INTEGRATED MARINE MAGNETICS OF THE NAPLES BAY – FROM OLD TO NEW DATA: EXAMPLES FROM NAPLES AND POZZUOLI GULFS (SOUTHERN ITALY)
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Introduction. The integrated marine magnetics of the Naples Bay, coming from the old to the new data is here tentatively resumed and discussed, focussing on some examples from Naples and Pozzuoli Gulfs (Southern Italy).

Significant correlations between geophysical data come from the comparative analysis of seismic and magnetometric datasets. A magnetometer usually measures the strength or direction of the Earth’s magnetic field. This last can vary both temporally and spatially for various reasons, including discontinuities between rocks and interaction among charged particles from the sun and the magnetosphere. Most technological advances dedicated to measure the Earth’s magnetic field have taken place during World War II. The most common are: the fluxgate, the proton precession, Zeeman-effect, sensor-suspended magnet and satellite magnetometers. The fluxgate and the proton precession magnetometers are effectively the most used for marine surveys, they are both cable drown. The fluxgate magnetometer was the first ship-towed instrument, and it can measure vector components of the magnetic field. Its sensor consists of two magnetic alloy cores that are mounted in parallel configuration with the windings in opposition. The proton precession magnetometer consists of a sensor containing a liquid rich in protons surrounded by a coil conductor. The sensor is towed from the vessel through an armoured coaxial cable whose length depends on vessel length and seafloor depth. Circulating current within the coil generates a magnetic field of approximately two orders of magnitude the Earth’s field. In this way, one proton each ten will follow the coil positioning. Stopping the induced magnetic field, the protons will align according to the Earth’s magnetic field through a movement of precession.

The proton precession magnetometer is one of the most used for offshore surveys and it records the strength of the total field by determining the precessional frequency \( (f) \) of protons spinning about the total field vector \( (F) \) as follows:

\[
 f = \gamma_p F / 2\pi \quad (1)
\]

where \( \gamma_p \) is the gyromagnetic ratio of the proton uncorrected for the diamagnetic effect, so that knowing it from laboratory measurements, the total field in nanotesla can be calculated as:

\[
 F = 23.4866xf \quad (2)
\]

The total magnetic field calculated through the Eq. (2) is stored by magnetometer into a string of data containing position data that is displayed as an \( x,y \) chart. The signal frequency is measured on a time span of 0.5 seconds when the signal-noise ratio is highest. To ensure a maximum value of initial value of proton precession the angle between the axis of the coil and the Earth’s field it is necessary to use two orthogonal coils. The measured field must be corrected with respect to the regional field in order to evaluate the anomalies.

The proton precession magnetometer was largely used to explore magnetic anomalies in the Bay of Naples. Interesting examples of magnetic data acquisition related in the Naples and Pozzuoli bays are reported in Galdi et al. (1988), Secomandi et al. (2003), Aiello et al. (2004) and will be discussed in the following paragraphs.

Geologic and geophysical setting. In the Gulf of Naples one of the most important lineaments is the Somma-Vesuvius volcano. The Vesuvius volcano has been intensively studied with respect to the eruptive events, the recent seismicity, the geochemistry and the ground movements of the volcano and the related volcanic hazard (Cassano and La Torre, 1987; Santacroce et al., 1987; Castellano et al., 2002; Esposti Ongaro et al., 2002; Mastrolorenzo et al., 2002; Saccorotti et al., 2002; Scarpa et al., 2002; Todesco et al., 2002). The Somma edifice started to grow after the eruption of the Campanian Ignimbrite deposits. Its eruptive
activity ranges from the “Pomici di Base” (18 ky) and the “Pomici Verdoline” plinian eruptions, enabling the collapse of the Somma edifice and the consequent calderization. Three main plinian eruptions (“Mercato”, “Avellino” and “Pompei”) followed among 7900 B.C. and 79 A.D. The total magnetic field map of the Somma-Vesuvius volcano (Fig. 1) shows interpretative elements that have an indicated value for the trend of volcanites in the volcanic complex’s peripheral areas (Cassano and La Torre, 1987). A main sub-circular anomaly is centred on the volcano; two positive appendages diverge towards SE and SW. They might correspond to a great thickness of lava products, possibly in pre-existing depressions of the sedimentary basement of the graben of the Campania Plain. These products should have enhanced the occurrence of an elongated magnetized body, which tends to move towards the Naples Bay from the Vesuvius volcano towards Torre del Greco; an alternative explanation would be the presence of a strip of eruptive vents, settled on a system of NE-SW normal faults (Bernabini et al., 1971; Finetti and Morelli, 1973). A new aeromagnetic map of the Vesuvius area has been produced (Paoletti et al., 2005). It is dominated by a large dipolar anomaly related to the volcano, showing a southwards trending elliptical shape. A narrow anomaly is located on the western flank of the edifice and small anomalies are located on the south-eastern slope of the volcano. High frequency anomalies occur in the area surrounding the edifice, related to the high cultural noise of this densely inhabited area.

The Phlegrean Fields are a volcanic district surrounding the western part of the Gulf of Naples, where volcanism has been active since at least 50 kyr (Rosi and Sbrana, 1987), corresponding to a resurgent caldera having a diameter of 12 km and erupting the Campanian Ignimbrite (37 ky B.P.) and the Neapolitan Yellow Tuff (12 ky B.P.) deposits. A volcanic tectonic uplift of the caldera center is indicated by coastal sediments ranging in age from 10 to 5.3 ky B.P., cropping out in correspondence to the marine terrace of La Starza (Gulf of Pozzuoli). Gravimetric and magnetometric informations available for the Phlegrean Fields have been summarized (Cassano and La Torre, 1987), focusing on volcanological and structural reconstruction of the area. From north to south, the most important gravimetric elements are the positive anomaly related to the carbonatic horst of the Massico Mount, the negative anomaly of the Volturino graben, the positive gravimetric anomalies of Villa Literno and Parete. The total magnetic field map (Cassano and La Torre, 1987; Fig. 1) has evidenced a strong positive anomaly in the area of Monte di Procida, related to the weaker anomalies of the Procida Channel, Procida and Ischia. It may be related to considerable volumes of lavas, confirmed by the presence of trachybasaltic and latitic eruptive centres at Procida. Another large

Fig. 1 – Total magnetic field map of the Somma-Vesuvius volcanic complex with sketch structural interpretation (modified after Cassano and La Torre, 1987).
magnetic anomaly characterizes the Astroni-Agnano volcanic area, probably the result of the overlapping of several lava bodies. A new aeromagnetic map supplement the northern sector of the Phlegrean Fields (Paoletti et al., 2004), allowing for a better geological interpretation of the structural patterns and morpho-structural features of the Volturro Plain and the Gulf of Pozzuoli and its offshore areas. The main magneto-structural features are the caldera rims of the Neapolitan Yellow Tuff and the Torregaveta anomaly. The Patria lake anomaly has a sub-circular shape and a diameter of about 10 km. A complex pattern of magnetic anomalies coincides with the Parete volcanic complex (Aiello et al., 2011), while another isolated anomaly corresponds to the Volturro river.

Data and methods. A Total Earth Magnetic Field (EMF) survey was performed in the Naples Bay during the oceanographic cruise GMS00-05 (Leg II – October November 2000) carried out by the CNR-IAMC of Naples, Italy onboard of the R/V Urania, resulting in a high resolution magnetic anomaly map of the Naples Bay (Aiello et al., 2004). The collected data have a densely-spaced coverage if compared to previous measurements, such as the airborne magnetic survey (Agip, 1981; Caratori Tontini et al., 2003). The acquisition of magnetic data at a shorter distance from the source and at a lower velocity has given more precise sampling and an improved field restoration. The magnetic data have been recorded using a G811 proton magnetometer; the sensor was placed in a fish towed at about 200 m from the ship and at an average depth of 15 m below the sea level. The magnetometer position was regularly controlled and recorded and the data were sampled at 3 sec, corresponding to an average spatial sampling of about 6.25 m. The magnetic anomaly map was compiled with a grid cell size of 200 m. A colorimetric scale expressed in nT is shown on the right side of the maps to quantify the intensity of measured magnetic anomalies. An accurate inspection of the magnetic lines recorded contemporaneously to the seismic lines has been preliminary carried out, since they showed spikes regular to the shot frequency. A non-linear filter has been used to remove the peaks due to non-geological sources. A repositioning of the marine lines has been carried out, taking into the account the offset among the fish and the GPS. The elimination of the variation for the diurnal component has been carried out using as reference magnetic station the geomagnetic observatory of L’Aquila. In order to recognize the total field anomaly linked to the geological structures, the values of the main magnetic field must be subtracted to the measured values corrected according to the Italian Geomagnetic Reference Field (Coticchia et al., 2001). Some factors contribute to explain the shifts in the magnetic field among adjacent navigation lines. They include the differences in height among the navigation lines and the inadequate removal of the variations of magnetic field due to the diurnal component. The elaboration of the magnetic data has been carried out according to a procedure of levelling, consisting in the removal of the short period magnetic variations.

The high resolution magnetic anomaly map of the Naples Bay. The main magnetic anomaly fields recognized on the high resolution magnetic anomaly map of the Naples Bay have been constrained by geological features based on the geologic interpretation and on the correlation with high resolution Multibeam bathymetry (Fig. 2; Aiello et al., 2004). The magnetic anomaly fields have been also correlated with morpho-structural features and volcanic edifices, recognized on high resolution seismic profiles recorded along the same navigation lines. Two main belts of sharp magnetic anomalies have been identified, the first located offshore the Somma-Vesuvius volcanic complex and the second offshore the Phlegrean Fields volcanic complex. The latter one is interpreted as the seaward boundary of the Phlegrean caldera (Pescatore et al., 1984; Orsi et al., 2002). The detailed interpretation of the magnetic anomaly field and related seismic structures offshore the Somma-Vesuvius volcanic complex suggests a NNW-SSE structural alignment, while in the Pozzuoli Gulf several complex E-W and NE-SW trending anomalies have been identified, whose values are related to small buried volcanic structures. The shape of magnetic anomalies is not directly related to the submarine topography of large volcanic banks, revealed by Multibeam bathymetry. Main fields are also
related to the Procida continental shelf, to the Gaia bank, to the head of the Magnaghi canyon, to an edifice located among the Dohrn and Magnaghi canyons, to the Magnaghi canyon and to the Ischia bank.

**Magnetic anomaly measurements in the Gulf of Pozzuoli.** The magnetic field anomalies in the Gulf of Pozzuoli (modified after Galdi *et al.*, 1988), have shown both positive and negative anomalies (Fig. 3). The area shows an interruption of the regional trend from NE to SW, where circular anomalies are probably connected to a post-calderic activity of the Phlegrean Fields. Moreover, the internal area of the Pozzuoli Bay is characterized by a negative anomaly, increasing towards the south. Conversely, in the external area there is mainly an alternance of positive and negative anomalies, with a dominance of positive values near the area of Bagnoli. The inner continental shelf of the Gulf of Pozzuoli is regarded as negative magnetic anomalies. In particular, the area surrounding the Pozzuoli harbour does not show significant magnetic anomalies. On the contrary, the area adjacent the resort Lucrino-Punta Pennata owns a negative anomaly increasing southwards up to the magnetic minimum at 600-700 m in correspondence to the Baia Castle. On the outer shelf of the Gulf of Pozzuoli it is possible to observe magnetic maxima and minima. In particular, an area of magnetic maximum is located on a belt long about 1.7 km, NE-SW oriented. At the same time, the inner continental shelf of the Gulf of Pozzuoli, from Bagnoli to the Rione Terra of Pozzuoli shows two strong magnetic anomalies, separated by a thin belt having a normal magnetic value. Proceeding seawards, in the offshore surrounding Bagnoli, two magnetic minima (40 nT and 60 nT) are positioned, which result slightly

Fig. 2 – High resolution magnetic anomaly map of the Naples Bay (on the left in the figure; modified after Aiello *et al.*, 2004). The inset shows a detail of the magnetic map offshore the Somma-Vesuvius volcanic complex.

Fig. 3 – Interpreted map of the magnetic anomalies of the Gulf of Pozzuoli (modified after Galdi *et al.*, 1988). The positive anomalies are represented in yellow and the negative anomalies in light yellow.
E-W elongated, culminating with the absolute magnetic minimum (-100 nT) in correspondence to the Baia Castle. Four magnetic sections have also been constructed (Aiello et al., 2012). The first one runs from Punta Pennata (Gulf of Pozzuoli) to the Pozzuoli town (Via Napoli). The total magnetic intensity shows a trending with a magnetic minimum of – 80 nT in the central area (corresponding to a depth of the sea bottom of – 90 m) and a magnetic maximum of 70 nT in correspondence to the Pozzuoli shoreline. The section section runs from Bagnoli to Capo Miseno and shows, starting from south-west a monotonous magnetic trend up to the offshore surrounding Nisida, where a strong increase to the gradient occurs. The magnetic highs occurring nearshore appear to be related not to the geology, but to the occurrence of the industrial systems of Bagnoli.

Conclusions. The Naples Bay is characterized by two main magnetic fields, offshore of Somma-Vesuvius and offshore the Phlegrean Fields volcanic complexes. Three magnetic maxima, dipolar in shape, are related to the Torre del Greco volcanic structure, already observed based on seismic interpretation (Aiello et al., 2010). The rising of the Torre del Greco volcanic structure corresponds to the occurrence of topographic undulations of the sea bottom of up to ten metres. This is confirmed by the interpretation of seismic profiles, showing three main vertical culminations of the volcanic structure, linked to significant magnetic anomaly extremes. Significant anomalies have been identified offshore the Phlegrean Fields volcanic complex, in correspondence to the outer belt of the Gulf of Pozzuoli. They are related to volcanic bodies buried by sediments and to small volcanic edifices. Significant anomalies also occur in correspondence to the Magnaghi canyon, which is completely incised in volcanic deposits. The interpreted map of the magnetic anomalies in the Gulf of Pozzuoli has allowed to distinguish positive and negative magnetic anomaly areas. The inner continental shelf of the Gulf of Pozzuoli is characterized by negative magnetic anomalies and the correlation with the volcanic structures evidenced by the Sparker data is not clear. The volcaniclastic units identified on seismic profiles does not seem to produce significant magnetic signatures, probably due to its composition (tuffs and lavas).

References
Agip; (1981): Carta magnetica – Anomalie del campo magnetico residuo – scala 1:500.000. S. Donato Milanese, Italy.


