THE SEARCH FOR SYBARIS WITH A PORTABLE CESIUM MAGNETOMETER

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With the kind permission and under the direction of Dr. Giuseppe Foti, Superintendent of Antiquities, Reggio Calabria, instrument surveys were conducted in the fall of 1965 on the plain of Sybaris by the University Museum, University of Pennsylvania, Philadelphia, as a continuation of the program initiated by Dr. Froelich Rainey, Director and Eng. Carlo M. Lerici (Lerici Foundation, Rome) in 1961.

These surveys were conducted with a new portable cesium magnetometer. This instrument was designed and constructed by Varian Associates, Palo Alto, California, especially, for the use of the University Museum in the search for Sybaris. (It was financed jointly by Varian Associates and the University Museum). It is a completely new instrument and has the capability of 50 times greater sensitivity than the proton magnetometer that had been used in previous campaigns. In addition, areas may be covered many times more rapidly. The design of the instrument is an outgrowth of tests made with the Varian Associates' rubidium magnetometer in October 1964. The new cesium magnetometer is completely portable and has many special features that enabled it to function in an ideal way on the plain of Sybaris.

The basic principle of the cesium and of other optical absorption magnetometers is that, due to the Zeeman effect, the energy levels become split into various sublevels whose separations are dependent upon the total intensity of the ambient magnetic field.

To detect this proportional splitting, optical pumping is required. The operation of optical pumping involves the excitation of electrons into metastable states by the absorption of appropriate electromagnetic radiation. When "pumping" is completed, redistribution of the pumped electrons to lower levels is accomplished by stimulation from a radio frequency corresponding to the difference in energy between the split levels. The resultant frequency that is detected by the instrument is, therefore, dependent upon the ambient magnetic intensity in the vicinity of the sensor (the detecting element). This is then related to a reference oscillator within the instrument and the readings appear in digital form directly in gammas when one sensor is used.

In order to make effective use of this sensitivity, an additional sensor is required to cancel out diurnal and other extraneous changes in magnetic intensity. One may read the difference between two sensors rather than the absolute field with one. (Alternately, if one desires, two readouts may be carried and they can be synchronized for simultaneous readings). One possibility is to carry two sensors, one above the other, at a fixed distance apart. This was not practical on the plain of Sybaris where possible structures of the 6-7th century B.C. city are buried at depths of 5 to 6 meters. To obtain maximum sensitivity at this depth, the sensors would have to be carried about 5 meters apart. Since each one with its associated electronics weighs about 3 kg., it was not physically possible to carry one aloft with stable motion at a height of 5 meters. Therefore, on the plain of Sybaris, one sensor was placed in a fixed position with a long cable(100 meters)

leading from it to the instrument. With this "difference" mode of operation, the fixed sensor then becomes the reference oscillator and the base reading (rather than absolute intensity in gammas) becomes 80,000 units. (If desired these units may be converted to gammas by the formula; $\gamma = \frac{80,000 - \text{unit}}{80,000} \times H$ where H is the intensity in gammas obtained with one sensor. On the plain of Sybaris, H is approximately 44,600 γ. Therefore, it happens that the sensitivity in the "difference" mode may be as low as 0.05γ (on the most sensitive 0.1γ range of the instrument).

The great advantage of the "difference" mode of operation is that all readings are "absolute" - not affected by diurnal or any other fluctuations in magnetic intensity - only the underground anomalies sought as the position of the movable sensor is changed. Also, by putting a small magnetic anomaly (a compass) near the fixed sensor, it was possible to relate each succeeding station to the previous one so that, for example, if a reading of 10 units was recorded in one field, the same reading in the next represented the same conditions of magnetic contrast. Because of this"absolute" feature, readings could be recorded directly in a notebook oriented in the same way that the grid was traversed. It was found convenient to make large grids, usually within the boundaries of fences or hedge rows, with lines taken at intervals of 5 meters and readings taken every 2 meters in the lines. The readings were then recorded in a notebook at a scale of 1:400. With this mode of operation, approximately 5000 square meters could be covered per hour (after the distances between the lines were measured and marked out on the fence posts). The 2 meter intervals were determined only as paces. The readings appear at the maximum rate

of one every 1.5 seconds, a comfortable pacing rate. At the completion of a grid, the pages of the notebook were then pasted together in the proper orientation and the lines of equal magnetic intensity were drawn. Examples of grids numbers 1, 4, 22, and 23 are included, and their locations are indicated on Map C. (Not shown on Map C are Grids #7, 8, 9 which were made west of and near the junction of the Crati and Coscile Rivers, and in which no significant anomalies were found. Q #14 was laid out southeast of Q #4, but was not completed. Q #1 and Q #4 have been redrawn so that the original notebook readings do not appear as in the others).

The remaining problem is that of interpretation. It can be seen in Q #22 that there is a large magnetic anomaly just north of Scavo #1 (1964-65). From our knowledge of what was found in that excavation, we may assume that this anomaly represents extensive deposits of roof tiles (fired clay is more magnetic than unfired), probably archaic, at depths of 4-5 meters. For the other grids made this fall, we must depend upon drilling for confirmation of the anomalies, age, and depth determination. On the basis of a short concurrent drilling program and the 1500 holes drilled in the past 3 years, Map C, which shows confirmed and probable structures, was made.

It is seen that the work was concentrated east and south of Casa Bianca. From directly east of Casa Bianca running south (not north), there are several structures confirmed by drilling and many other possible ones. It is quite probable that the easterly limit of these structures coincides with the eastern limit of Sybaris (or of a later city). Most of the confirmed structures

are deep - from 4.8 to 6.0 meters and the sherds, predominantly archaic. Except for structure A in Q #1, the anomalies were small in magnitude, about 10 units (5 gammas) or less over our usual base reading of 80,010 units.

Structure A, however, made a pronounced anomaly (see Q #1) with regularly spaced parallel contours of equal magnetic intensity in more or less of a rectangular shape. It was hoped that this significant anomaly might represent a temple or other major building (dimensions approximately 20x50 meters) of the archaic period. At the center, the drill was stopped (presumably by walls) at 3.8 meters or more and at the easterly end at 4.1, 4.2, 5, and 4.2 until the area of friable resistance (from 4.5 to 6.0 meters deep) was reached. Close examination of the drill results indicates, however, that in almost every drill hole, some mortar was found. Microscopic study of the mortar revealed that this is most likely man-made mortar. Therefore, it is probable that this anomaly is due to a structure which could not be earlier than the late 4th century B.C. and may be much later. Whether or not there is an archaic structure beneath it can not be determined with certainty without excavation. In the drill holes of some of the other confirmed anomalies of Q #1 and Q #2, there was also evidence of mortar even though these structures were all found at depths of 4.8 meters or greater.

If, however, there are archaic buildings beneath the later ones, then the anomalies indicate that part of the eastern limit of Sybaris has been found from just north of the Crati River, to the region directly east of Casa Bianca, a distance of 800 meters.

This northern limit is terminated by a pronounced path of sand at less depth (Q #13 and #15). Then to the north of this, there are deep pockets of clay (Q #15, 17, 18, 19 and 20) which may indicate the locations of lagoons in ancient times.

The anomalies of Q #4 (south of the Crati River) are very much larger and offered only friable resistance to the drills at depths of 4 meters or more. The potsherds retrieved, represent all periods of occupation, but contain many archaic examples. The anomalies fall roughly in a line running northwest to southeast. It is conceivable that these represent a necropolis.

If we assume that these are a part of Sybaris and that there are underlying archaic structures southeast of Casa Bianca and again archaic deposits around Scavo 1 (Q #22 and Q #21), then the limits of "the city" as presently determined form a triangle with sides 2 x 1.3 x 2.2 kilometers. The western side (2.2 km), however, is hypothetical at this time since it is not known what deep anomalies lie to the west of Parco del Cavallo and Lattughella.

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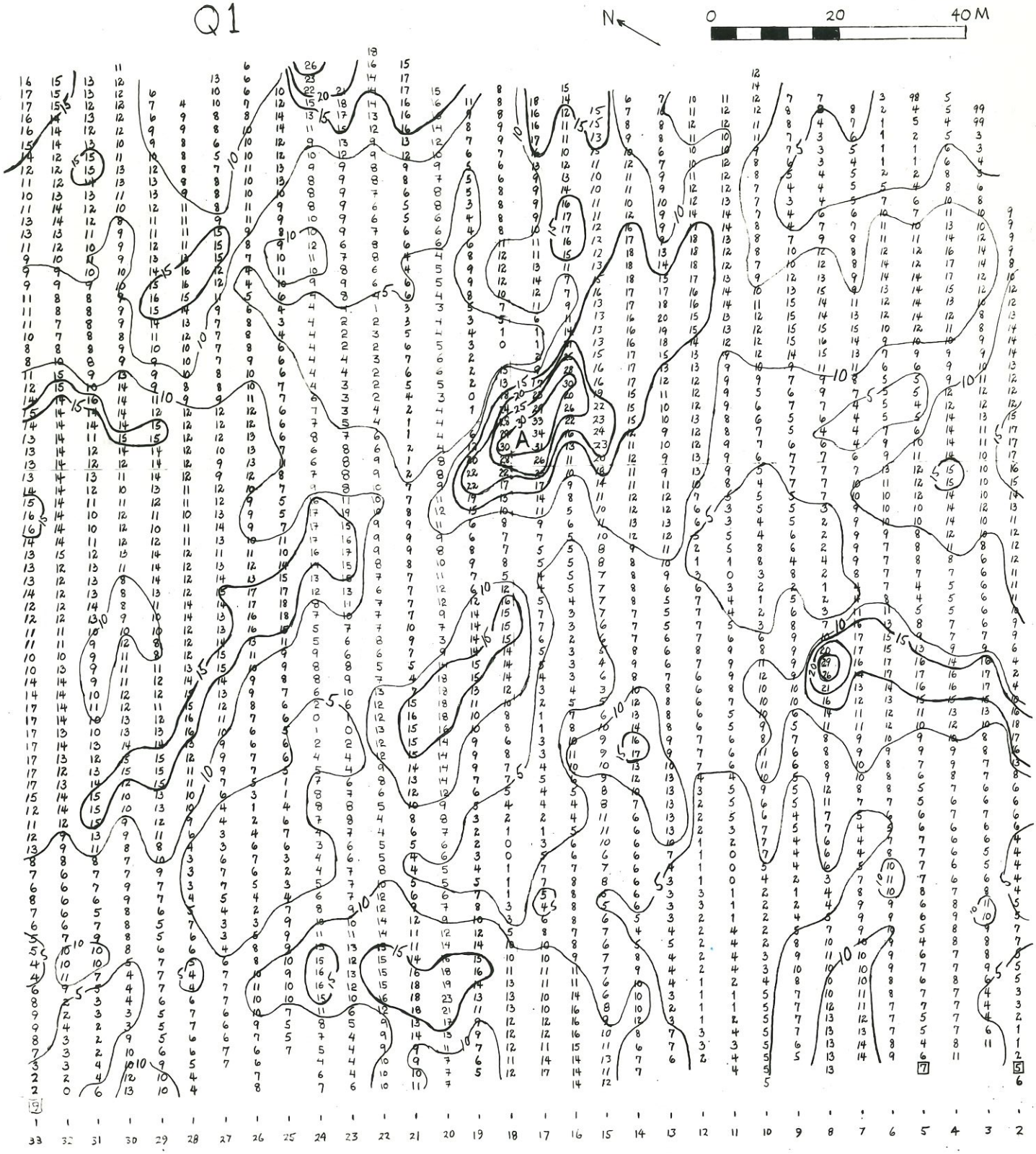
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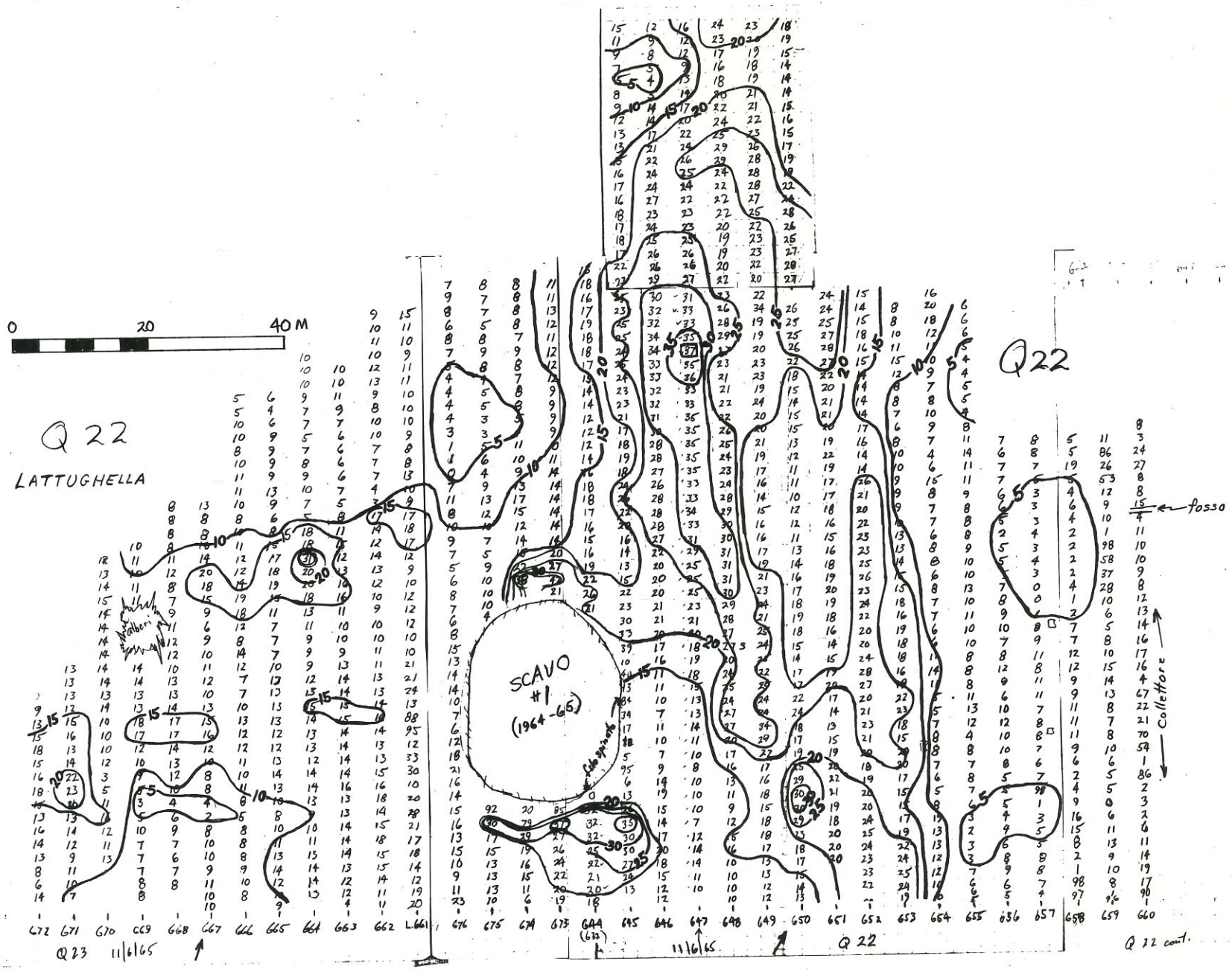
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LATTUGHELLA
SCAVO
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(1964-65)
Q22
fosso
Colletore
Q23 11/6/65
11/6/65
Q 22
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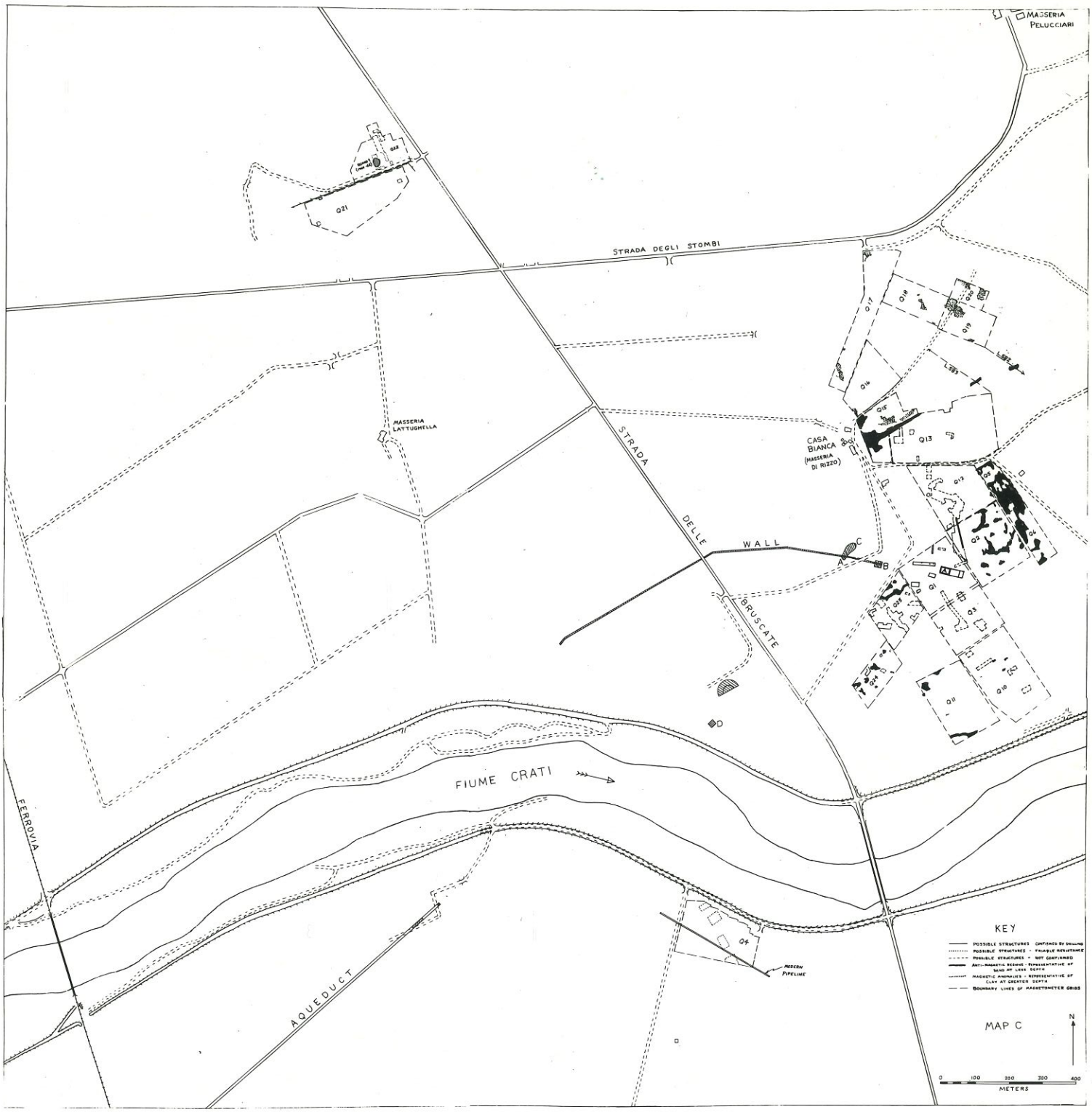
MASSERIA PELUCCIARI
STRADA DEGLI STOMBI
MASSERIA LATTUGHELLA
CASA BIANCA (MASSERIA DI RIZZO)
STRADA DELLE WALL
BRUSCATE
FIUME CRATI
FERROVIA
AQUEDUCT
MODERN PIPELINE
KEY
POSSIBLE STRUCTURES CONFIRMED BY DRILLING
POSSIBLE STRUCTURES - FRIABLE RESISTANCE
POSSIBLE STRUCTURES - NOT CONFIRMED
ANTI-MAGNETIC READING - REPRESENTATIVE OF SAND AT LESS DEPTH
MAGNETIC ANOMALIES - REPRESENTATIVE OF CLAY AT GREATER DEPTH
BOUNDARY LINES OF MAGNETOMETER GRIDS
MAP C
N
0 100 200 300 400
METERS