High Definition Magnetometric Survey of Pre-roman and Roman Settlements and Pottery Kilns

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Abstract High definition magnetometric technique allows the correction of the temporal magnetic field fluctuations, in order to reduce the temporal noise of the detected signal at the level of the instrumental sensitivity. At the same time, the spatial location of the measurement points is carefully determined in order to build a precise gradient map showing the buried site. We applied this technique in two areas of archaeological interest: Isola di Coltano (Pisa) and Vada (Livorno).

The Dipartimento di Scienze Storiche del Mondo Antico (chair of Ancient Topography) started a factual interest in non destructive techniques applied to archaeology within the framework of the POPULUS Project (Human Capital and Mobility Programme, EU, 1994-1996). Integrated studies are applied to a large area in North-Western Tuscany (Italy), more exactly to the ancient coastal territories of Pisa and Volterra.

In this area palaeo-ecological and archaeological researchs provide large evidence for the history of the environment and human impact since Palaeolithic (Mazzanti 1994, ed.). Archaeometry (chemical and minero-petrografic analyses) , till now applied to pottery dated VIth cent. B.C-A.D. VIIth cent., gives evidence of local productions and imported wares (Del Rio et al., 1996).

Remote sensing, geophysics and geochemicals have been applied with special reference to landscape archaeology and extra-urban sites.

In particular, the geomagnetic prospection in the areas of archeological interest is a powerful investigation tool, that may present some advantage over other geophysical methods. This technique is absolutely passive, the modern experimental apparatus is very simple in the use, of small size and do not require cumbersome energy system (Faggioni et al., 1996 a; Bozzo et al., 1985). At difference from geoelectric methods, where parasitic electrodic currents may mas the effective signal, it is possible to operate with high accuracy also in the conditions of very weak contrast. The technique is particularly efficient for the localization of kilns, furnaces and brickwork, that have a large magnetic signature for the abundant presence of iron oxides.

The observed magnetic signal is however affected by two principal limiting factors, first the temporal fluctuations of the geomagnetic field, that are superimposed as a noise to the spatial variations, secondly the interference between the signal generated by the artificial sources, that are the object of the research, and the signal generated by natural unknown geological sources. The high definition technique allows to overcome these problems.

The first effect is controlled by the method of temporal reduction. At the same time that the magnetic total field value is measured point by point in the survey area, a second magnetometer placed in a fixed station enregistrates the temporal evolution of the field. By deconvoluting the data measured by the mobile station with the magnetogram obtained from the fixed station, the temporal component can be separated from the spatial component (Faggioni et al, 1996 b). If the fixed station is placed in the proximity or better in the inner part of the area, in spite of using a remote fixed station, this experimental procedure allows also the correction of the temporal fluctuations due to artificial sources, like electrified railways, electric transmission lines, etc., increasing the final identification of the static artificial anomalies, associated for instance with archeologic objects (Berti et al., 1991).

The geological background is eliminated by deconvoluting the bidimensional matrix of the detected field values from a reference field. This reference cannot be a standard reference field, like the planetary one (IGRF) or also the regional one (in our location the ItGRF or the ItNGRF), because these reference fields do not resolve the structures at the length scale of interest in a detail survey. It must be calculated from the same detected field values from a harmonic spectral analysis by the Fourier transform methods. The geological sources are farer from the sensor than the near-superficial static artificial sources, and then are producing an anomaly field characterized by longer wavelengths.

Bronze and Iron Age settlements and/or burials have been identified in the Pisa area and in the coastal strip. The protohistorical village at Isola di Coltano (fig. 1 : in the plain 9 Km SSW of Pisa) was selected for a geo-magnetic survey because of its archaeological and palaeo-ecological interest (Marchisio et Al. 1995).

According to the archaeological surveys evidence, the village extended at least 30 m N-S and 18 E-W. In this area two trenches have been dug (1993-1994): under the humus, we found layers made of clay-plasters, coarse pottery and semifired-clay finds, obviously due to the destruction of ancient huts.

These archaeological layers were on geological layers of slime with calcareous nuclei and crumbled conchs : so it turns out that the area was swamped by a lagoon; according to the chronology of the above-cited pottery, this overflow seems to have occurred before the VII cent. B.C.

Below the geological layers we dug two others phases of the village life, dated XI-VIII cent. B. C. and divided off by the interposition of geological sediments (yellow-gray slime with conchs, especially *cerastoderma edule)* due to the presence of a sea-water ambient with a low salinity.

In this archaeological area, so large and complex, magnetic surveys were carried out in order to locate ancient fireplaces (1994). A proton procession magnetometer Geometrics G856A (with sensivity of 0.1 nT) was used as fixed station and a proton gradiometric magnetometer EDA Omni Plus as mobile station.

The magnetometric surveyed trench extended for 12 m N-S and 11.5 m E-W ; the spacing grid was very closed (0,25 m x 0,5 m). A detailed magnetic map of the site was produced and within the trench there were four evident anomalies (**A, B, C, D**) which seemed interesting indications of the presence of fireplaces (fig.2).

Further excavations were performed in 1995. We dug part of the clay pavement of an hut, whose walls , at bottom, were made of little stones and, above, of stakes covered with clay-plaster. In the anomalies area we identified:

A) Roasted stones forming an oval shape; layers of ash and coal.

B) Bones, layers of ash and coal.

C) One clay find with rounded section, usually interpreted as support for a fireplace.

D) is still to be excavated.

It has resulted that the anomalies were really indications of the presence of fireplaces; these were connected with the settling phase of final bronze age (XII-XI cent. B.C.). The detailed study of the pottery, now in progress, will specify the different chronological phases of the village.

Etruscan and Roman ports were identified along the VIII-I cent.B.C. coastline, which progressively prograded westwards (Pasquinucci-Mazzanti 1987). Pisa was the main city in the coastal district. In the countryside farmsteads and mountain forts have been identified; the archaeological finds show that the area was densely populated up to Late Roman Period (Pasquinucci-Menchelli 1995).

In the Vada (Livorno) area (fig.1) a large coastal settlement has been identified, dated IXth-VIIth cent. B.C. (earliest evidence: huts on coastal dunes) and Ist cent. A.D.-A.D. VIIth.) .The site is identified as *Vada Volaterrana* ancient port of *Volaterrae* (Volterra) at least since the V th cent. B.C. It is the largest and most important preserved ancient seaport-town along the Tuscan coast between Luni and Populonia.

Archaeological excavations carried out since 1982 in the S. Gaetano di Vada area (North of present day Vada) have displayed two Roman *thermae* , large *horrea* and a probable *macellum* (fig. 3) (Pasquinucci-Menchelli 1994).

In the SW sector of this area, to be excavated, a preliminary geomagnetic survey has been performed by the high definition methods. The total geomagnetic field has been measured with a proton procession magnetometer along two crossed profiles 56 m long (in the approximate directions N-S and E-W) with a step of one meter. Fig. 4 reports the E-W profile after the temporal reduction operation, and has evidenced an interesting big anomaly, surely associated with a superficial artificial source. The location of the source should be in the position of the maximum field variation. If we plot the gradient profile by calculating the spatial field gradient in the profile direction, the location appears in coincidence of a maximum, and is then much more definite (Fig. 5). In the present case the anomaly is very large, and yet the field profile can locate with accuracy the source, but the use of the gradient map can be fundamental for the interpretation of anomalies of small intensity.

It is possible that in this area are ancient buried buildings; the big anomaly, besides, shows the presence of a metal deposit ; the next archaeological campaign will allow us to display and date it.

Complete survey of this area and of other sites, where the presence of kilns is expected, is in progress. In the near future, new instrumental apparatus will be used in order to push the performances of geomagnetic surveys to its ultimate limits. Effectively, the proton procession magnetometer has an useful sensitivity of the order of 1 nT, at a data acquisition rate of about 0.1 samples per second. Both sensitivity and acquisition rate can be improved of about two orders of magnitude by the potassium vapor magnetometer that we are now developing and that should be in use for the next year.

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References

C. Berti, P. Cantini, R. Carrara, O. Faggioni, E. Pinna, 1991, Atti X Conv. GNTS, Roma.

E. Bozzo, G. Caneva, M. Cattaneo, O. Faggioni, A. Meloni, 1985, *Anomalie delle variazioni geomagnetiche di origine lito-astenosferica nall'Italia Nord-occidentale,* Atti IV Conv. GNTS, Roma

A. Del Rio, T. Mannoni, S. Menchelli, M.Pasquinucci, 1996, *Importations et productions locales de la haute Etrurie tyrrhénienne, de la période de la romanisation jusqu' au VI è siecle apr. J.-C.. Un exemple d'étude archéométrique,* Revue d'Archéométrie, in press.

O. Faggioni, N. Beverini, C. Carmisciano, L. Rossi, 1996 a: *Sulla misura delle variazioni temporali del campo magnetico terrestre in provincia della Spezia* Accademia Lunigianese "Capellini", special issue, in press

O. Faggioni, N. Beverini, C. Carmisciano, 1996 b: *Time variation and high definition study of the geomagnetic field space structure in the eastern Ligurian sea* (Italy) Boll. Geof. Teor. Appl., in press

O. Faggioni, C. Carmisciano, R. Carrara, E. Pinna, 1993 *Sistema automatico di Misure delle variazioni del campo geomagnetico per lunghi periodi di osservazione,* Atti XII Conv. GNTS, Roma

M. Marchisio, M. Pasquinucci, L.Sambuelli, E. Comino, L. D'Onofrio, S. Menchelli, L.V.Socco 1995, *Una prospezione magnetometrica su un sito arcaico ad Isoala di Coltano (Pisa, Italia), in* I Intern. Congress on "Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin", Catania 1995, in press.

R. Mazzanti et Alii, 1994 (R. Mazzanti ed.),*La pianura di Pisa e i rilievi contermini. La natura e la storia,* Società Geografica Italiana, Roma 1994.

M. Pasquinucci, S. Menchelli, 1994, *Vada Volaterrana* : l'*area archeologica in loc. S. Gaetano* , Casciana Terme 1994.

M. Pasquinucci, S. Menchelli, 1995, *Paesaggio agrario e produzioni artigianali nell' Etruria settentrionale costiera (ager Pisanus e Volaterranus),* in The Fifth Conference of Italian Archaeology. Settlement and Economy, 1500 B.C.-A.D. 1500, N.Christie ed., Oxford 1995, pp. 209 ss.

M. Pasquinucci, R. Mazzanti, *La costa tirrenica da Luni a Portus Cosanus* , in Déplacements des lignes de rivage en Méditérranée, Colloque Intern. CNRS , Paris 1987.

Fig. 1. Ancient coastline

Fig. 2. Isola di Coltano (Pisa). Total Magnetic Field at 0.3 m with correct temporal fluctuations. Four anomalies (**A, B, C, D**) are evident.

Fig. 3. S. Gaetano di Vada area.(Livorno).

A : Thermae

B : Horrea

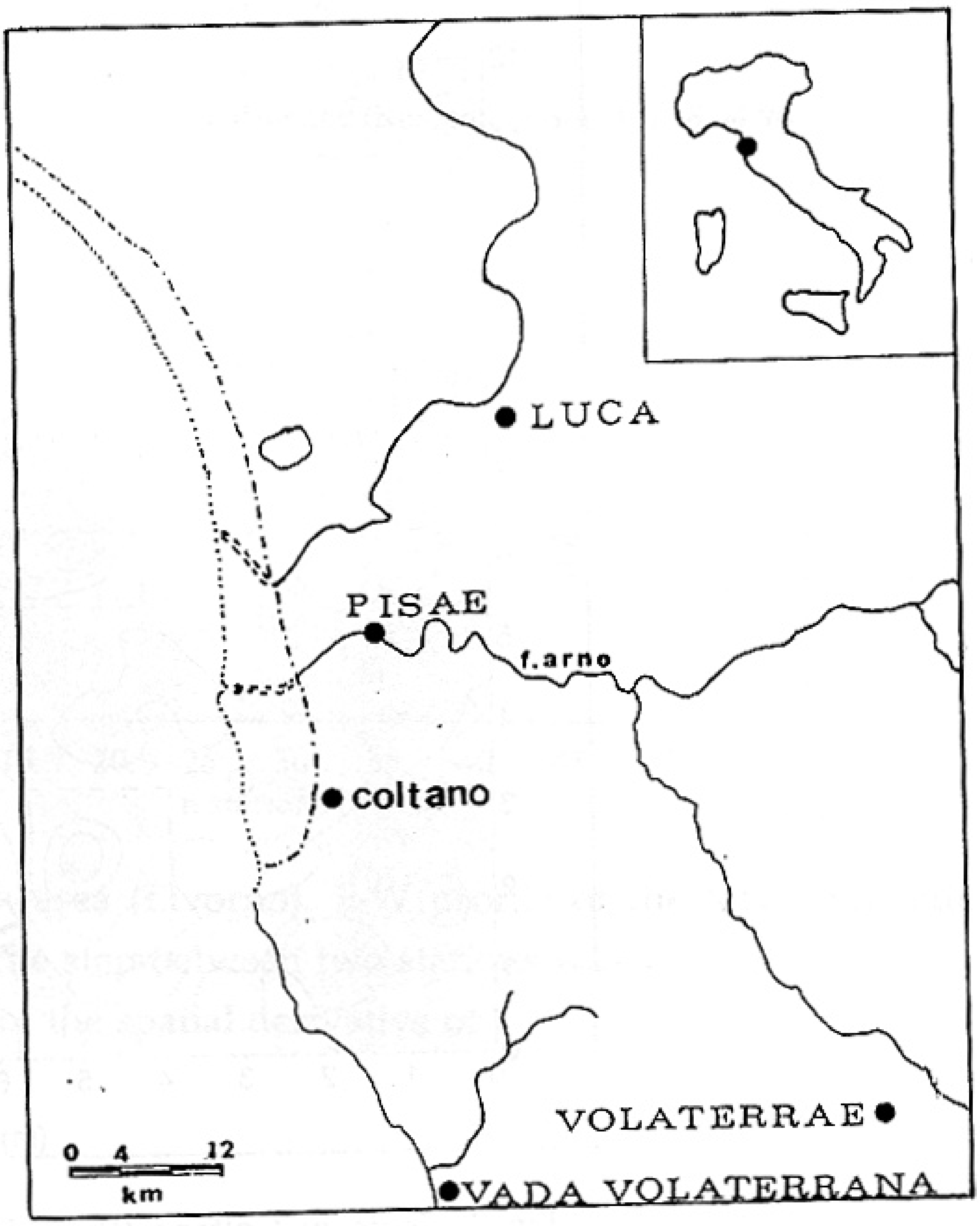
C : Macellum (?)

D : Thermae

Survayed area.

Fig. 4. S. Gaetano di Vada area (Livorno). E-W profile of the total magnetic field intensity F. The step between two stations was 1 m.

Fig. 5 As in Fig. 4, profile of the spatial derivative of F.



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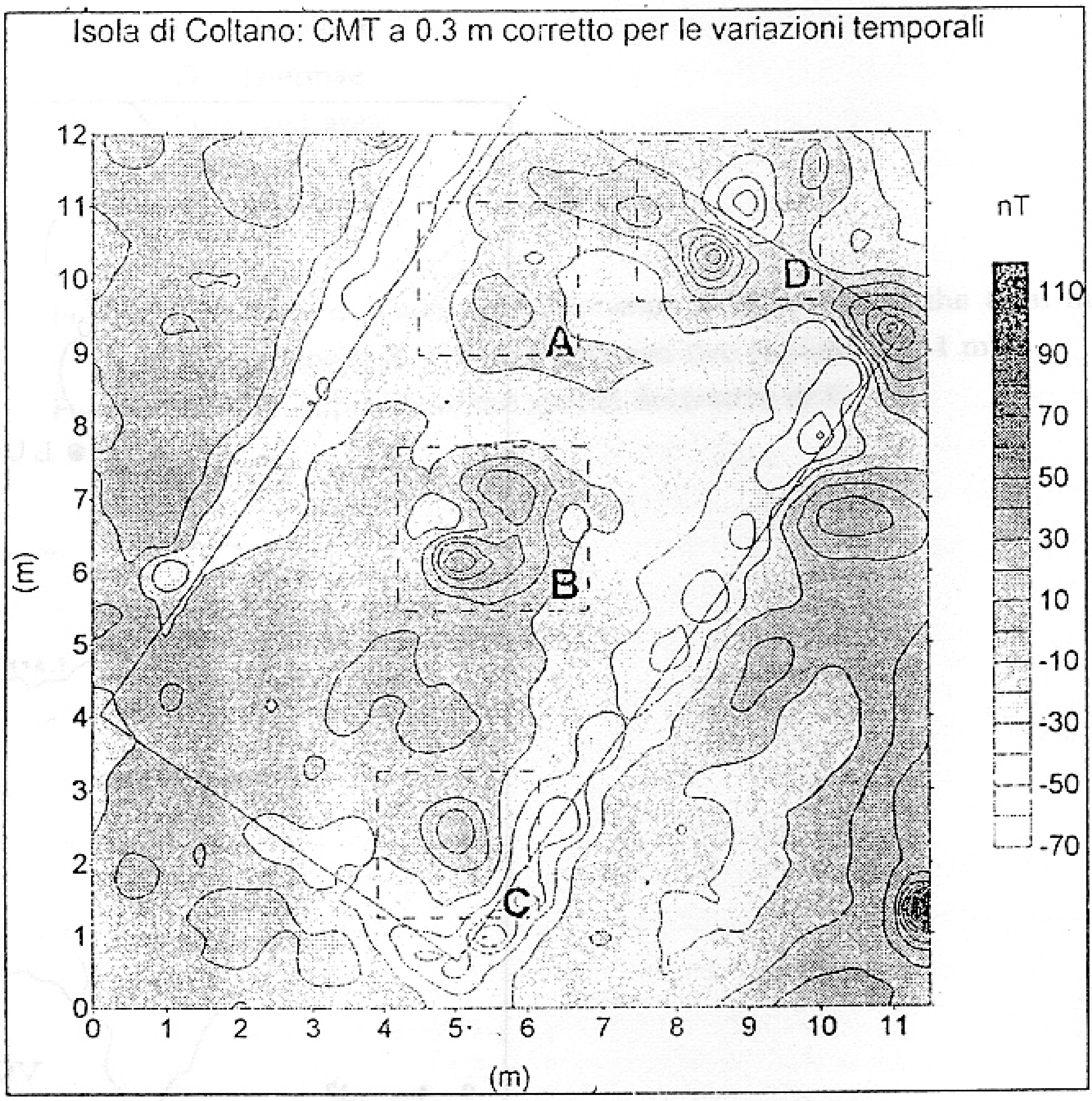
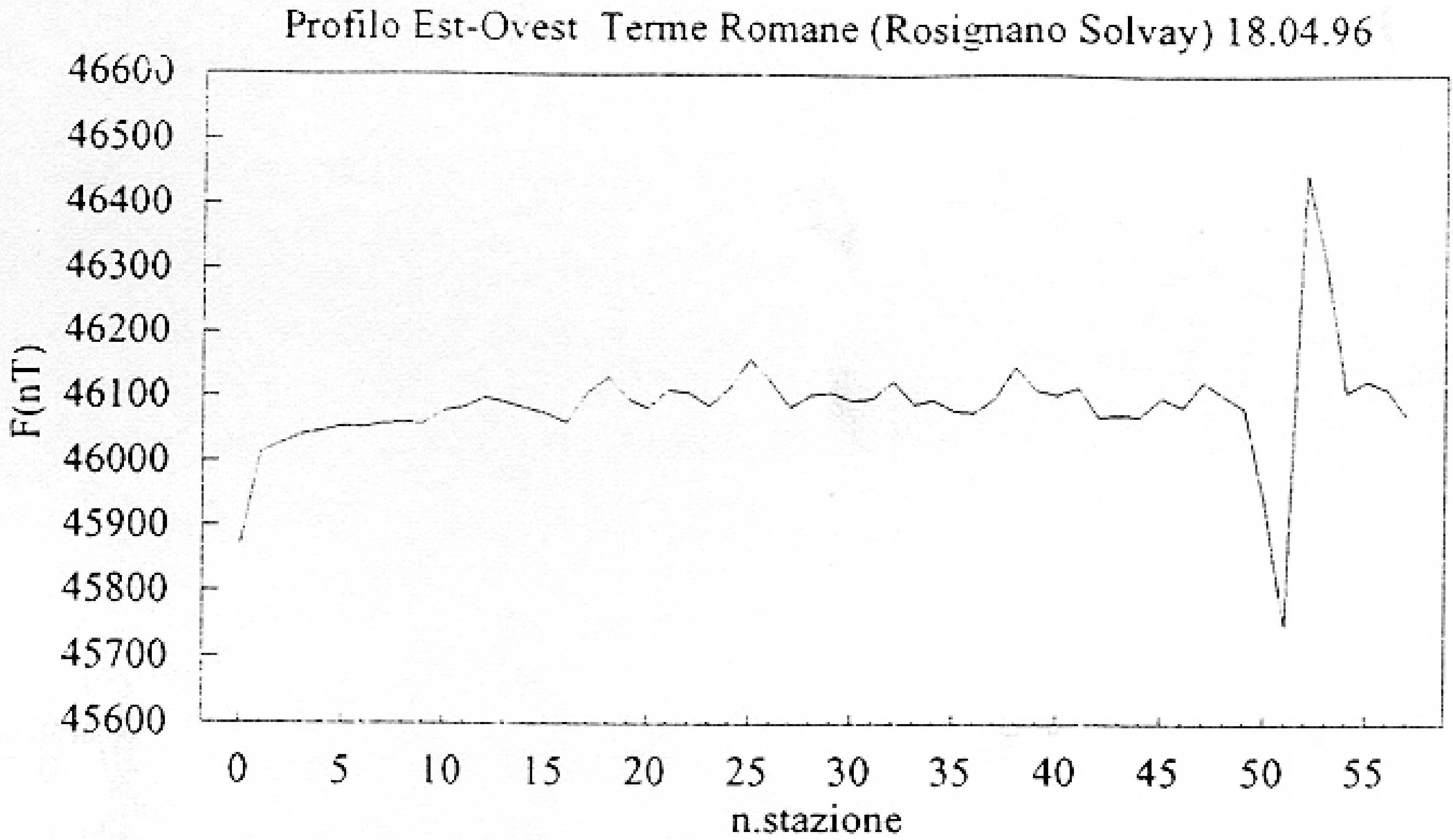
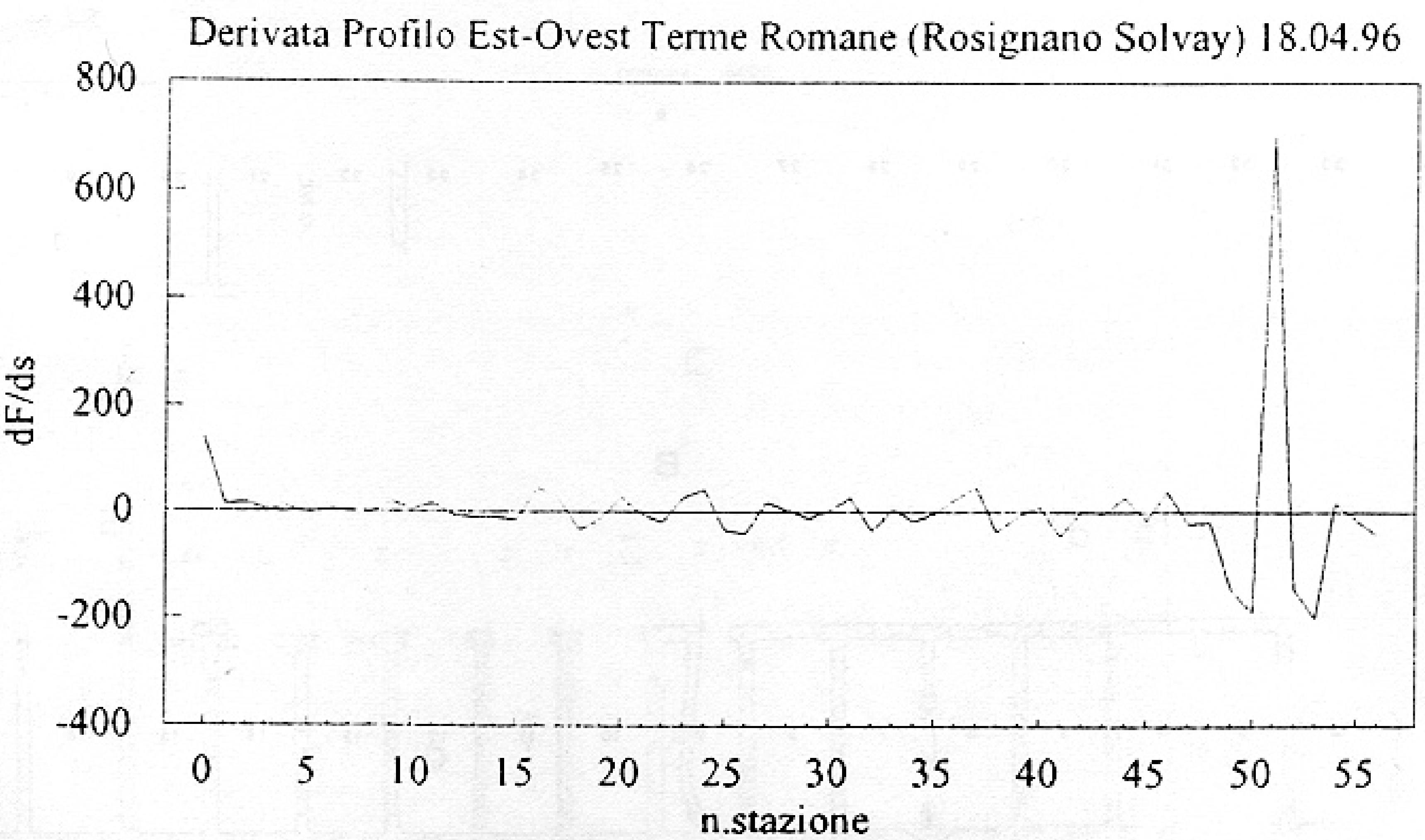


Fig. 2. Isola di Coltano (Pisa). Total Magnetic Field at 0.3 m with correct temporal fluctuations. Four anomalies (A, B, C, D) are evident.





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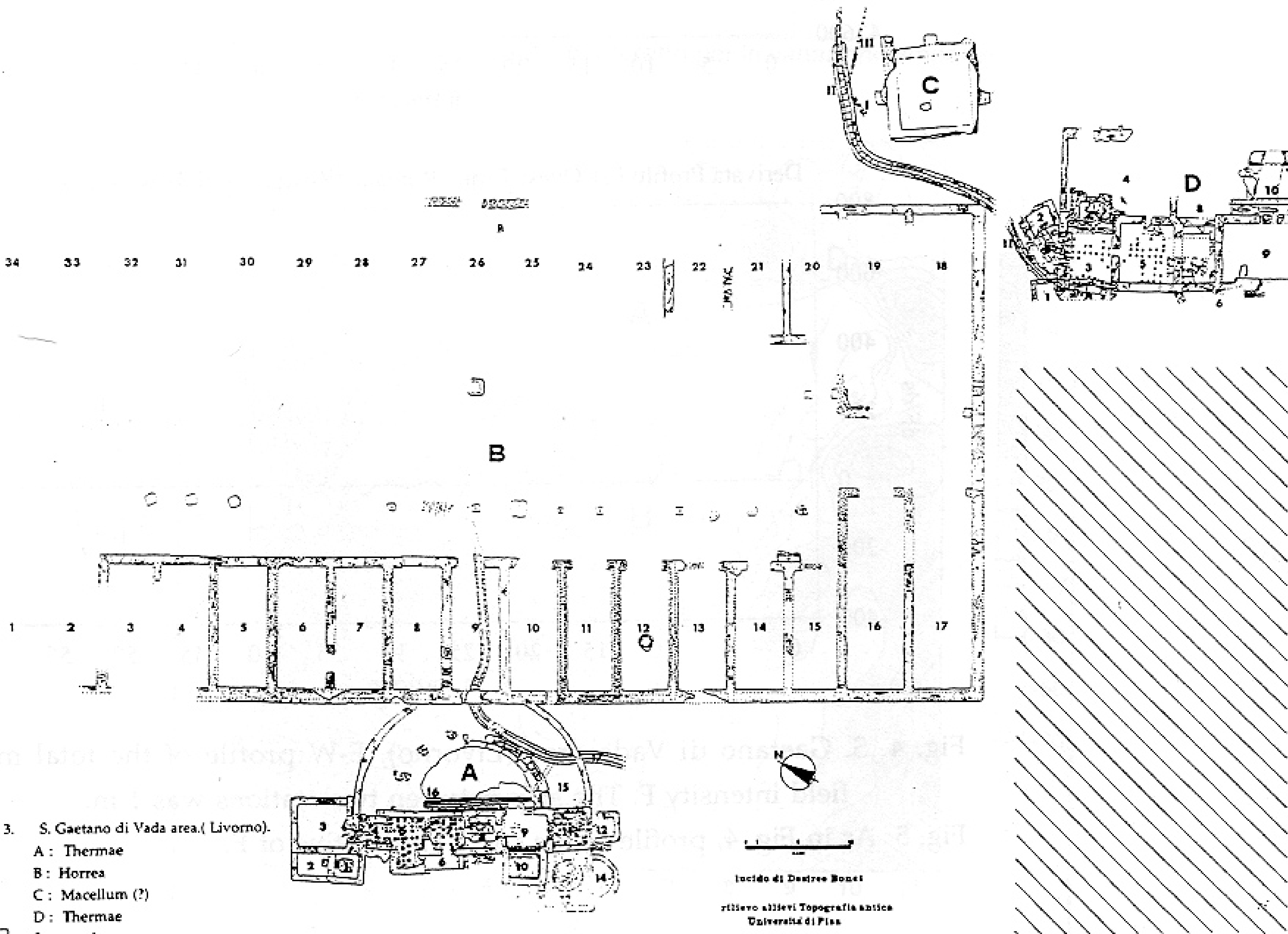

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