Journal of Applied Geophysics 124 (2016) 148–154

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Self-constrained inversion of microgravity data along a segment of the Irpinia fault

Davide Lo Re [a,*], Giovanni Florio [a], Luigi Ferranti [a], Simone Ialongo [b], Gabriella Castiello [b]

[a] Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli 'Federico II', Italy

[b] Formerly Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli 'Federico II', Presently Geophysical Consultant, Italy

ARTICLE INFO

Article history:
Received 29 July 2015
Received in revised form 26 November 2015
Accepted 1 December 2015
Available online 2 December 2015

Keywords:
Gravity
Parameter estimation
Interpretation
Inversion
Potential field
Active fault throw

ABSTRACT

A microgravity survey was completed to precisely locate and better characterize the near-surface geometry of a recent fault with small throw in a mountainous area in the Southern Apennines (Italy). The site is on a segment of the Irpinia fault, which is the source of the M6.9 1980 earthquake. This fault cuts a few meter of Mesozoic carbonate bedrock and its younger, mostly Holocene continental deposits cover. The amplitude of the complete Bouguer anomaly along two profiles across the fault is about 50 μGal. The data were analyzed and interpreted according to a self-constrained strategy, where some rapid estimation of source parameters was later used as constraint for the inversion. The fault has been clearly identified and localized in its horizontal position and depth. Interesting features in the overburden have been identified and their interpretation has allowed us to estimate the fault slip-rate, which is consistent with independent geological estimates.

1. Introduction

The gravity method is sensitive to horizontal density contrast in the subsurface. It is well known that gravity is a useful tool to detect and locate buried fault structures, for example in the basement (Nabighian et al., 2005). Gravity applications to small-scale problems are also known, as the cavity or shallow structures detection and studies (e.g., Blizkovsky, 1979; Berrino et al., 1982; Fajklewicz, 1983; Al-Rawi et al., 1989; Allen and Michel, 1996; Bishop et al., 1997; Leucci and De Giorgi, 2010; Gambetta et al., 2011; Martínez-Moreno et al., 2014).

In the applications to small-scale problems the anomaly amplitudes are very low, generally below 1 mGal, and for this reason the technique is called microgravity (Morelli, 1968; Qianshen et al., 1996; Martínez-Moreno et al., 2015). Therefore, this implies some special procedures in the acquisition, in the data processing and in calculation of the Bouguer anomaly.

In this paper, an application of the microgravimetric method to the study of a shallow complex geological structure is illustrated.

The studied area is a small karst basin (named "Piano di Pecore") partly filled-in with colluvial and fluvio-palustrine deposits (Ascione et al., 2003) nested on top of Monte Marzano, a mountainous ridge of the axial part of the Southern Apennines, Italy (Fig. 1a). The Monte Marzano ridge, that hosts the Piano di Pecore basin, is composed of Mesozoic–Cenozoic slope limestone and is one of the tectonic units of the Southern Apennines fold and thrust belt (Patacca and Scandone, 2007). Close to the surface, the limestone is weathered and fractured, and karst forms and deposits are widespread.

The basin is underlain by a segment of the Irpinia fault, which slipped during the devastating Mw = 6.9, 1980 earthquake causing the longest (nearly 40 km) albeit discontinuous co-seismic surface break so far observed in Italy (Pantosti and Valensise, 1990). Co-seismic rupture observations showed that the fault is segmented, and paleo-seismological investigations have suggested a 0.4–0.6 mm/yr. extension rate (DISS Working Group, 2010).

In Piano di Pecore basin, the morphological expression of the displacement generated by the 1980 earthquake has been recognized as a sharp flexure in the basin fill, which outlines the presence of a blind segment of the fault immediately beneath (Cinque et al., 1981; Pantosti et al., 1993). Previous studies, like paleoseismic trenches (D'Addezio et al., 1991; Pantosti et al., 1993) and other geophysical surveys (Improta et al., 2003; Galli et al., 2014), showed the top of the fault surface at a depth of few tens of meters within the Mesozoic carbonate bedrock. The study of the stratigraphy observed in trenches excavated normal to the fault plane shows that the fault slipped during at least 5 earthquakes in the last 9000 years, with a vertical slip rate per event between 40 and 70 cm (Pantosti et al., 1993).

The geological setting of the area is relatively complex because the Irpinia fault crosses the Piano di Pecore basin with a bend relative to

* Corresponding author at: Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli 'Federico II', Largo S. Marcellino 10, 80134 Napoli, Italy.
E-mail address: davide.lore@unina.it (D. Lo Re).

http://dx.doi.org/10.1016/j.jappgeo.2015.12.002
0926-9851/

its regional trend (Cinque et al., 1981). This is way the fault is expressed by a bend in the basin fill and not by a surface break during earthquakes.

Gravity data, as others geophysical methods, suffer from an inherent ambiguous interpretation. Thus, in order to obtain reasonable geological models it is required to use inversion algorithms able to include external information as a constraint to the resulting model (e.g. geological, geophysical and/or borehole data). In this work, besides the available geological information, a self-constrained inversion approach was used (Paoletti et al., 2013), where the necessary information derives from the intrinsic properties of the anomaly itself, deduced from preliminary steps of interpretation.

The purpose of this work is therefore to obtain independent geophysical information about the geometry of the fault plane in the subsurface of the Piano di Pecore, by studying the density distribution at depth.

2. Methods

2.1. Gravimetric survey

The survey consisted on the measurements of gravity data along two profiles across the plain, oriented orthogonal to the fault trace (Fig. 1b).

We used a Scrintrex CG5 autogravimeter and determined the elevation of each station by a Wild Na2 automatic level (Leica), integrated with parallel plate micrometer (0.3 mm accuracy) and invar leveling staffs. The geographic position of the gravity stations was detected using a DGPS Leica System 500 (accuracy between 0.01 and 0.05 m).

The measurement spacing was 5 m. The first profile, 150 m long, consists of 30 measurement stations, while the second profile, 115 m long, includes 24 measurement stations (Fig. 1b). In order to monitor the instrumental drift, gravity was repeatedly measured at a base station on average every 90 min.

Each measurement consisted by three consecutive measuring cycles, 1 min in duration and 6 Hz in frequency. We considered acceptable all the measurements with repeatability within ±5 μGal. As regard the elevation measurements, the closing loop error was sub-centimetric, implying an error of about 2 μGal.

2.2. Gravity data processing

The acquired data were processed by removing all the unwanted gravity effects, to obtain the Bouguer anomaly.

The processing included the tidal correction, the drift correction and the free-air correction.

The Terrain Correction was calculated by a two-step procedure. The first step accounts for the gravity effects of the topography around the gravity stations. Thanks to the elevation data and to the substantially flat area around the profiles, it was possible to calculate the 2D gravimetric effect of the masses (with a density of 1.4 g/cm^3) between the topography and the minimum elevation of the measurement points by the Talwani et al. (1959) algorithm. This density value was estimated by the Gardner's relation (Gardner et al., 1974) applied to the seismic velocities relative to the uppermost part of a seismic tomography model in the area (Improta et al., 2003).The amplitude of this computed micro-topographic effect changes proportionally to the elevation drop along the profiles. The first profile has an elevation drop of 0.8 m, and the amplitude of the micro-topographic effect is about 60 μGal. The second profile has a larger elevation drop, about 1.7 m, and the amplitude of the computed micro-topographic effect is less higher then 100 μGal.

The second step of the computation of the Terrain Correction involved the computation of the topographic effect of the surrounding hills (we assumed a density of 2.67 g/cm^3). This calculation was made by using two digital terrain models, one of greater detail (2 × 2 km, cell size 5 m) that includes an area around the gravity stations up to a radius of 1 km (Fig. 2), and the other with a cell size of 10 m and extending up to 35 km away from the study area (Tarquini et al., 2007, 2012).

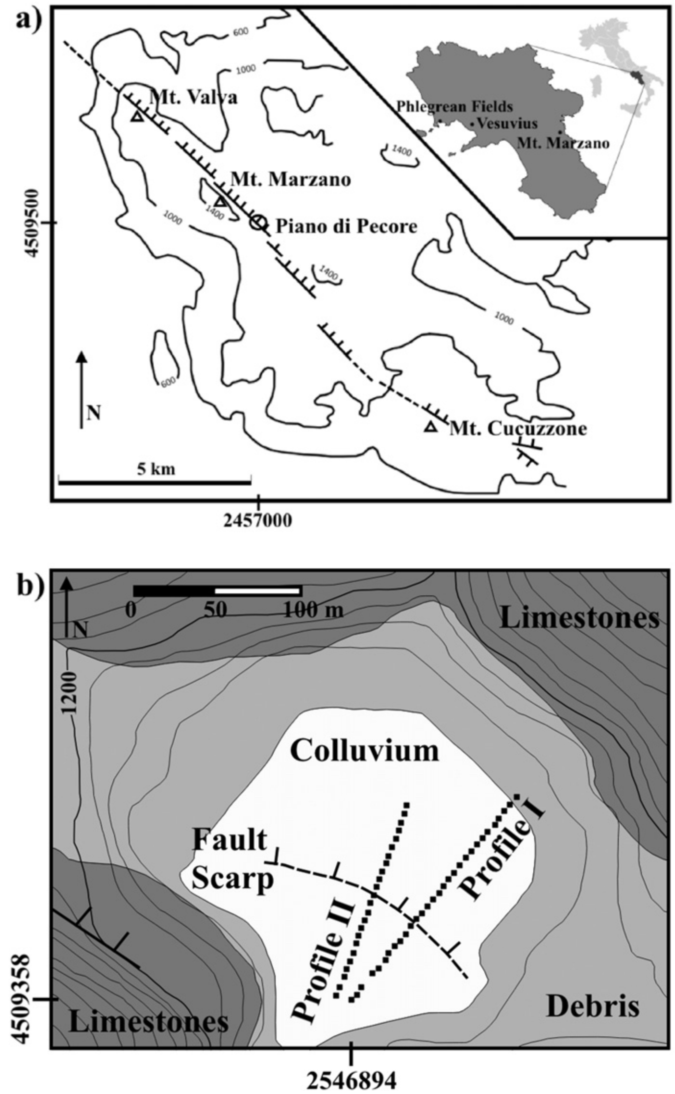

Fig. 1. a) Map of the fault scarp of the 1980 earthquake, focused on Mt. Marzano area (modified after Pantosti and Valensise, 1990). Projection: Rome40/Italy zone 2 (EPSG 3004). b) Geological sketch of Piano di Pecore showing the location of measurements. Contour interval is 5 m. Gray is Mesozoic limestone, light gray are debris slope, white are colluvium, and the fault trace is solid when exposed and dashed in the basin, where it is marked by a morphological step on the ground (modified after Improta et al., 2003). Projection: Rome40/Italy zone 2 (EPSG 3004).

The computation of the terrain correction was made using the GEOSOFT Oasis Montaj software. The obtained gravity effects have a rather strong amplitude, varying between 500 and 600 μGal (Fig. 3).

Note that this two-step terrain correction includes also the classical Bouguer slab correction.

The error associated to the individual gravity measurement was calculated according to the method proposed by Debeglia and Dupont (2002). The square of the uncertainty associated with the complete anomaly of Bouguer *uAB* is the sum of the squares of the effects related to the uncertainties on the measurements of gravity *ug*, the uncertainty on the elevation estimates *uz* (that affect both the calculation of free air and Bouguer corrections), and the uncertainty related to the terrain correction *uCT*:

$$uAB^2 = ug^2 + uz^2 + uCT^2. \quad (1)$$

In our case study, the measured gravity values are the result of the average of three measurements with repeatability within 5 μGal, therefore it can be estimated that the uncertainty ug = ±2.5 μGal.