Bulletin of the Mineral Research and Exploration

http://bulletin.mta.gov.tr

Imaging the tectonic components under the Eastern Mediterranean and Black Sea with gravity (satellite) data

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Short Note

Keywords:
Gravity, East Mediterranean, Cyprus Arc, Antalya Arc.

Received Date: 03.03.2021
Accepted Date: 28.07.2021

ABSTRACT

Tectonic structures in the Black Sea and the Levantine Sea were mapped using satellite gravity data. The relationship between Antalya and Cyprus arcs is revealed by the deformation traces of the arc formation. The Cyprus arc which over the slice that disappears from the South of the Anaximander seamounts to the Northeast, can traceable at the western end of the Antalya Bay. The distinction of western and eastern basins in the Black Sea is also mapped. Due to the low spatial resolution, additional studies with higher resolution are required.

1. Introduction

Data processing methods applied to satellite gravity data are similar to those applied to data collected on land. The large area coverage of the satellite data and the resolution obtained due to the measurement ranges offer the opportunity to examine large-scale tectonic structures. Unlike satellite data, undesirable information that appears as surface effect in data collected on land and added to the measured values needs to be filtered out. Satellite gravity data are less noisy and more stable compared to data collected on land. Therefore, we choose satellite gravity data for this study because it is more suitable for imaging long-wavelength structures with the Upward Continuation (UC) process, in which the signature of the deep structures is increased. In addition to the vertical derivative operator and the UC process, the boundaries of large wavelength structures become clear with the help of the depth transform and it is seen that the boundary relations become suitable for interpretation. (e.g., Pınar et al., 1994).

In this study, unlike previous studies, it was shown that the tectonic elements can be mapped at regional scale with the help of continuation-filter operators. The findings were interpreted in terms of economic value.

2. Data and Method

The gravity data used in this stud are the gridded data obtained from the satellite data with a point spacing of approximately 7 km (Figure 1). With the UC method, a 2-dimensional (2D) UC map was created in accordance with a height of 0.215^0. This value is equivalent to height at approximately 0.350 km. At this interval, large structural elements with high detectability can be observed. As an example, fractured and interlaced structures located between Aegean and Cyprus arcs can be observed as regional structural elements (Figure 2). However, in the north of the Central Mediterranean ridge, south of the Anaksimander sea mountains, at the western end of

Citation Info: Toker, C. E., Ulugelgerli, E. 2021. Imaging the tectonic components under the Eastern Mediterranean and Black Sea with gravity (satellite) data. Bulletin of the Mineral Research and Exploration 166, 189-194. https://doi.org/10.19111/bulletinofmre.975929

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the Cyprus arc; there is a strike at the deeper part of the Antalya bay.

With the crustal depth transform relation approximate Moho depth (Wollard and Strange, 1962)

$$\text{Depth} = 40.5 - [32.5 * \text{atan}(G + \frac{75}{275})] \quad (1)$$

where G is gravity value.

In the study, the first vertical derivative of the gravity data was calculated, then UC was applied. Then, depth transformation was performed using Wollard and Strange (1962)'s depth transformation. 3D visualization of tectonic and structural elements at a depth range of approximately 14-42 km given in Figure 3.

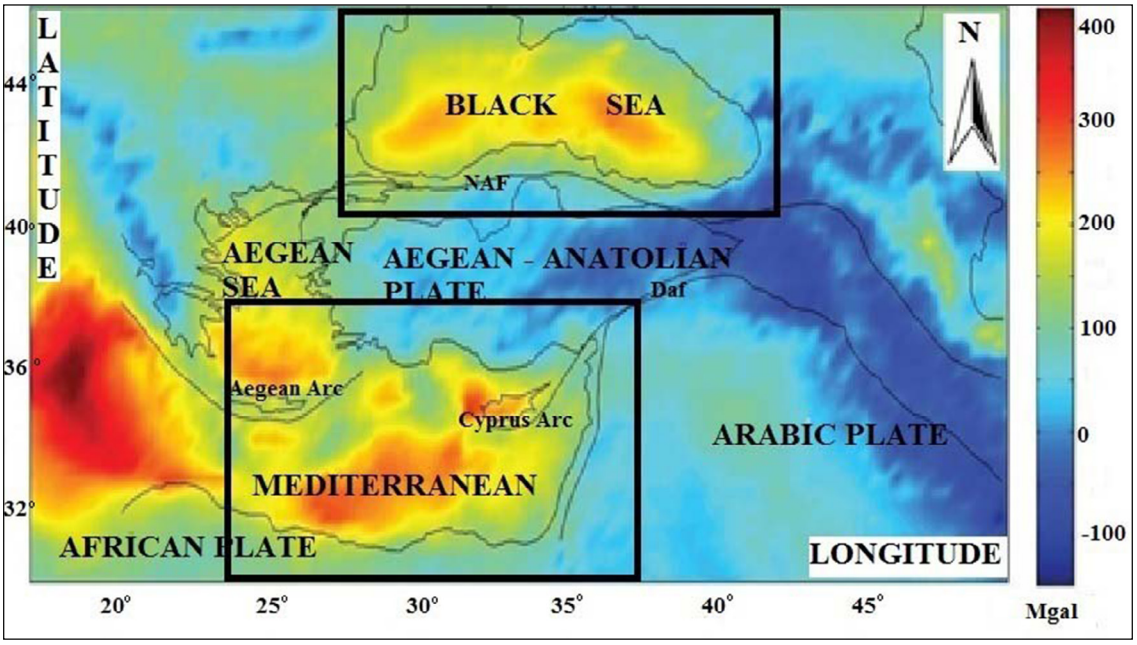

Figure 1- Bouguer gravity data and study areas. (http://bgi.obs-mip.fr/)

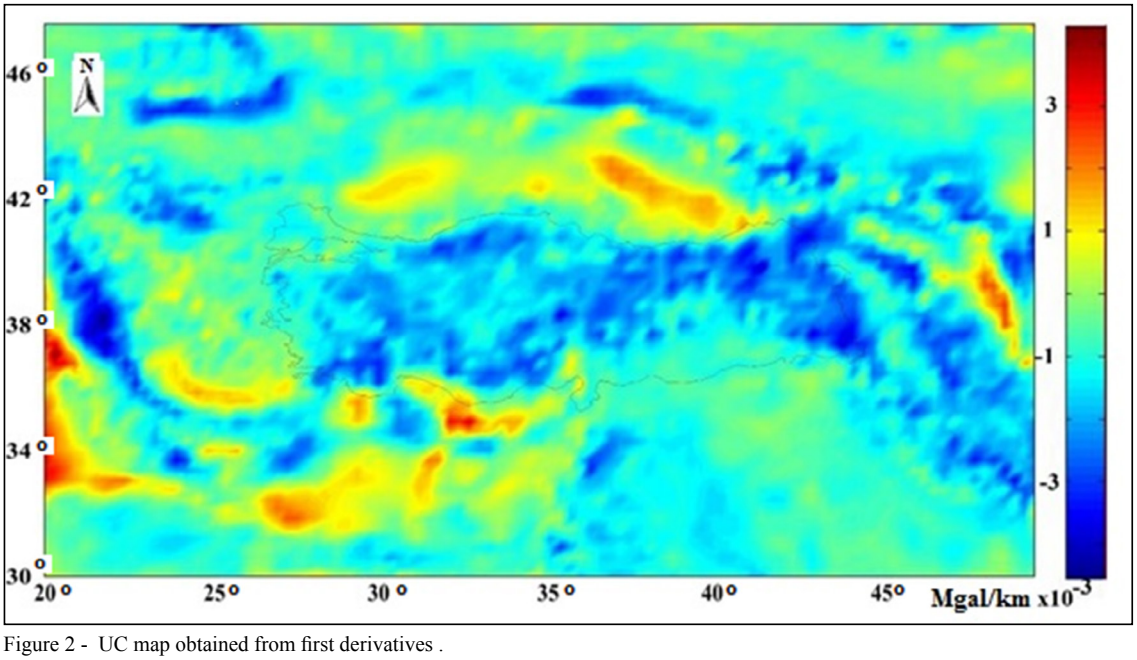

Figure 2 - UC map obtained from first derivatives .

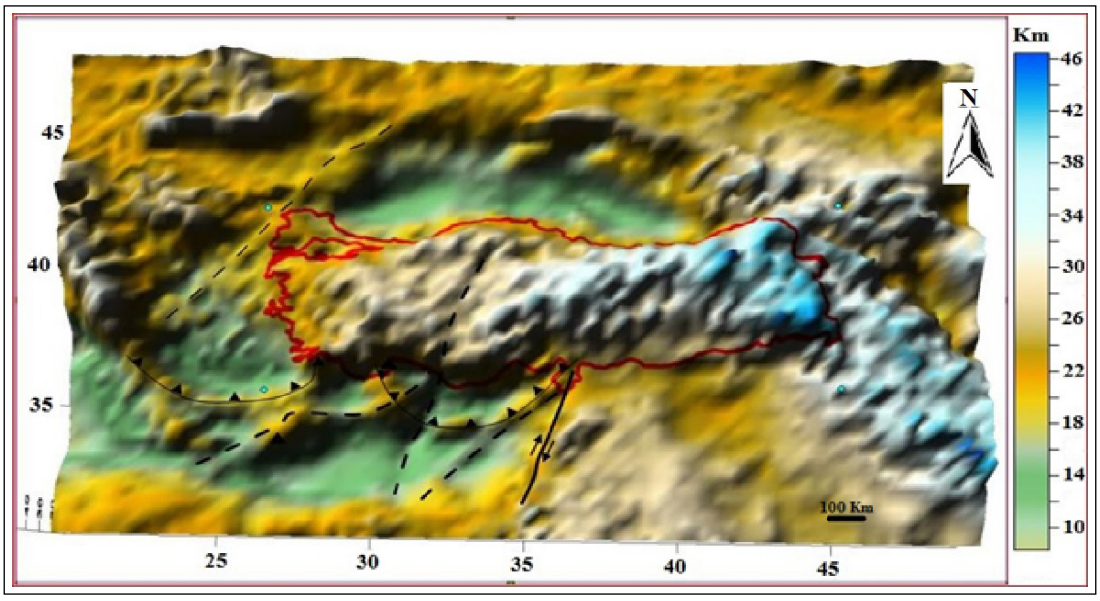

Figure 3- Regional crustal structure with Moho trend.

3. Results

Ergün et al. (2005) stated in their study that the boundary between the African plate and the Aegean/ Anatolian microplates is in the process of transition from subduction to collision along the Cyprus arc (Figure 4). The continuation of the movement is also the cause of current tectonic structures.

In the light of the tectonic elements described in Figure 4a, the findings in this study can be given in the following way.

In the Bouguer gravity map (Figure 1) high amplitudes, reaching 300-400 mgal intensities, define the marine area data (Herodotus Basin), and the light blue sections in the 0-75 mgal range define the terrestrial crust.

In dark blue structures, the resolution in gravity, which develops due to the elevation of the asthenosphere, decreases to the range of 50 – 100 mgal. This structure starts from Southern Anatolia, which is divided by the Aksu thrust, and extends to Iran. The deposition area of the Aegean graben system in front of the Aegean arc is separated from its surroundings with a value range of 200-300 mgal.

Both basins of the Black Sea are prominent (200-300 mgal) and host thick sedimentary sequences. With the proposed process steps, discontinuities in the density distribution in the Antalya Bay and Cyprus arc were also revealed. The projection of the dashed lines indicates the lost plate slice.

Figure 2 shows the UC map. Structural elements and tectonic traces become more evident when compared to the first map. The distinction observed in the Eastern Black Sea basins also emerges among other structural elements. When the Eastern Mediterranean is examined in terms of structural elements; Aegean arc, Cyprus arc and Anaximander uplift causing discontinuity between them are evident. In the Levantine Sea, the tectonic border has emerged between the Iskenderun Bay and the Nile delta in the northeast direction, where the Cyprus arc is tangent. The Dead Sea Transform Fault can be traced. The tectonic line extending at a steeper angle from the gulf to the 300^{o} longitude of the Antalya slice, which is also highlighted by the earthquake foci, and the uplift between the Pliny and Strabo trenches were defined (Figures 4a and 4b). In the literature, Le pichon et al., (2019) stated that the Eastern Mediterranean is the continental lithosphere south of the Cyprus arc (Lebanon coast), Bouguer gravity data support this suggestion.

4. Discussion

The line connecting the Peloponnese Peninsula and Turkish Thrace border extends in the northeast

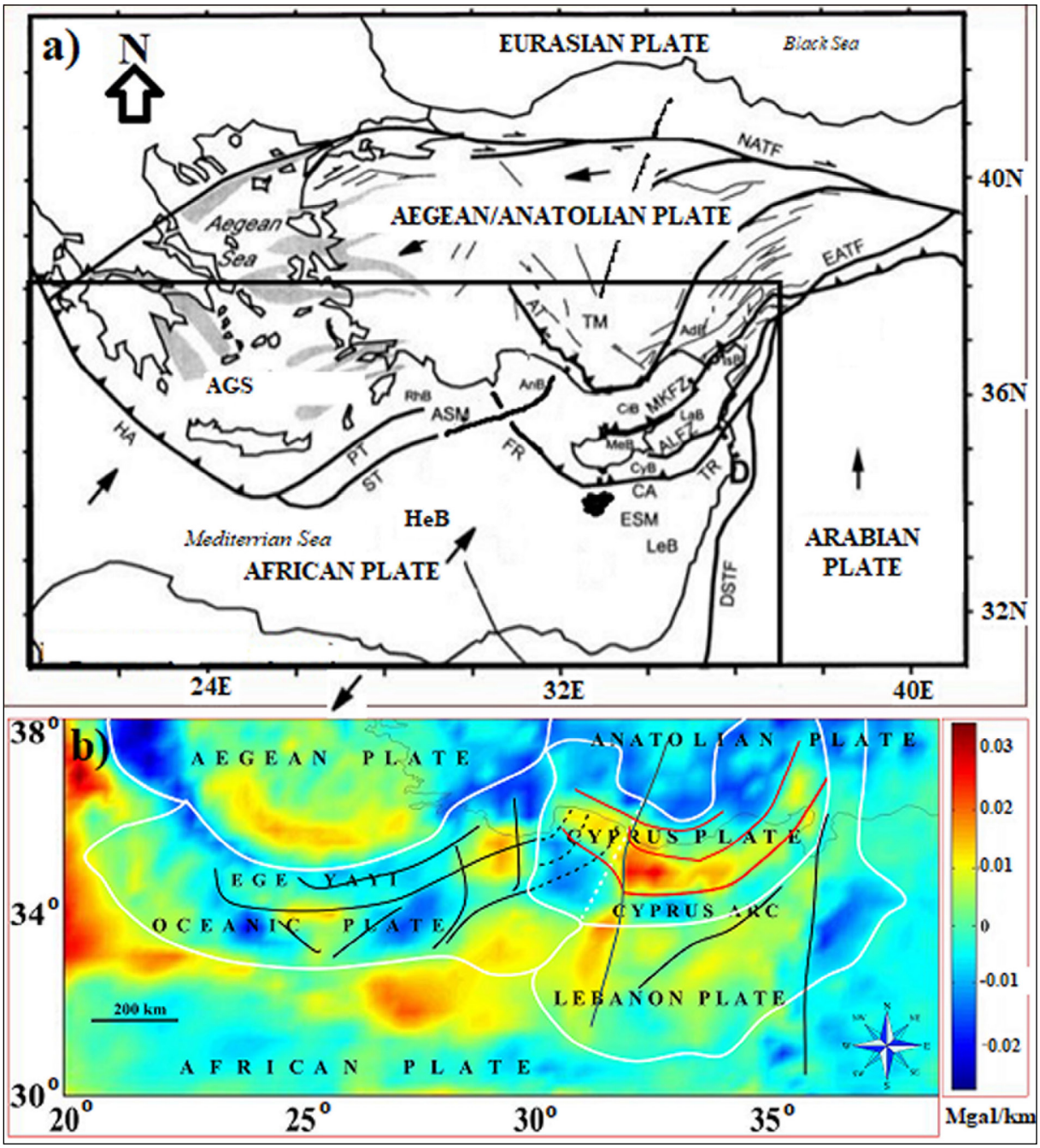

Figure 4- a) Main geological elements (structures) of the Eastern Mediterranean (modified from Ergün et al., 2005). Main geological elements of the Eastern Mediterranean (Figure 4) modified from Ergün et al., (2005); dark arrows show directions of plate movements. Shaded gray represent Aegean graben systems. Dark black area Eratosthenes seamounts. The main deformation axis is indicated by a sawtooth line. The nomenclatures are as follows. AdB, Adana Basin; AGS, Aegean Graben System; ALFZ, Amanos - Larnaca Fault Zone; AnB, Antalya Basin; ASM, Anaximander Seamount; AT, Aksu Thrust; CA, Cyprus spring; CiB; the Cilician Basin; CyB, Cyprus Basin; DSTF, Dead Sea Transform Fault. EATF, East Anatolian Fault; ESM, Eratosthenes Seamount; FR, Florence ascent; HA, Hellenic Arc, b) structural discontinuities.

direction and this may be a large-scale tectonic contact (Figure 3).

The Lebanese plate is divided into three parts by two NE directional tectonic lines starting from the West Nile Delta in the south of the Cyprus Arc (Figure 3).

Despite the intersecting appearance of the Cyprus Arc and the Antalya slice on the map, it can be predicted that they may be at different depths and that the Antalya slice will probably be deeper and cannot be observed on the surface in seismic tomography studies (Figure 4). Looking at the crustal structure of the Black Sea associated with Moho; It is thought that there may be a subduction from the Aegean Sea to the Black Sea in Western Thrace and this subduction is effective in the geological and tectonic evolution of Thrace (Figures 3, 4, 6). In the Central Black Sea, there are traces of plate-sized movements due to the effect of the Anatolian block under the compression effect regime.

Examination of the obtained results in terms of natural resources reveals the following results. The delta of the Danube covers a very deep mid-sea basin. In terms of geological history, even before the Danube river formed after the Pleistocene in the Western Black Sea region, there was sufficient depth for sedimentation and the formation of hydrocarbon reserves in this region (Figure 5).

The result of the boundary analysis performed with the standard deviation moving window filter (Toker, 2019) on the gravity data of the Black Sea region presented that the compression forms regional tectonic boundaries, including the edges of the western and eastern basins (Figure 6).

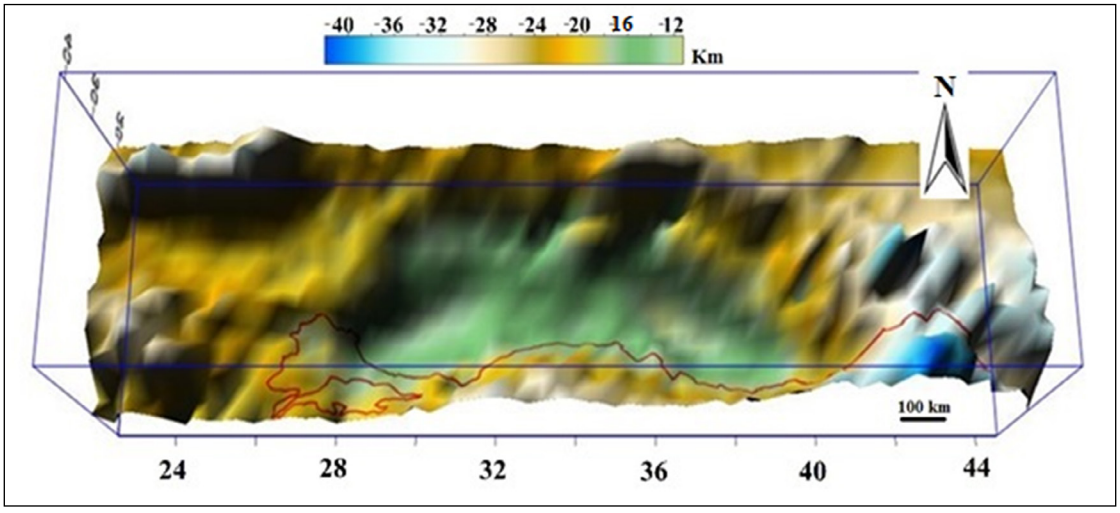

Figure 5 - Crustal structure of the Black Sea with Moho trend.

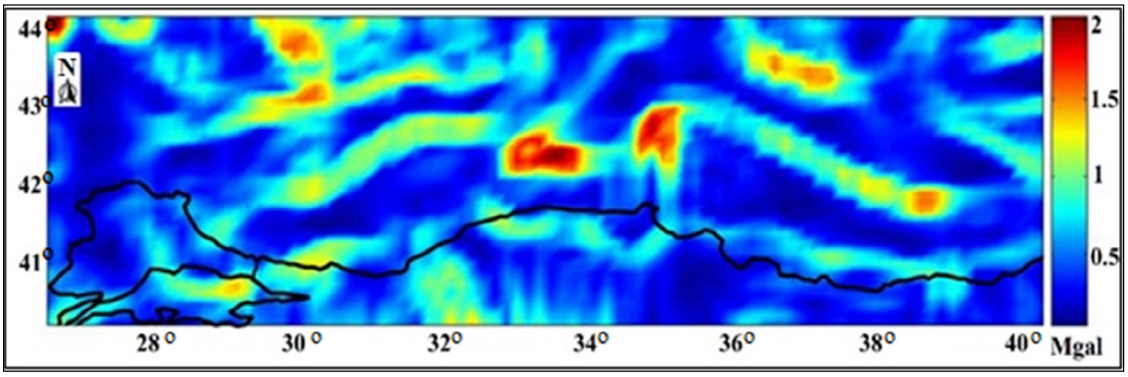

Figure 6 – The result of 2D standard deviation moving window filter.

Considering that the aforementioned reserve area is observed on a deeply integrated tectonic boundary, and considering that passive continental boundaries adjacent to the main ocean basins constitute one-third of the hydrocarbon basins in the world, the importance of imaging long-wavelength structure boundaries becomes clear (e.g. Mann et al., 2003).

Due to the compression of Central-North Anatolia, the perpendicular borders (valleys perpendicular to the sea) were formed at the base of the crust, and there are transition zones in the basins in front of these borders. We believe that these areas should also be investigated in terms of economic resources (Figure 5 and 6).

5. Results

In the study, regional structures were examined in the light of gravity data and boundary relations of large-scale structures were investigated. Considering the results of the hydrocarbon exploration studies carried out in the Western Black Sea Region, the regions within the exclusive economic zone where similar depths and associated average seismic velocities are expected should be investigated in detail.

This approach would also be appropriate for the Mediterranean. The locations of the basins that will provide sufficient depth can be mapped. However, thrusts within the stacks are an obstacle to carry out detailed studies.

Acknowledgements

We thank Doç. Dr. Y. ERDOĞAN, General Manager of Mineral Research and Exploration, and the employees of the institution for providing the working conditions. We developed a computer program to calculate the depth at each gravity point using the depth transform. It can be obtained from the authors.

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