15th International Congress of the Geological Society of Greece
Athens, 22-24 May, 2019 | Harokopio University of Athens, Greece
Bulletin of the Geological Society of Greece, Sp. Pub. 7 Ext. Abs. GSG2019-093

Urban Gravity Measurements for the Subsurface Investigation of Athens Basin (Greece)

Spyridon Dilalos, John D. Alexopoulos
NKUA, Department of Geology and Geoenvironment, Panepistimiopolis, Zografou, Greece, sdilalos@geol.uoa.gr

Introduction

Taking into consideration the major damage caused by the disastrous earthquake of 7th September 1999 (5.9R), the need for further and deeper investigation of the geological structure of the subsurface came up. The damage distribution of an earthquake is usually related to the tectonic structures of the area (Dilalos and Alexopoulos, 2017). Unfortunately, since the areas are covered with artificial surfaces, such as buildings, industrial infrastructures, roads, bridges and generally artificial surfaces, the geological research is quite complicated. The missing geological information for the deep subsurface can only be retrieved using geophysical methods. Given the fact that the 54.5% of Athens basin is covered with artificial surfaces (Dilalos, 2018), not all the geophysical methods can be applied. The land gravity measurements seem like the most applicable method for such a deep geotectonic investigation.

Geological regime

In Figure 1, a simplified geology map of the area (Dilalos, 2018) is provided, mostly based on the geotectonic study by Papanikolaou D. *et al.,* (2002). The autochthonous Metamorphic Unit is compiled mainly of dolomites, marbles and shales. On the other hand, the "*Ypopelagoniki"* unit consists of Triassic-Jurassic limestones and some base clastic formations from Paleozoic. The *Athens Unit* (upper allochthonous unit) is comprised of two main parts, the upper one which is basically limestones and the lower one, called "*Athens Schists*" which is basically a geological mélange that consists of sandstones, shales, phyllites, limestones and marls. The "*Alepovouni"*, located tectonically between the autochthonous metamorphic unit and the "*Athens"* unit, consists of limestones (upper part) and additionally schists and phyllites in the base, because of its low metamorphism. The post-alpine geological formations cover the biggest part of the basin. More than ten different post-alpine, Quaternary and Neogene geological formations had been proposed by Papanikolaou D. *et al.,* (2002), but here they are observed simplified in groups that will help the gravity survey, based on Dilalos (2018).

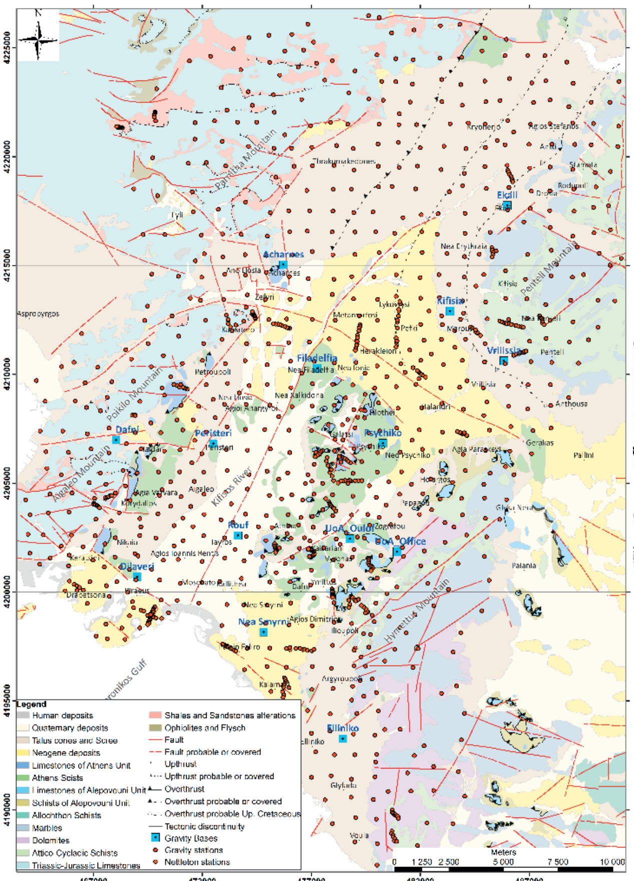

Figure 1. Geological and tectonic map along with the locations of the gravity stations and gravity bases.

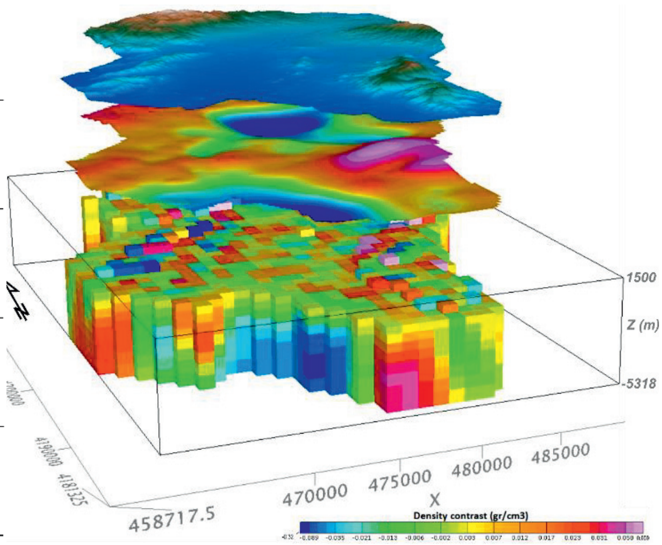

Figure 2. 3D gravity inversion of Athens basin, with cell size of 1000m. The upper plane is the area DEM and the lower is the grid of the Residual Anomaly.

Establishment of gravity bases and data acquisition

Taking into account the traffic jam of this over-populated metropolis and the increasing time that we would spend moving among the stations and the base re-measurements, we planned and established very cautiously the gravity base network, distributing spatially **fourteen (14) gravity bases** (Fig. 1-blue squares). The entire gravity base network is referred to the IGSN'71 datum (Morelli *et al*., 1974) as it was tied with repeated measurements (ABABA type) to an already established gravity base in the University of Athens (Hipkin *et al*., 1988).

Due to the complicated geology of the area and the urban environment, the gravity measurements were planned on a grid, with a station grid spacing set to 1km. Afterwards, some stations were added among the first ones, in order to clarify the status of some ambiguous areas. The gravity database is comprised of 1122 gravity stations (Fig. 1), acquired with the LaCoste & Romberg G-496 gravity meter. The essential coordinates of the gravity stations and bases were determined with high precision, using a Differential Global Positioning System (dGPS) and the *static* technique.

Table 1: Established gravity bases in Athens along with their determined absolute values.

Gravity base name	Absolute gravity (mGal)	Standard Deviation (mGal)	Easting (Egsa '87,m)	Northing (Egsa '87, m)	Elevation (m)
UoA_Office	980010.745	±0.00	480948.310	4201848.100	252.000
UoA_Oulof	980029.856	±0.03	478772.001	4202445.816	134.792
Rouf	980049.351	±0.04	473639.680	4202590.600	20.239
Psychiko	980017.268	±0.03	480288.710	4206831.900	179.091
Nea Smyrni	980043.877	±0.04	474819.600	4198156.400	42.662
Peristeri	980044.151	±0.07	472514.450	4206815.757	51.888
Dilaveri	980052.977	±0.08	469013.766	4200694.898	7.536
Kifisia	979991.509	±0.04	483373.599	4212901.998	287.379
Filadelfia	980029.065	±0.04	477276.990	4210270.695	116.118
Elliniko	980039.123	±0.07	478453.689	4193259.660	80.884
Acharnes	980017.082	±0.07	475726.609	4215036.626	168.425
Ekali	979981.326	±0.07	485997.896	4217756.564	344.891
Vrilissia	979997.111	±0.07	485846.098	4210619.196	269.935
Dafni	980031.436	±0.05	468050.208	4206980.671	109.281

Results and Conclusion

A geologically constrained 3D gravity modelling was produced (Fig. 2) using the "*VOXI*" Earth modelling module, based on the Complete Bouguer Anomaly calculated after the standard data reduction and the application of the innovative Building Correction (Dilalos *et al.,* 2018). The subsurface was discretized in a 3D block mesh, where all blocks have a cell size equal to 1000m for X-Y and 500m for Z direction. The produced block mesh (Fig. 2) is constituted by a total of 12760 blocks of individual density contrast. The density contrast ranges from -0.32 gr/cm^3 (bluish colors) to 0.669 gr/cm^3 (reddish colors), with a maximum depth of almost 6800m. The evaluation of this density model, given the fact of the geological formations' densities (Dilalos, 2018) provide valuable information for the subsurface geological structure of Athens basin. It verifies the existence of faults mapped as possible but also indicates the location of possible new ones.

Acknowledgements

The fieldwork was partially supported by the NKUA-SARG (contract no. 70/4/9254). The authors would like to thank Ms. Achtypi S., Ms. Kaplanidi H., Mr. Mavroulis S., Mr. Michelioudakis D.and Ms. Drosopoulou E. for their contribution during the field measurements. We would also like to gratitude Mr. Stylianos Chailas for the kind supply of the established gravity base data.

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