

Some magnetic evidences of the 1st century BC Salapia harbor near the Margherita di Savoia shoreline, SE Italy

M. Gambetta,^{1} C. Carmisciano,¹ M. Locritani¹*

L. Cocchi,¹ F. Caratori Tontini,¹ P. Stefanelli¹

M. Ciminale,² S. Cipriani,³ M. Demarte⁴

¹ *Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy*

² *Dipartimento di Geologia e Geofisica, University of Bari, Italy*

³ *Provincia di La Spezia, Italy*

⁴ *Istituto Idrografico della Marina, Italy*

ABSTRACT

This paper highlights some magnetic evidences revealed by a recent marine magnetic survey ran near the Margherita di Savoia shoreline, Puglia (Italy). The survey has been planned to probe one of the expected settlement site not perused yet. The accurate elaboration of high density total magnetic field intensity data shows some features which can be interpreted as markers of harbor framework, at present time partially uprooted. A model of the bodies which cause the magnetic anomaly is also provided.

Key words: Marine magnetic surveys, marine archeology

1 INTRODUCTION

Geophysical surveying provides a relatively fast, non invasive and low cost tool that succeeds in obtaining different kinds of information on shallow subsurface features (Urbini et al. 2007) and this distinctive feature become much more relevant in submerged settlement sites probing. The magnetic survey was carried out in order to provide information over the site number 6 of the Salapia archaeological site ensemble fig. 1, pointed out but not surveyed yet. The Salapia harbor framework are, at present time, fully submerged due to the known sea level uplift (Mastronuzzi and Sans 2002) and, newly, to the alteration of shoreline balance engendered by human activity and notably by quarrying (Comune di Margherita di Savoia 2006). The relevance of Salapia harbor is testified first by Strabone (Strabone) and recent topographic studies (Marin 1968) figure out the river connections used to goods shifting from inland to the Salapia shipping facilities. The whole area was subject to major rejig (Vitruvio) and a new settlement was built up in the Ist century BC by *patronus M. Hostilius* together with a fairway channel which linked the new town of *Salapia Romana* to the above said shipping facilities (Volpe 1990). Aerial photography and direct archaeological prospecting (Franchin Radcliffe 2006) uphold the historical reference.

2 SURVEY SETUP

The study area (fig. 1) has been probed with a profile network composed by 54 along-shore lines and 10 tie lines, adding up 35484 m of magnetic profiling over a surface of 348.110 m^2 . Surveying operations occurred between June and July 2005. A Geometrics G880 caesium marine magnetometers has been operated to collect the scalar values of the Earth magnetic field at a sampling rate of 1Hz. The a-magnetic boat, sensors and ancillary instruments (DGPS) were provided by IMM technicians which operated the equipment following the assigned survey plan.

3 MAGNETIC DATA PROCESSING

In order to obtain a residual magnetic map with particular emphasis about shallow magnetic sources a robust processing scheme of magnetic total field data was applied. A general process-

ing flow includes manual editing of survey lines, despiking, IGRF and time varying magnetic field removal. (Luyendyk 1997) (Pozza et al. 2004) To get rid of short wavelength components due to heavy seas conditions while surveying a low pass filter have been applied to the recorded data before any further processing. The time dependent recording of the magnetic field have been provided by L'Aquila INGV magnetic observatory. The time varying Earth magnetic field exposed only slow and low amplitude variation (22.2 nT peak-to-peak). The preprocessed data were then leveled (Soul and Parson 1998) and an intermediate magnetic anomaly map was produced by minimum curvature interpolation (Briggs 1974). The leveled map was then microleveled (Ferraccioli et al. 1998) to remove leveling error still present, achieving a clean final map, suitable for digital enhancement. This TMI (Total Magnetic field Intensity) anomaly map exhibits a strong 150N trending noise which was removed by means of frequency domain sharp cosine directional filters. The resulting map was then analytically draped (Cordell 1985) (Paterson et al. 1990) (Pilkington and Thurston 2001) to a clearance of 1,5 m with a high-cut filtering to remove the known instability (Ridsdill-Smith and Dentith 2000) of the downward continuation.

In order to achieve a better comprehension of the causative bodies of the anomalies B and D (fig 3) the Analytic Signal depth solutions from magnetic profile of fig 3 has been calculated (Nabighian 1972) (MacLeod et al. 1993) using :

$$A(x, z) = \frac{\delta M(x, z)}{\delta x} - j \frac{\delta M(x, z)}{\delta z} \quad (1)$$

where A is the Analytic Signal, M is the TMI anomaly, j is the imaginary number, x and z are the Cartesian coordinates for the horizontal and vertical direction perpendicular to the strike of the causative body. The horizontal and vertical derivatives have been calculated using FFT. The ensemble of the solution was calculated using an operator window to detect peaks and calculate depths, ranging from 1 to 100 m with expansion increment of 1 m. The profile was chosen using the calculated horizontal gradient of the TMI anomaly (not reported) which singles out the features labeled B and D in figure 3.

4 INTERPRETATION

A number of magnetic lineaments arise from the processed dataset (fig. 3). A general SW-NE trend, roughly perpendicular to the shoreline, is recognizable. The maxima labeled A, B, C form an ensemble that could be interpreted as the marker of man-made brick or stonework. The magnetic evidence labeled D could be seen as an uprooted piece of the above said structure tilted and shifted northwards. If this reconstruction would be accepted the magnetic survey would figure out the trace of some waterway as those reported by the historical references (Vitruvio) Figure 2 shows a dipping elongate stonework piece which is expected to be the survey target; as visible on the right the framework can be uprooted, tilted and shifted as the magnetic maps seems to assume. The magnetic lineaments appears not to be constrained by any topography as reported by the draped dataset of figure 3 which underscores the significance of the features revealed by the magnetic anomaly map. Moreover, the spatial coherence of the magnetic lineaments labeled E and F and highlighted by the draped magnetic map (fig. 3) cannot be disregarded. These features exhibit sharp and elongated anomalies which span over 200 m. The 3D analytic signal map (not reported) shows almost no evidence of the trending features revealed by the draped RTP magnetic anomaly map (fig. 3). This lack of signature suggests a very shallow placement of the bodies which generate the magnetic anomalies. Figure 4 reports the solution of the Analytic Signal calculated for elongated prismatic bodies with strike orthogonal to the profile. Since there are no evidence of outcropping structures from the seabed the solution placed above the bathymetry have not been considered. Red diamonds figure out the ensemble of solutions clustered with a half window size of 10 m. The clustered solutions report shallow causative bodies with expected mean susceptibility of 0.0045 ± 9.5^{-5} SI. A conceivable overall interpretation of the results counts some masonry related to the shipping facility and the plants likely exiting nearby the waterway. A quantitative model, calculated using the above profile data, shows two tilted prismatic bodies of about 12 m wide and 4 m high. These bodies figure out the docks structure and the estimated magnetic susceptibility suggest that they were built using local stone blocks bonded with mortar grit. The bulk of the pier structure is responsible of the low amplitude but persistent magnetic anomalies.

5 CONCLUSIONS

The survey singles out a number of magnetic anomalies that has been interpreted as the markers of residual structures belonging to the I century BC shipping facility of new town of *Salapia Romana*. Even if the interpretation may be not unique, the persistence of the magnetic anomalies cannot be disregarded. Pattern of the TMI anomaly map is similar to the results achieved by magnetic prospecting in analogous environment (Boyce et al. 2004). The evidences provided by this study suggest a direct survey in order to confirm the presence of hypothesized shipping facility framework.

ACKNOWLEDGMENTS

The authors are very grateful to the Italian Navy (Istituto Idrografico della Marina) for the logistic support.

REFERENCES

- Boyce J.I., Reinhardt E.G., Raban A., Pozza M.R. (2004) Marine Magnetic Survey of a Submerged Roman Harbour, Caesarea Maritima, Israel *The International Journal of Nautical Archaeology* **33.1** : 122-136
- Briggs, I.C.(1974) Machine contouring using minimum curvature. *Geophysics* **23** 39-84.
- Comune di Margherita di Savoia, Amministrazione Pubblica. Piano Urbanistico Generale (PUC). (2006) *Atti della Pubblica Amministrazione : Comune di Margherita di Savoia*.
- Cordell, L. Applications and problems of analytical continuation of New Mexico aeromagnetic data between arbitrary surfaces of very high relief.(1985) *Proceedings of the International Meeting on Potential Fields in Rugged Topography (Institut de Geophysique de Universite de Lausanne, Lausanne, Switzerland)* **Bulletin 7** : 96-101.
- Ferraccioli F, Gambetta M., Bozzo E. (1998) Microlevelling procedures applied to regional aeromagnetic data: an example from the Transantarctic Mountains (Antarctica). *Geophysical Prospecting* **46**, n. 2 : 177-196.
- Franchin Radcliffe, F. Paesaggi sepolti in Daunia. John Bradford e la ricerca archeologia dal cielo (1945-1957).(2006) *Foggia: Grenzi Editore*.
- Luyendyk, A.P.J. (1997) Processing of airborne magnetic data. *Austr.Geol. Geophys.* **17**, n. 2 : 31-38.
- Macleod, I. N., Vierra, S., Chaves, A. C., (1993) Analytic signal and reduction-to-the-pole in the inter-

- pretation of total magnetic field data at low magnetic latitudes. *Proceedings of the third international congress of the Brazilian society of geophysicists.*
- Marin, M. D. (1968) Introduzione ad una topografia storica della Daunia preromana. *In La Capitanata*, 27-50. Provincia di Foggia
- Mastronuzzi, G., e P. Sans. (2002) Holocene coastal dune development and environmental changes in Apulia (southern Italy). *Sedimentary Geology* **150**, n. 1-2 : 139-152.
- Nabighian, M. N., (1972) The Analytic Signal of Two-Dimensional Magnetic Bodies with Polygonal Cross-Section: Its Properties and Use for Automated Anomaly Interpretation *Geophysics* **37**,3, 507-517
- Paterson, N. R., S. W. Reford, e K.C. H. Kwan. (1990) Continuation of magnetic data between arbitrary surfaces: Advances and applications. *Society of Exploration Geophysicists, Sixtieth Annual International Meeting Expanded Abstract* : 666-669.
- Pilkington, M., e J.B. Thurston.(2001) Draping corrections for aeromagnetic data: line- versus grid-based approaches. *Exploration Geophysics* **32**, : 95-101.
- Pozza, M.R., J.I. Boyce, e W.A. Morris.(2004) Lake-based magnetic mapping of contaminated sediment distribution, Hamilton Harbour, Lake Ontario, Canada. *Journal of Applied Geophysics* **57**, : 23-41.
- Ridsdill-Smith, T., e M. Dentith. (2000) Drape corrections of aeromagnetic data using wavelets. *Exploration Geophysics* **31**, : 39-46
- Roest, W. R., Verhoef, J., Pilkington, M. (1992) Magnetic interpretation using 3-D analytic signal. *Geophysics* **57**, : 116-125.
- Soul, S.J., e M.J. Parson. (1998) Levelling of aeromagnetic data. *Can. J. Explor. Geophys.* **34**, n. 1-2 : 9-15.
- Soprintendenza Archeologica della Puglia, (1991) Scavi e Scoperte. *Bollettino di Archeologia del Ministero per i Beni Culturali ed Ambientali. Istituto Poligrafico e Zecca dello Stato*, **7**, Gennaio-Febbraio 1991.
- Strabone. *Gheographik* - (translation of N. Biffi in *L'Italia di Strabone. Testo, traduzione e commento dei libri V e VI della Geografia* 1988).
- Urbini S., Cafarella L., Marchetti M., Chiarucci P., Bonini D. (2007) Fast geophysical prospecting applied to archaeology: results at Villa ai Cavallacci (Albano Laziale, Rome) site. *Annals of Geophysics* **50**, n. 3 : 291-299.
- Vitruvio. *De Architectura Liber I*, 4 - 12.
- Volpe, G. (1990) La Daunia nell'et della romanizzazione. Paesaggio agrario, produzione, scambi. *Bari: EdiPuglia.*

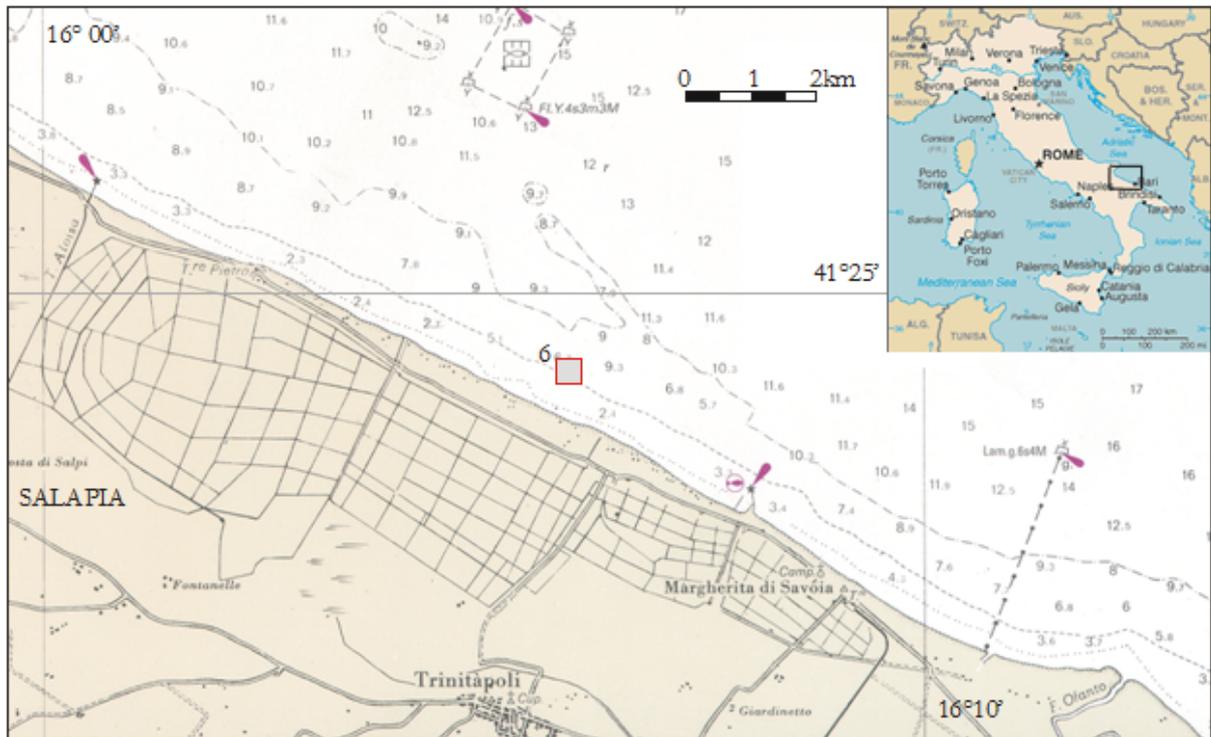


Figure 1. Survey location

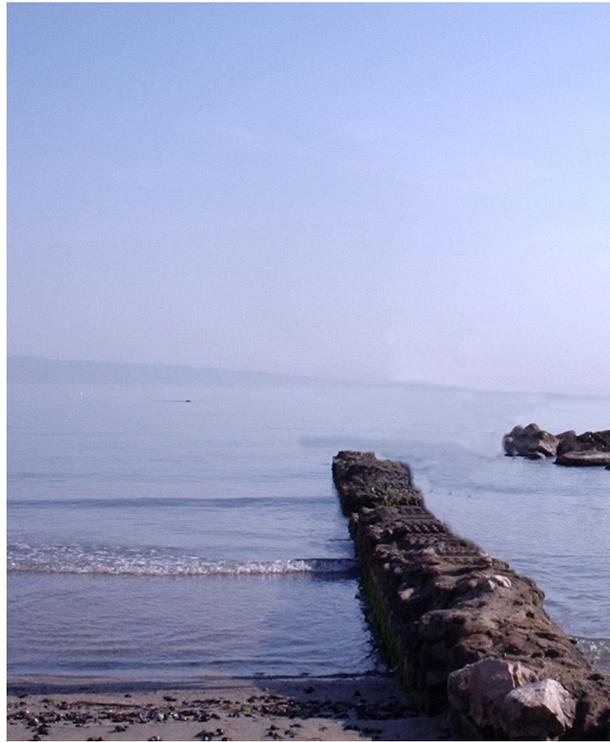


Figure 2. Target of the geophysical survey

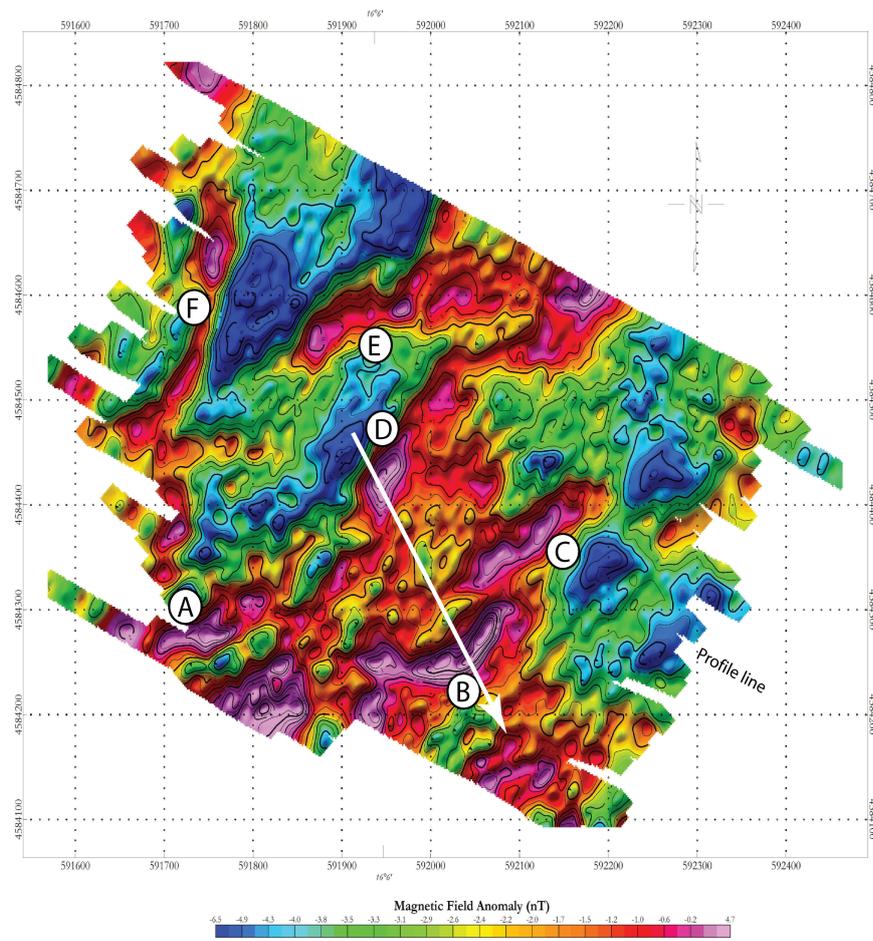


Figure 3. Draped TMI anomaly map

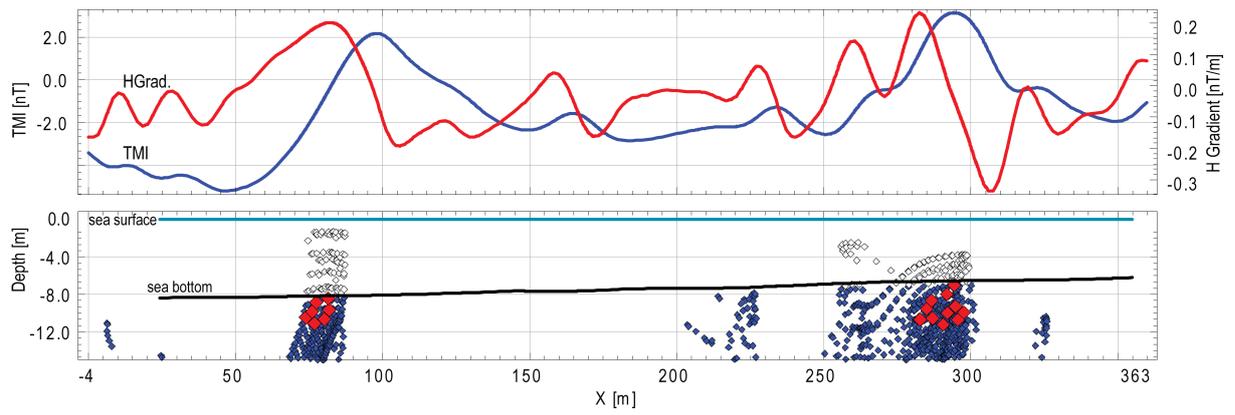


Figure 4. Analytic Signal solution calculated for elongated bodies