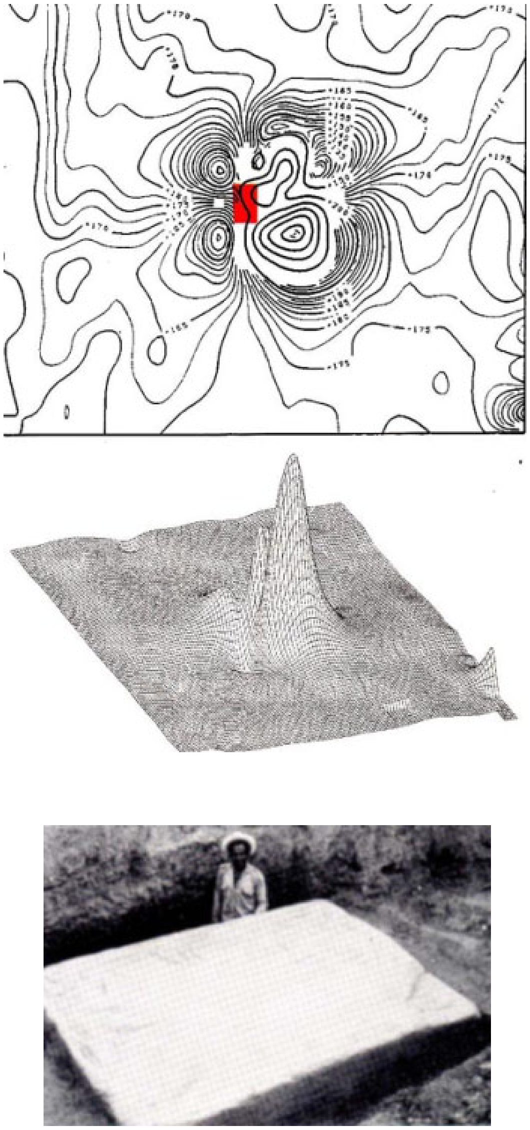

Figure 5. Total magnetic intensity contour map *(above)* and perspective view of contoured data *(center)* over a buried Olmec altar (Monument 51), shown *~below)* after excavation. The altar caused the prominent anomaly in the center, indicated by the colored block; other anomalies are caused by neighboring small monuments. The sharply defined square depression on the perspective view is the effect of missing data. The map represents an area approximately 50 meters on a side.

It was necessary, however, to conduct a survey systematically in order to obtain complete coverage of the area and to find objects that responded less noticeably to the sensor or that were more deeply buried. This required that we produce a magnetic map of the entire San Lorenzo plateau, a program that was largely completed in the following field season by Elizabeth Ralph, of the Applied Science Center of Archaeology of the University Museum of the University of Pennsylvania. Mapping procedures using the instrument in the survey mode require that measurements be made on a regular grid whose dimensions are determined by the probable size and maximum depth of the anomalies of interest. We decided to seek Olmec monuments with a minimum size of one cubic meter, large enough to produce an anomaly detectable at a maximum distance of about 2 to 3 meters. This indicated a grid interval of 2 meters for the entire surface.

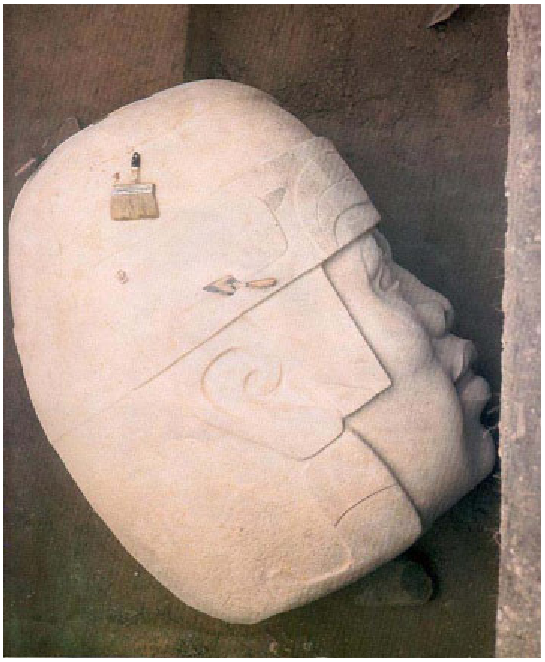

Figure 6. A colossal Olmec head (Monument 61), buried at a depth of approximately 5 meters, was the most perfectly preserved large sculpture found at San Lorenzo.

We divided up most of the accessible parts of San Lorenzo into approximately 31 major grids measuring 100 meters on a side. Ropes were marked off in 2-meter lengths and laid on opposite sides of each grid. A third rope marked similarly was laid between them along corresponding marks. A reading would be taken over each mark on the latter rope with the magnetometer held one-half meter above the ground. A total of 80,000 measurements were taken in this manner and transcribed to field notes or into a portable tape recorder held at some distance from the site of the measurements. Unfortunately, the steep terrain and dense forest precluded coverage of many areas of the plateau.

There are some inherent problems in a survey of this sort. One of the most serious is that the measurements show not only the magnetic variations of the underlying monuments and artifacts but also extraneous time variations of the magnetic field. These solar-induced time variations, called micropulsations or diurnal variations, make it difficult to sort spatial from time anomalies. To remove the major effect of the time variations, a constant value was added to or subtracted from each point on a given line to make the average value of that line equal to the average of the entire grid. Large line-to-line level offsets were thus eliminated, allowing for the preparation of a more presentable contour map.

The survey results showed the effects of deposits of physically small but anomaly-producing artifacts, especially stone debris from ancient workshops. Also, because of the large grid interval, the effect of some moderately large monuments appeared principally on one grid point and only very subtly on several adjacent points, and the effect of very small monuments appeared on one grid point alone. In both cases there were doubts about the significance of that single data point. For all grids, therefore, we computed what the magnetic field would have been at an elevation one meter higher. In this way, more weight would be given to the subtle effect at neighboring points, thereby establishing greater confidence in the location and existence of an object of significant size, while the effect of the very shallow, small, and insignificant anomalies would be almost completely eliminated. This process, known in geophysical exploration as "upward continuation," is a mathematical technique based upon accurate knowledge of all the data on a plane surface.

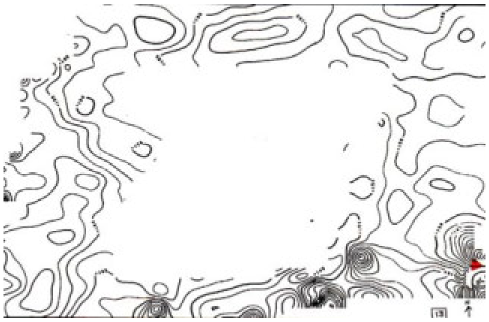

Figure 7. Contour map of magnetic intensity over Monument 61 (shown in Figure 6). The head was found under the anomalous area indicated by the colored marker in the lower right-hand corner of the map. The area at the center of the map was covered by a large artificial pond, where no measurements were made.

Using points 2 meters apart does not produce a readily interpretable contour map, nor does it allow for much refinement in the location and character of the anomalies. We therefore computed, from the original 80,000 locations, an additional 400,000 points, using the bicubic spline technique, a method for low-order interpolation between the already established values. All the points thus computed were used to derive total magnetic field intensity contour maps of approximately 300,000 square meters over the San Lorenzo plateau, an enormous job accomplished by using a very efficient technique of electrostatic plotting. The maps were then interpreted for the precise location, depth, and estimated size of the anomalously magnetic features. Three-dimensional perspective views of the contoured data were also derived to, portray vividly the complex magnetic field variations observed over the relatively simple geometric shapes of the monuments, as shown in Figure 5.

Survey results

The survey occupied three field seasons, during which archaeologists from Mexico's Instituto Nacional de Antropologia e Historia and from Yale University conducted the digging to test whether there actually were monuments under the mapped magnetic anomalies. The largest and/or shallowest monuments, as determined above, were excavated first. Of course, some "dry holes" resulted from such features as burned soils or stone workshop debris (Fig. 9), but most efforts were crowned by success. Seventeen Olmec monuments were discovered that would otherwise have completely eluded even the shrewdest and most patient archaeologist. The majority were not in the ridges (where the magnetic survey was incomplete) but on the central part of the San Lorenzo plateau, where we had not expected to find them. Among the most impressive were two new colossal heads: Monument 53, found lying face up and less than one meter deep, wears a unique helmet embellished with a pair of hands (Fig. 8); Monument 61, without doubt one of the finest masterpieces of pre-Columbian art, is a perfect, un-mutilated sculpture which had been buried in a pit at a depth of 5 meters, presumably very early in the San Lorenzo phase (Figs. 6 and 7). It was missed by the iconoclasts in their mass act of destruction at the site.

Other stones included stelae, columns (one decorated with a bas-relief scene showing a man and a jaguar), fragments of oblong "altars," and a round "altar." One of the stelae bears a motif completely new to Olmec iconography, an extraordinary fish with the head of a jaguar, of entirely unknown significance. Monument 52, the important statue of the Olmec rain god, has already been mentioned.

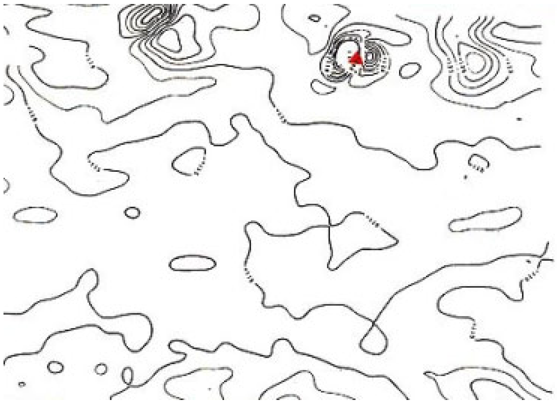

Figure 8. Contour map *(above) of* total magnetic intensity *of* a grid containing the colossal Olmec head (Monument *53) (upper right*). The anomaly caused by the head is indicated by the colored marker at the top of the map.

The center of the mesa at San Lorenzo is occupied by a "pyramid" and a rectangular set of ridges extending in a north-south direction. The ridges exhibited a magnetic anomaly conformable to their topography, suggesting that their cores are composed of uniformly magnetic soil or other such material. The pyramid itself was entrenched through to its "floor" and the interior of the trench explored with the magnetometer for evidence of monuments. Clay materials, magnetic rock fragments, and uniformly magnetic stratified horizons were noted, but no monuments were detected or found.

After the San Lorenzo magnetic survey, the magnetometer was tried out on a similar pyramid at the great Olmec site of La Venta by Morrison et al. (9), of the University of California. One anomalous area was noted not far below the summit of the structure.

The magnetometer is thus a reliable and, so far, unique instrument for the prospecting of Olmec sites. It can save immeasurable time and expense in guiding excavations for the relatively "obvious" anomalies detected at such ideal sites as San Lorenzo. The magnetometer may also find use in the search for buried features producing "negative" anomalies, that is, features in the ground that have zero magnetization in contrast to their surroundings. Such features might be the hidden openings of underground tombs, such as those detected with the use of a magnetometer by Linington (10) in Italy. Tombs and buried entries are relatively common in the New World from western Mexico to Colombia.

It should be emphasized, however, that most sites are not suitable until proven otherwise through some knowledge of the magnetic properties of the archaeological features and the surrounding materials. Furthermore, someone experienced in magnetic surveying should be present, because the procedures of measurement and the interpretation of the results are still too complex for an archaeologist untrained in these techniques to carry out by himself. Under the right conditions, however, magnetic exploration should be a standard procedure at archaeological sites around the world.

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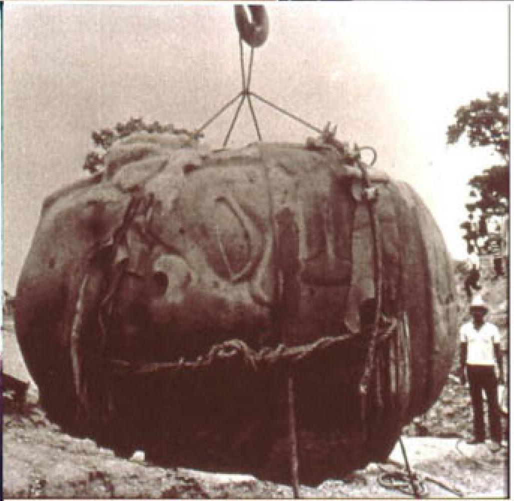


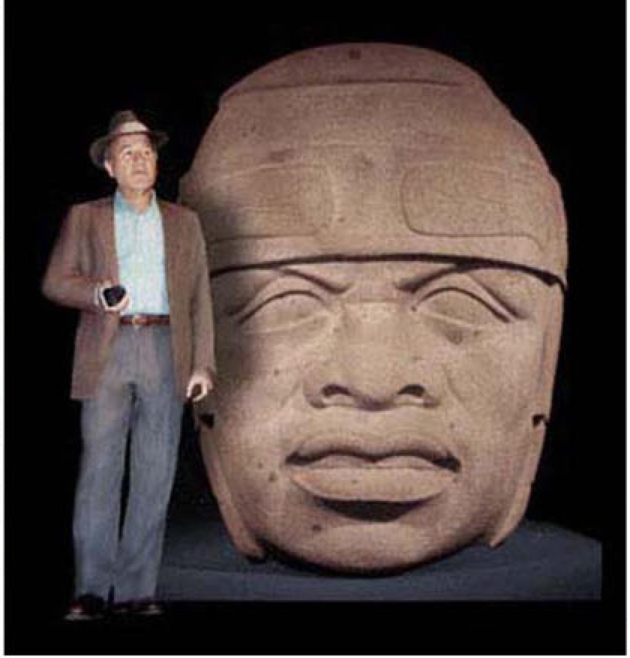



"fire starters"

magnetic map
of pile of 5,000
fire starters at
San Lorenzo