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Deep geological structures as revealed by 3D gravity stripping: western part of the Moesian Platform, Romania

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Abstract: *The gravity stripping technique has been described several decades ago as a valuable tool for geophysical exploration of deeper geological structures in old oil fields. It has been tested in a 3D approach in a suitable area located in the Moesian Platform, Romania, in a region with old oil fields. The new stripped gravity map offers information on the geological structures situated beneath the stripping surface, meaning depths situated between 3,000 and 6,000 m in the testing area. The newly contoured gravity anomalies may be associated with basic or acidic magmatic rocks within the basement and with folded or uplifted sedimentary structures, associated with oil and gas accumulations.*

Key words: *gravity stripping, 3D geophysical models, deep geological structures.*

Introduction

The "deep gravity interpretation by stripping" technique has been described in the early '60 (Hammer, 1963), as an attempt to improve the geological interpretation of existing gravity data in old oil fields. Its author stated that "old gravity data never die" and this proved to be true in many cases, including our recent work in the Moesian Platform, Romania.

The gravity stripping, as a complex processing and interpretation procedure, evaluates and computes gravity effects of shallow sedimentary strata aiming to derive a new Bouguer gravity map that includes only effects from deeper geological structures.

The method was originally designed as a 2D approach in oil fields with consistent information on the geometry and density of "shallow" sedimentary deposits, resulted from analyses of large numbers of boreholes.

Our work, which modified the original gravity stripping 2D approach in order to test a more suitable 3D one, is based on a detailed information on the Neogene and Quaternary sedimentary deposits, resulted from reflection seismic and numerous boreholes, on a background of much older Bouguer gravity data and a very effective 3D gravity modelling software developed by Marian Ivan, University of Bucharest, Romania.

Testing area

Within the testing area, located in the western part of the Moesian Platform (Romania) (Figure 1), important oil accumulations have been found beneath the Quaternary and Neogene sedimentary deposits.

The Neogene deposits of Badenian to Levantine age are included in the last major sedimentation cycle in the Moesian Platform. They cover transgressively Cretaceous, Jurassic, Triassic and Palaeozoic formations with thickness ranging from 100 m in the vicinity of Danube River and more than 4,000 m towards the northern part of the Moesian Platform.

Since geological information on deep Mesozoic and Palaeozoic structures is many times based on boreholes, due to poor coverage and resolution of reflection seismic surveys, such data provided by gravity reprocessing and interpretation may prove to be valuable in the geophysical exploration of hydrocarbon accumulations.

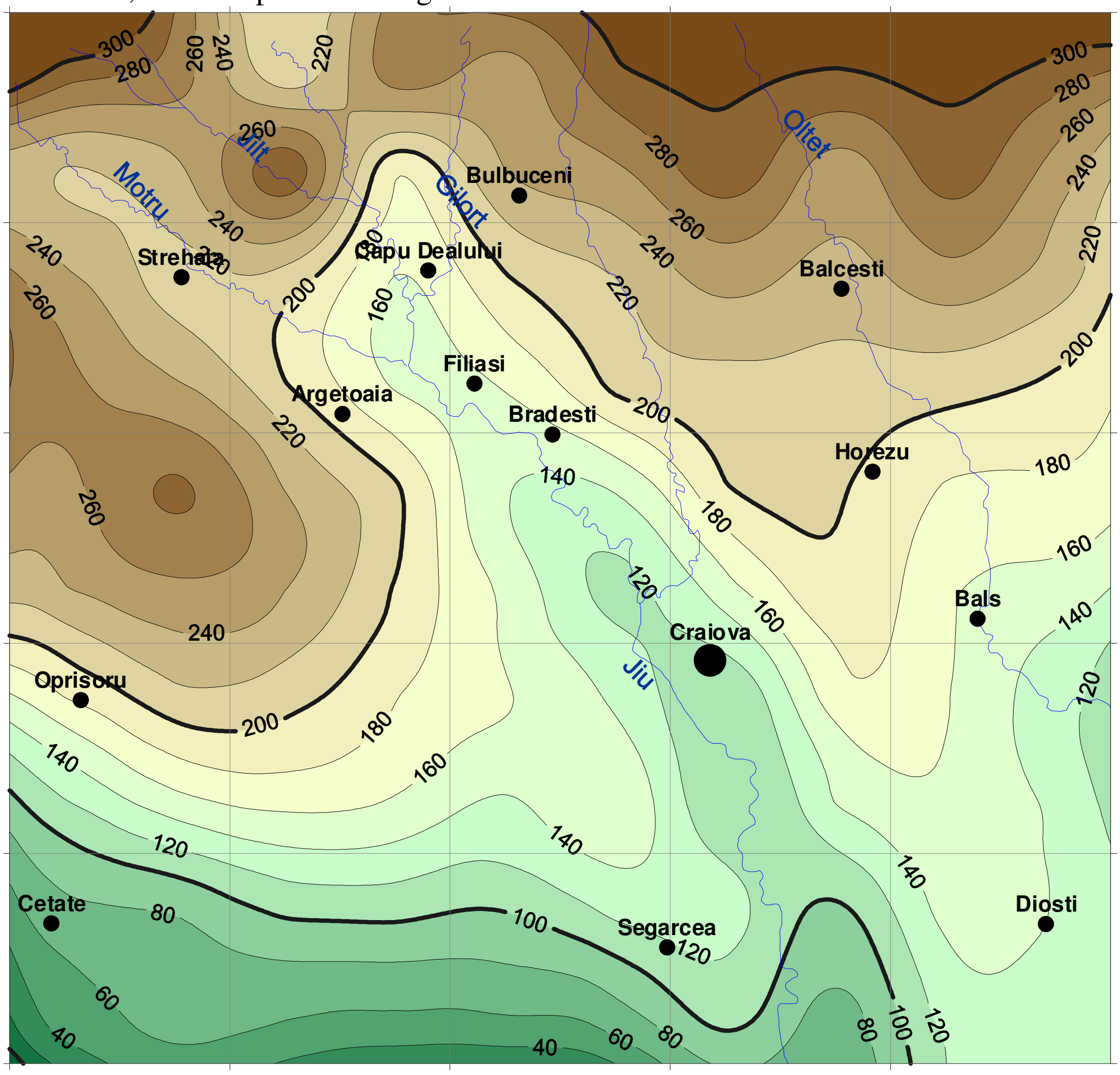

FIG. 1 – Location of the testing area Moesian Platform, Romania

Gravity data

The Bouguer gravity data for the testing area have been digitized using the gravity map of Romania at scale 1: 500,000 published towards the end of the ‘50, calculated for 2.20 g/cm^3 density and contoured at 5 mGal interval. The gravity mapping was performed using a network with profiles located at distances between 2 and 6 km and gravity stations between 1 and 2 km. Considering the utilised network and the low accuracy of both gravity and topographic measurements of those times, the Bouguer gravity map includes mainly effects from deep structures, the shallower ones being mostly “filtered” due to mapping and digitising techniques.

The main features of the Bouguer gravity map, presented in Figure 2, are the following:

a) the southern sector displays large high gravity anomalies, exceeding 20 mGal, that are considered to be associated with elevated high density formations located in the basement, Palaeozoic and Mesozoic formations;

b) the northern area is characterised by a very active horizontal gradient of Bouguer anomalies, that decreases rapidly the gravity towards a E-W regional gravity low associated with the Getic Depression, filled with low density sedimentary deposits.

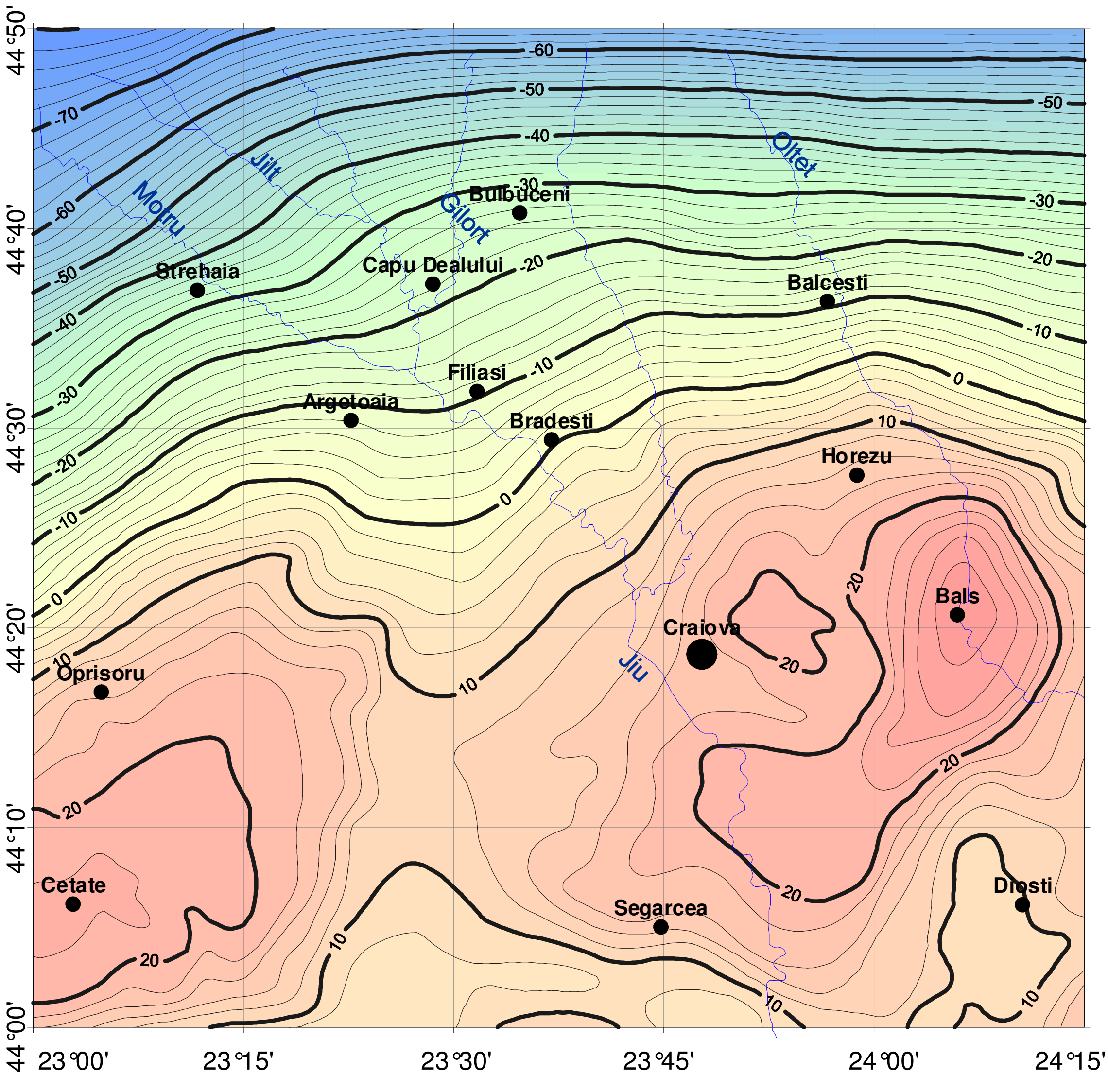

FIG. 2 – Bouguer gravity anomalies

Gravimetric models of Neogene sedimentary deposits

The gravity stripping procedure requires a suitable gravimetric model, meaning a geophysical model built with strata and bodies with density contrasts, their computed gravity effect being eliminated from the original Bouguer gravity map.

In the same time, this technique needs a "stripping surface" representing the boundary between the overlying strata, whose gravity effects are eliminated, and the deeper geological structures, whose gravity effects are to be interpreted.

For the testing area situated in the western part of the Moesian Platform as "stripping surface" was designated the bottom of the Neogene sedimentary deposits. The gravimetric model was built using:

a) topographic data as mean elevation values in a 5' x 7.5' grid for the upper limit of the model (Figure 1);
b) seismic reflection and boreholes information for the lower limit of the model;
c) information on the sedimentary deposits densities derived from boreholes cores and density logging.

The stripping surface, situated at the bottom of the Neogene strata (Figure 3), shows complex relationships between these low density deposits and the much older and higher density Mesozoic, Palaeozoic and basement formations. Its main features consist of:

a) a deep N-S trending "canyon" filled with more than 2,500 m of low density Neogene deposits, that separates areas of elevated high density Palaeozoic and crystalline rocks, a structural situation that is easy to be correlated with the Bouguer anomalies (Figure 2);
b) a fragment from a larger E-W trending "canyon", representing the southern flank of the Getic Depression, filled with more than 5,000 m of low density Neogene deposits that covers older and higher density geological structures.

Several gravimetric models have been built using different boundaries within the Neogene strata and specific density contrasts. Density variations of Neogene deposits were found to be related to the lithology, age and depth of burial. As extreme mean density values we may emphasize 2.20 g/cm^3 for shallow Meotian deposits and 2.60 g/cm^3 for deeply buried Badenian deposits. The densities of Mesozoic and Palaeozoic formations are ranging between 2.55 g/cm^3 and 2.75 g/cm^3, while the rocks in the crystalline basement are considered to be represented by a mean density value of 2.80 g/cm^3.

The most effective model for the geophysical and geological goals of the applied gravity stripping technique proved to be that using the structural limit showed in Figure 3 and a major density contrast of +0.35 g/cm^3 between the pre-Neogene geological formations (mean density 2.65 g/cm^3) and Neogene + Quaternary sedimentary deposits (mean density 2.30 g/cm^3) (Figure 4).

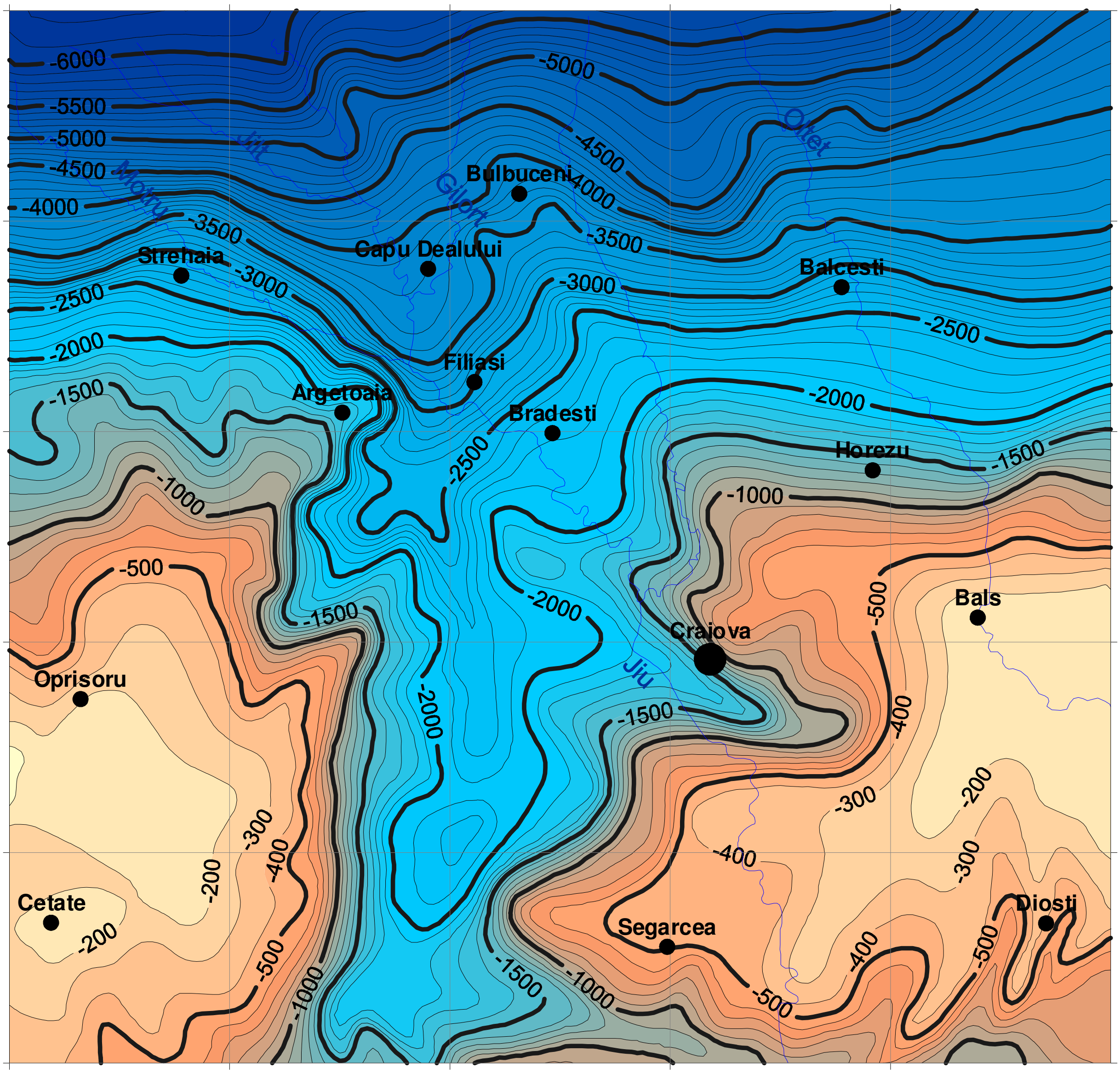

FIG. 3 – The boundary Neogene / pre-Neogene geological formations (stripping surface)

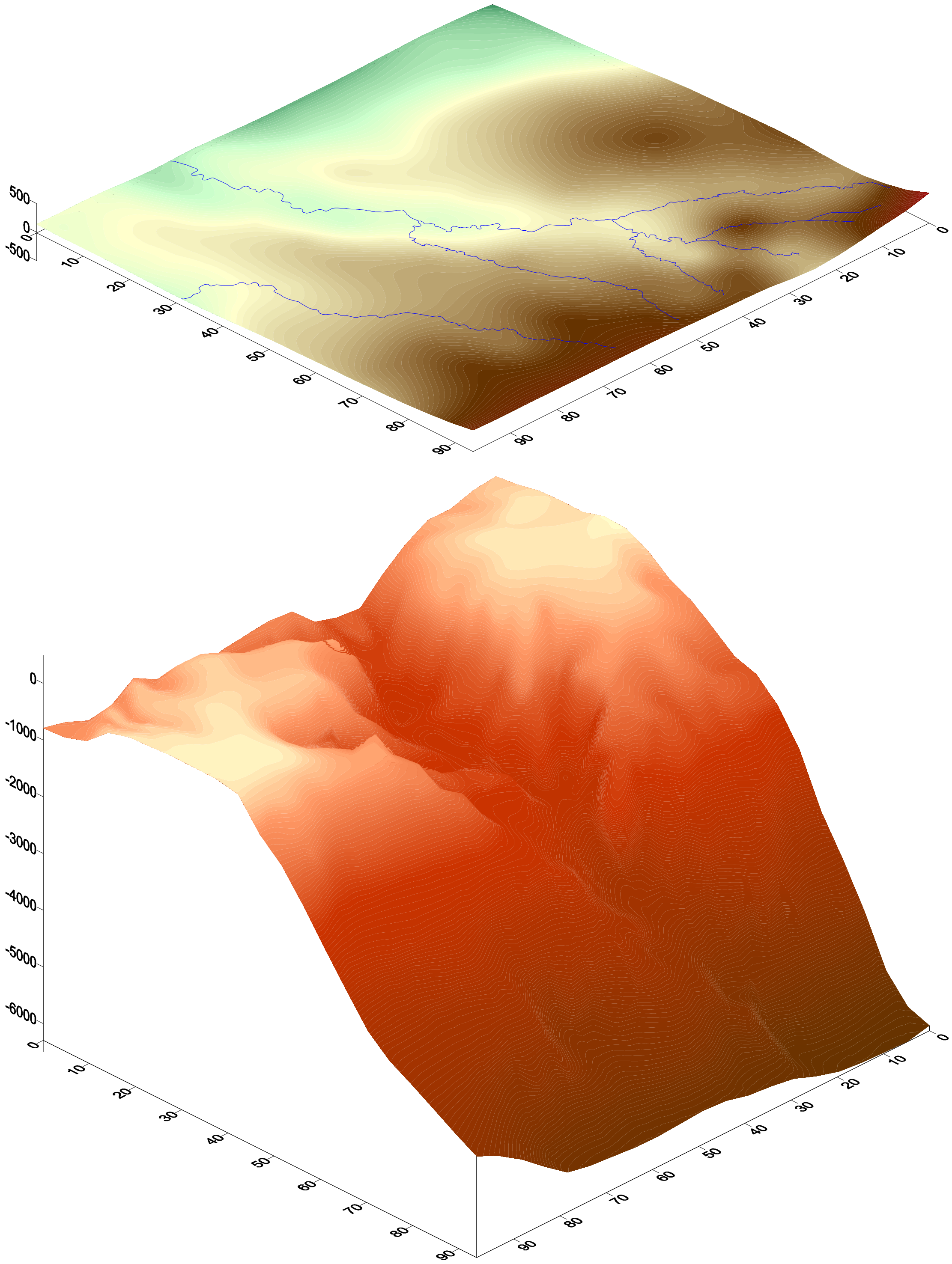

FIG. 4 – Selected geophysical model for gravity stripping

3D gravity stripping for deep geological structures

Using the 3D modelling gravity software, the gravity effect of the selected gravimetric model has been calculated and represented in Figure 5. Due to the simplicity of the model, involving a single density contrast between the Neogene + Quaternary and pre-Neogene geological formations, the map of the model gravity effect looks similarly to the structural map describing the stripping surface (Figure 3).

Very important for the effectiveness of the stripping technique is the intensity of the gravity effect in the northern half of the testing area, where gravity effects of the deep structures are obscured, in the original Bouguer gravity map, by more than 5,000 m of low density sediments.

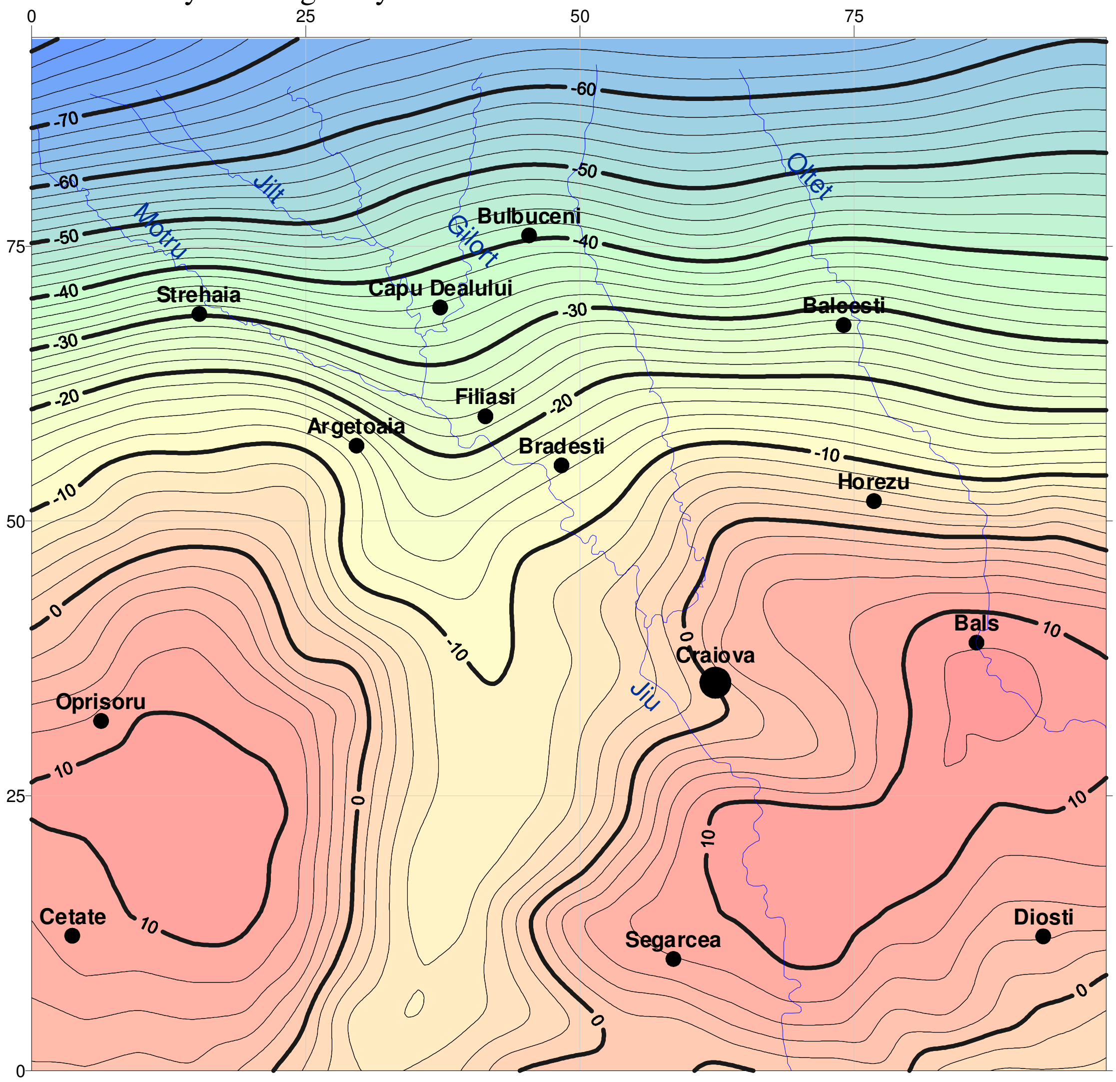

FIG. 5 – Gravity effect calculated for the selected geophysical model

The gravity effects of the geophysical model are ranging between +10 and -10 mGal in the southern half of the testing area, where the Quaternary + Neogene sedimentary strata display low thicknesses, and between -10 and -80 mGal in the northern part, the highest gravity effect corresponding to a thickness of 6,000 m of such sediments. The 3D stripped gravity map, resulted as a difference between the original Bouguer gravity anomalies (Figure 2) and the gravity effects of the selected gravimetric model (Figure 5) is presented in Figure 6. Following Hammer's original approach, it may include gravity effects determined only by geological structures situated beneath the stripping surface, meaning mostly within the Mesozoic, Palaeozoic and crystalline basement formations.

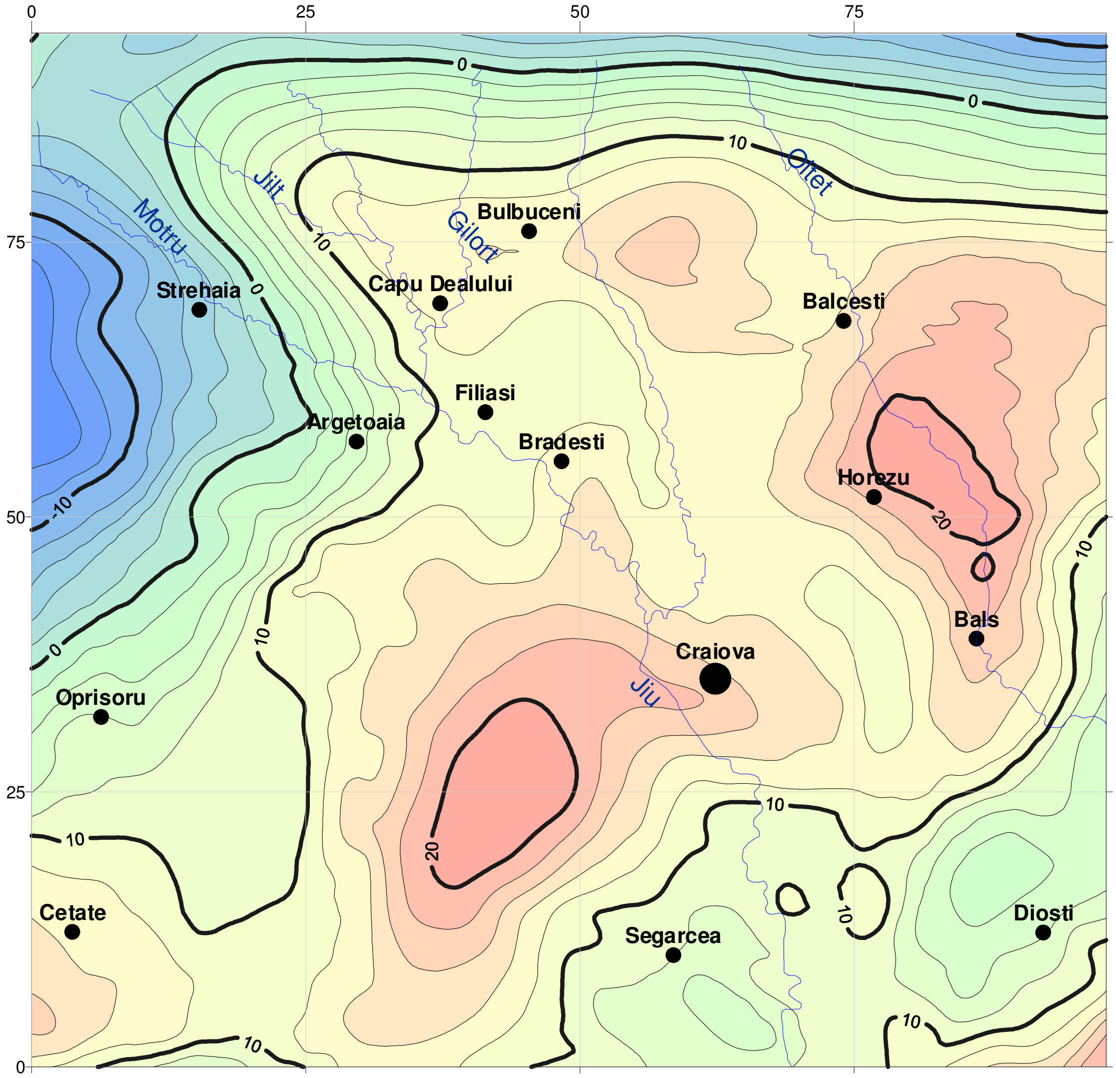

FIG. 6 – Stripped gravity map

As compared to the Bouguer gravity map, with gravity variations of ca 100 mGal, the stripped gravity map shows gravity variations of ca 30 mGal, a fact that may be in good agreement, especially in the northern half of the testing area, with the well known decrease of gravity effects with distance.

The newly obtained gravity map displays totally new features as compared to the Bouguer one, their interpretation suggesting different geological causes:

a) the two high anomalies located in the southern half in the Bouguer map are replaced by a high anomaly situated between these anomalies, well correlated with the N-S trending "canyon" (Figure 3). The aeromagnetic map located in this area a magnetic high anomaly, interpreted as effect of a magmatic structure within the basement. Recently obtained high resolution reflection seismic data showed folded Palaeozoic structures associated with this basement structure (Matresu, 2003). We interpret this high gravity anomaly as due to a basic magmatic structure that controlled locally the folded Palaeozoic sedimentary strata;

b) the high gravity anomalies trending N-S and E-W (Craiova, Bradesti, Bals, Balcesti, Bulbuceni, Capu Dealului) may be interpreted as effects of deep high density folded structures or elevated blocks, including sometimes Triassic high density dolomites, associated with oil and gas accumulations;

c) the low gravity that opens west of Strehaia may be interpreted as effect of a deep large granitic body emplaced in the basement, and possibly within the Palaeozoic deposits, that have been penetrated by boreholes in this area (Matresu, 2004).

Conclusions

The gravity stripping, that was described as an effective processing and interpretation technique four decades ago in a 2D approach (Hammer, 1963), has been adapted for a 3D one, in a suitable testing area located in the western part of the Moesian Platform.

Several gravimetric models were built using reflection seismic and borehole information on the complex structural architecture, and borehole cores ore density logging information on the rocks density.

The gravity effect of the selected gravimetric model has been removed from the original Bouguer gravity map, resulting a new gravity map, the stripped one.

The gravity high anomalies contoured in the gravity stripped map correlate well with deep folded or uplifted structures that involve basement or high density sedimentary rocks (dolomites).

The main gravity low may be associated with large granitic bodies penetrated at deep levels by boreholes in the westernmost part of the Moesian Platform.

The 3D gravity stripping technique proved to be a useful tool in exploring deeply buried geological structures in an area lacking of high resolution reflection seismic data, or at least, as a valuable additional information.

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