METHODOLOGY ELABORATION FOR PROCESSING OLDER GEOPHYSICAL DATA AS INPUT IN 3D GEOMODELLER SOFTWARE WITHIN THE SAME THREE-DIMENSIONAL GRID

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Abstract. Depending on the depth of the model that we want to achieve and the physical properties of the formations, the geophysical data we introduce must be filtered in different ways. So, if we want to make a surface model (of small depth) we need to use gravimetric and magnetic residual data. If we want to perform a large depth model then we will use the filtered data with a low pass filter. The gravimetric data measured at surface contain information about the weighted undergrounds density from the surface to the Lithosphere-Astenosphere boundary, and the magnetic data contains weighted average information from the topography surface to the depth at which rocks lose their magnetic properties (Curie surface). In view of the above, our paper is concerned with the development of appropriate filters for gravimetric and magnetic data, to be in accordance with the depth of the geological model.

Keywords: 3D Geomodeller Software, geophysical data, gravity anomaly, magnetic properties.

Rezumat. Elaborarea procedurilor pentru procesarea datelor geofizice vechi ca intrare în software-ul 3d GeoModeller în acelasi grid tri-dimensional. În funcție de adâncimea modelului pe care dorim să-l realizăm și de proprietățile fizice ale formațiunilor, datele geofizice pe care le introducem trebuie filtrate în moduri diferite. Deci, dacă vrem să facem un model de suprafață (de mică adâncime), trebuie să folosim date reziduale gravimetrice și magnetice. Dacă vrem să realizăm un model de adâncime mare, atunci vom folosi datele filtrate cu un filtru trece-jos. Datele gravimetrice măsurate pe suprafețe conțin informații despre densitatea subterană ponderată de la suprafață până la limita de lithosferă-astenosphere, iar datele magnetice conțin informații medii ponderate de la suprafața topografică la adâncimea la care pietrele își pierd proprietățile magnetice (suprafața Curie). Având în vedere cele de mai sus, lucrarea noastră se referă la dezvoltarea unor filtre adecvate pentru date gravimetrice și magnetice, care să fie relevante pentru profunzimea modelului geologic.

Cuvinte cheie: 3D Geomodeller Software, date geofizice, anomalia gravitației, proprietăți magnetice.

INTRODUCTION

We have evaluated the trend of magnetic anomalies by filtering and smoothing the gravity and magnetic data for small area from Curbure Carpathians. We calculated the regional effect, which we lowered from the initial data and obtained the residual effect. The used filtering methods, for which we have developed computational programs, are based on mobile averages with windows of different sizes and the calculation of the analytical expressions of polynomial surfaces of different degrees. The results of these types of filters were compared with spectral filters, in the context of existing knowledge data and their geological significance. We obtained qualitative information, with varying degrees of regionality and from different depths, but which cannot be quantified by themselves. These filters can provide information about local and surface effects (residual maps, "high pass filters"), medium depth structures (through "band pass filters"), and deep structures ("low pass filters") (ASIMOPOLOS & ASIMOPOLOS, 2017a; ASIMOPOLOS & ASIMOPOLOS, 2017b; ASIMOPOLOS & ASIMOPOLOS, 2017).

We made some software for direct and inverse transformation of the data from the table (longitude, latitude, and parameter) format, the input format into the EXCEL, SURFER and so on, in the grid matrix format, input format in the MATLAB and 3D GeoModeller.

An analysis method that streamlines data filtering with trend surfaces is based on the progressive decrease, based on the degree of polynomial used, from unfiltered initial data. Thus, firstly, the residual to the trend plan can be calculated. Then, for these residual values, upper-order trend surfaces can be calculated. In this way, successive residues can be calculated based on which components reflecting certain degrees of regionality and depth of anomalous sources will be removed.

GEOLOGICAL AND GEOPHYSICAL MODELLING

A project in 3D GeoModeller begins by importing or digitizing all geographic / geodetic data. The mapped geology is created on the digital terrain model (DTM) (https://www.intrepid-geophysics.com/ig/index.php?page=Home, ABDELRAHMAN et al. (1999), www.igr.ro).

- Establish the necessary conditions and data for the optimal use of the iterative 3D modelling/inversion software and select the most suitable algorithms for pre-processing and filtering multi-parametric data.
- Elaboration of calculation procedures and software programmes for the adaptation of the geological / geophysical / geodetic input data formats, specific to each parameter used in the GeoModeller 3D modelling program and for statistical-spectral analyses, multi-parametric correlations and spatial graphical representations on the grid 3D dimensions.

- Systematization, processing and concatenation of input data (geophysical and geodesic) in formats compatible with the modelling software.
- Making geological and tectonic model sketches as inputs in the form of 3D grid and assigning the physical properties (density, magnetic susceptibility, residual magnetization, temperature, geothermal flux, etc.) specific to formations in each cell of the 3D grid geological. Depending on the depth of the model, we will recalculate physical properties according to the thermodynamic conditions (temperature, pressure, stress, strain, etc.).
- Elaboration of software procedures for processing older geophysical data for input in GeoModeller 3D software within the same three-dimensional grid like us the new geophysical data.
- Achieving an indexed, quantifiable database that will encompass all input parameters in the programme for each selected study area.
- Making modelling (direct problem solving) and inversion (solving the indirect problem) based on the input data for the areas chosen as a test.
- Changing input parameters, within acceptable tolerances, to resume a new iterative model / inversion cycle to obtain an improved model. After several program runs and parameter changes, we get the 3D geological model.
- Obtaining the 3D geological model and validating it, taking into account both the input data of the model and other knowledge data that did not participate quantitatively in the realization of the model.

CASE STUDY

For the integrated study of geomagnetic and gravimetric data with geological data on section A14 (ŞTEFĂNESCU et. al., 1985), we drew up table 1 of physical properties (magnetic susceptibility and density) for different types of formations, from a number of bibliographic sources unpublished.

The regional sections are located on Fig. 1, and geophysical data are presented in Figs. 2-5.

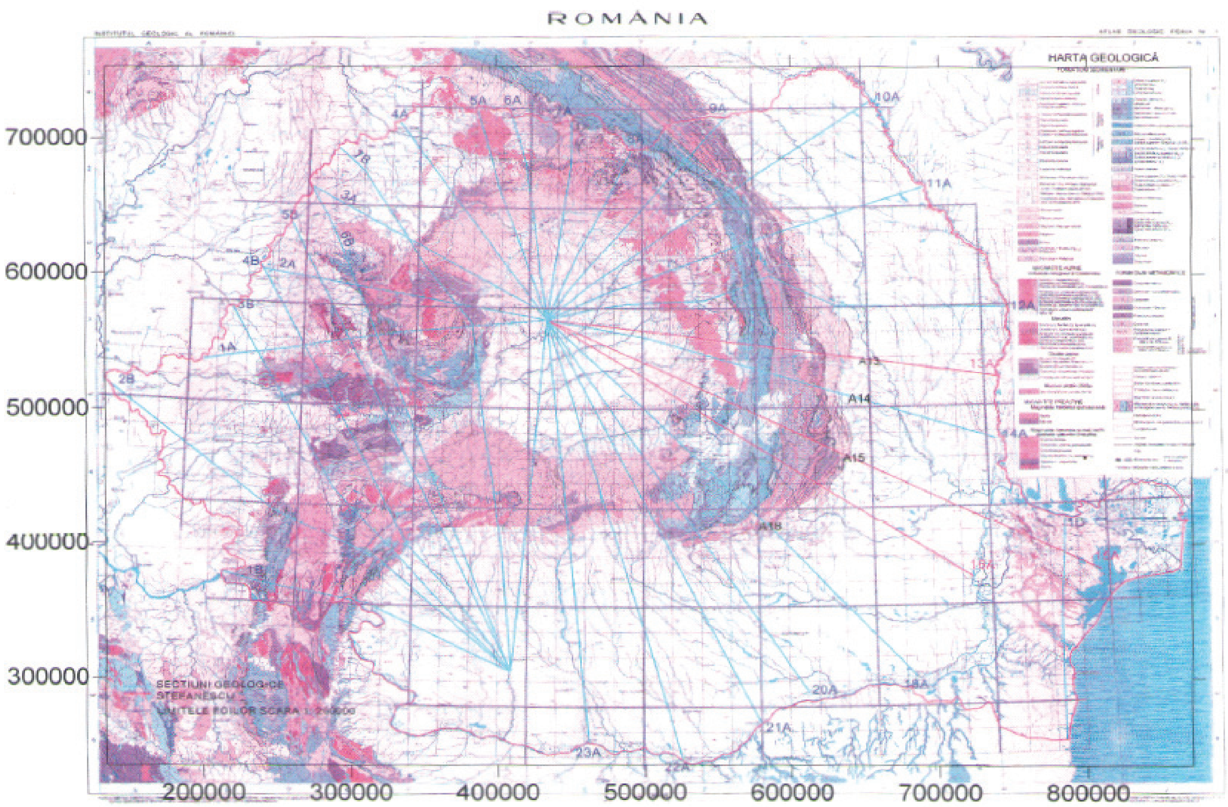

Figure 1. The location of sections A13, A14, A15 (ŞTEFĂNESCU et al., 1985).

These physical properties, together with the geometric delimitation of the formations in the basement, represent the input data for the iterative modelling/inversion software used. Based on the 2D models obtained on the studied A14 section as well as on other sections, which we complete with the elevation data of the terrain, we can move to the 3D model representing a superior phase of knowledge of the basement based on the multi-parametric response functions of the Earth.

Table 1. Physical properties of geological formations included in section A14.

Geological formation	**Age**	**Magnetic Susceptibility (10^{-6} CGS)**	**Average density (g/cm^3)**
Pre-Dobrogea Depression (Depression of Bîrlad)	Proterozoic medium	800	2.8
	Palaeozoic	600	2.75
	Permian + Triasic	60	2.65
	Jurassic 2+3	25	2.65
	Sarmatian	150	2.45
	Meotian	120	2.4
	Dacian	130	2.35
	Quaternary + Romanian	160	2.25
The North-Dobrogea Orogen (Consul Unit)	Proterozoic medium	800	2.8
	Palaeozoic	600	2.75
	Triasic	60	2.65
	Devonian inferior + Silurian	100	2.65
	Medium Miocene (Badenian)	60	2.4
	Sarmatian	150	2.45
	Meotian	120	2.4
	Dacian	130	2.35
	Quaternary+Romanian	160	2.25
The North-Dobrogean Orogen (Macin Unit)	Proterozoic medium	800	2.8
	Devonian inferior + Silurian	100	2.65
	Lower Carboniferous	200	2.55
	Upper Jurassic	30	2.65
	Medium Miocene (Badenian)	60	2.4
	Sarmatian	150	2.4
	Meotian	120	2.4
	Pontian	60	2.4
	Dacian	130	2.33
	Quaternary+Romanian	160	2.25
Moesic Platform	Upper Proterozoic + Cambrian	800	2.8
	Lower Devonian + Silurian	200	2.65
	Palaeozoic	600	2.75
	Triasic	60	2.65
	Upper Jurassic	30	2.65
	Upper Jurassic+ Cretacic	50	2.65
	Cretacic	120	2.55
	Palaeogene	100	2.5
	Medium and lower Miocene	120	2.5
	Medium Miocene	130	2.4
	Sarmatian	130	2.4
	Meotian	150	2.4
	Pontian	100	2.4
	Dacian	120	2.4
	Romanian	120	2.35
	Quaternary + Romanian	130	2.35
	Quaternary	130	2.25
The Pericarpathic Weave	Lower Miocene	135	2.5
	Lower Miocenesalifer	15	2.2
	Medium and lower Miocene	130	2.4
	Medium Miocene	120	2.4
The Marginal Weave – the Coza Digitation	Neocomian-Turonian	35	2.65
	Senonian	40	2.6
	Palaeogene	100	2.55
	Palaeocene Luteţian	130	2.55
	Priabonian	130	2.5
	Lower Miocene	100	2.5
	Medium Miocene	130	2.5
	Oligocene-Miocene	150	2.4

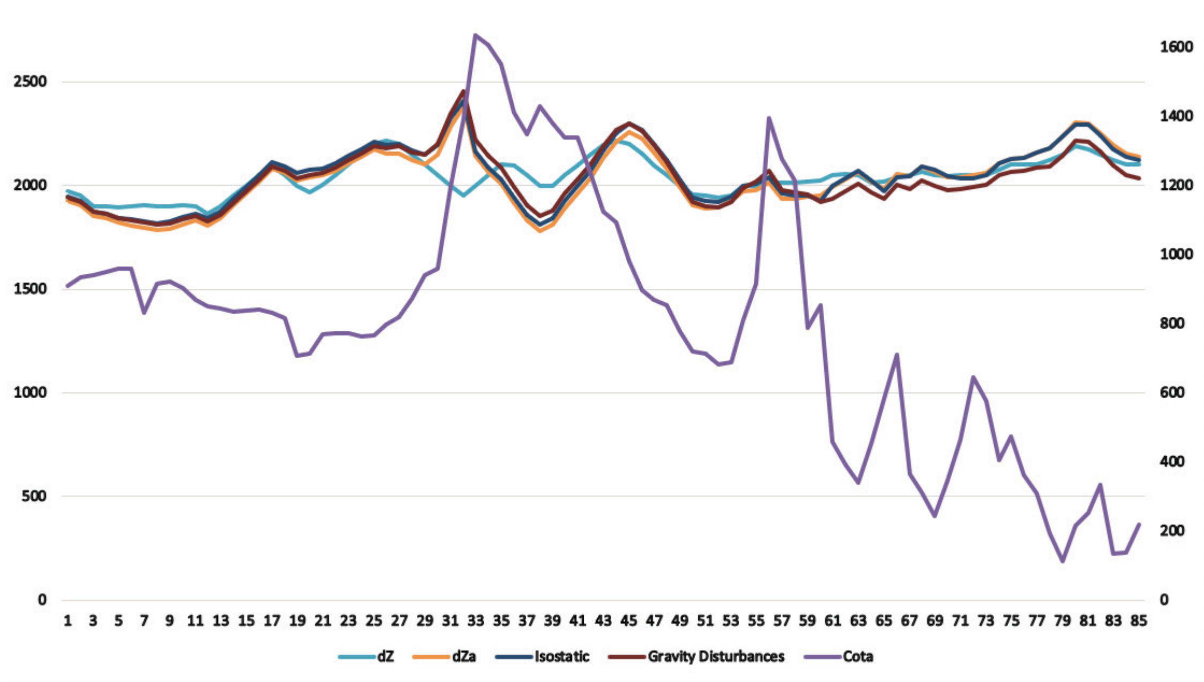

Figure 2. Geophysical data from sections A13. In the left part, the y-axis represents the magnetic anomaly (dZ and dZa, in nT), isostatic anomaly and gravity disturbances (in mgal). In the right part, the y-axis represents the Digital Terrain Model (in meter). The x-axis contains samples for the digitalization of geophysical data.

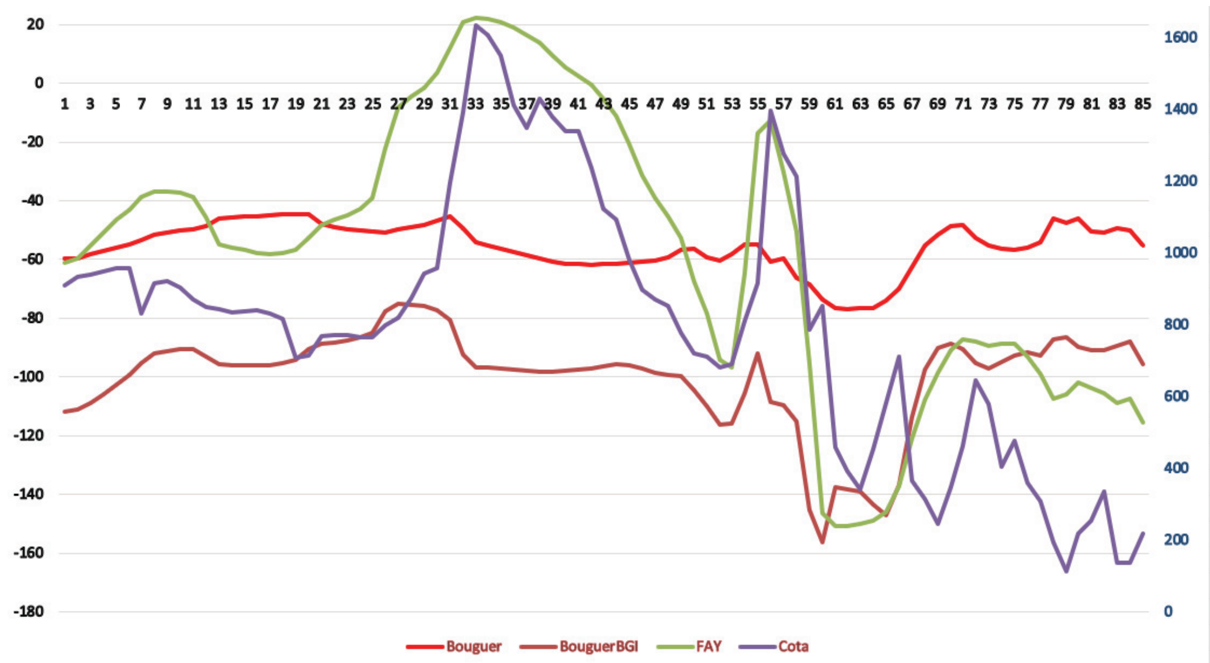

Figure 3. Geophysical data from sections A13. In the left part, the y-axis represents the gravity anomaly (Bouguer anomaly from map, Bouguer anomaly from Bureau Gravimetrique International and FAYE anomaly, in mgal). In the right part, the y-axis represents Digital Terrain Model (in meter). On the x-axis there are samples for digitalization of geophysical data.

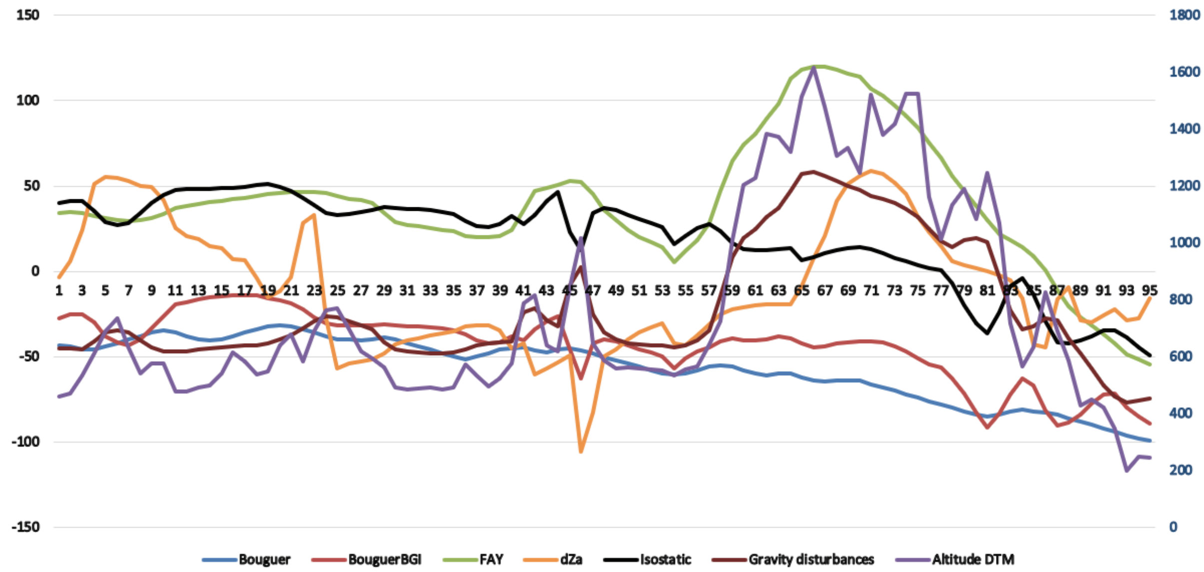

Figure 4. Geophysical data from sections A15. In the left part, the y-axis represents the magnetic anomaly (dZa, in nT), the Bouguer anomaly -from map and from BGI, isostatic anomaly and gravity disturbances (in mgal). In the right part, y-axis is Digital Terrain Model (in meter). On the x-axis there are samples for the digitalization of geophysical data.

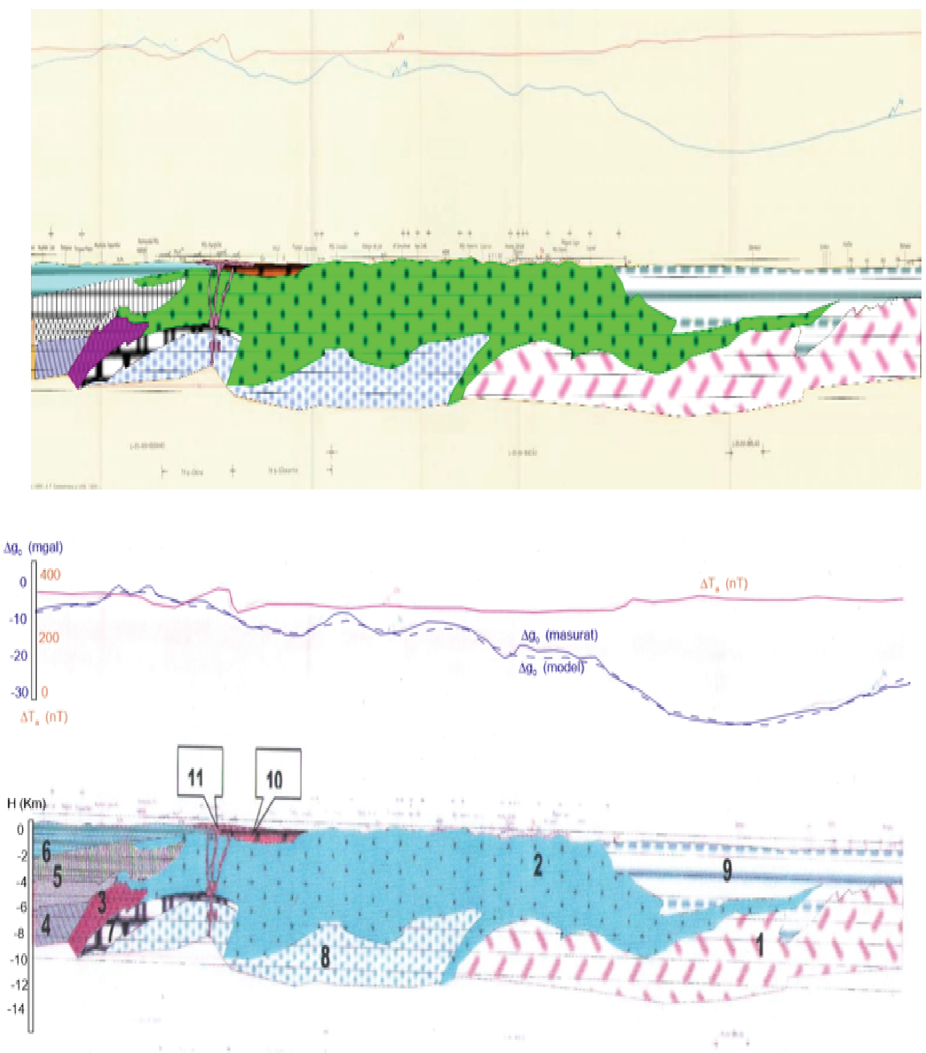

Figure 5. Section A14 (ŞTEFĂNESCU, 1985), with the graphs of variance of the Bouguer anomaly and magnetic anomaly, scanned from the maps at the level of Romania). In the middle figure are the graphs of the Bouguer anomaly (scanned from the map - full curve and those obtained based on the pattern - the dotted curve). In the bottom figure - A14 section model obtained with the modelling software based on the following parameters (denoted by 1-11 for each of the geological formations). 1) The foundation of the Moesian Platform 2) Mesozoic sedimentary formations of the Oriental Carpathian nappes 3) Crystallin Danubian 4) Infra-bucovinic formations 5) Under-bucovinic formations 6) Sedimentary cover of the Transylvanian Basin 7) Triassic and Jurassic lower formations 8) Crystalin formations from the Moesic Platform 9) Sedimentary formations 10) Sedimentary volcanic formations 11) Neogene volcanic formations.

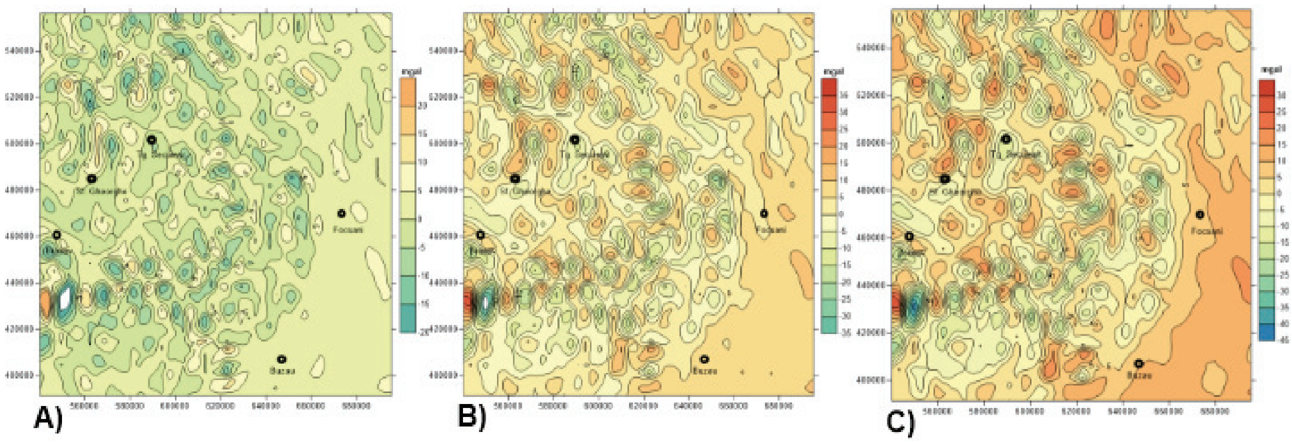

Figure 6. The residual Bouguer anomaly calculated with the mobile averages of 3 different square windows: A) The residual Bouguer anomaly calculated with the mobile averages of 9 values; B) The residual Bouguer anomaly calculated with the mobile averages of 25 values; C) The residual Bouguer anomaly calculated with the mobile averages of 49 values.

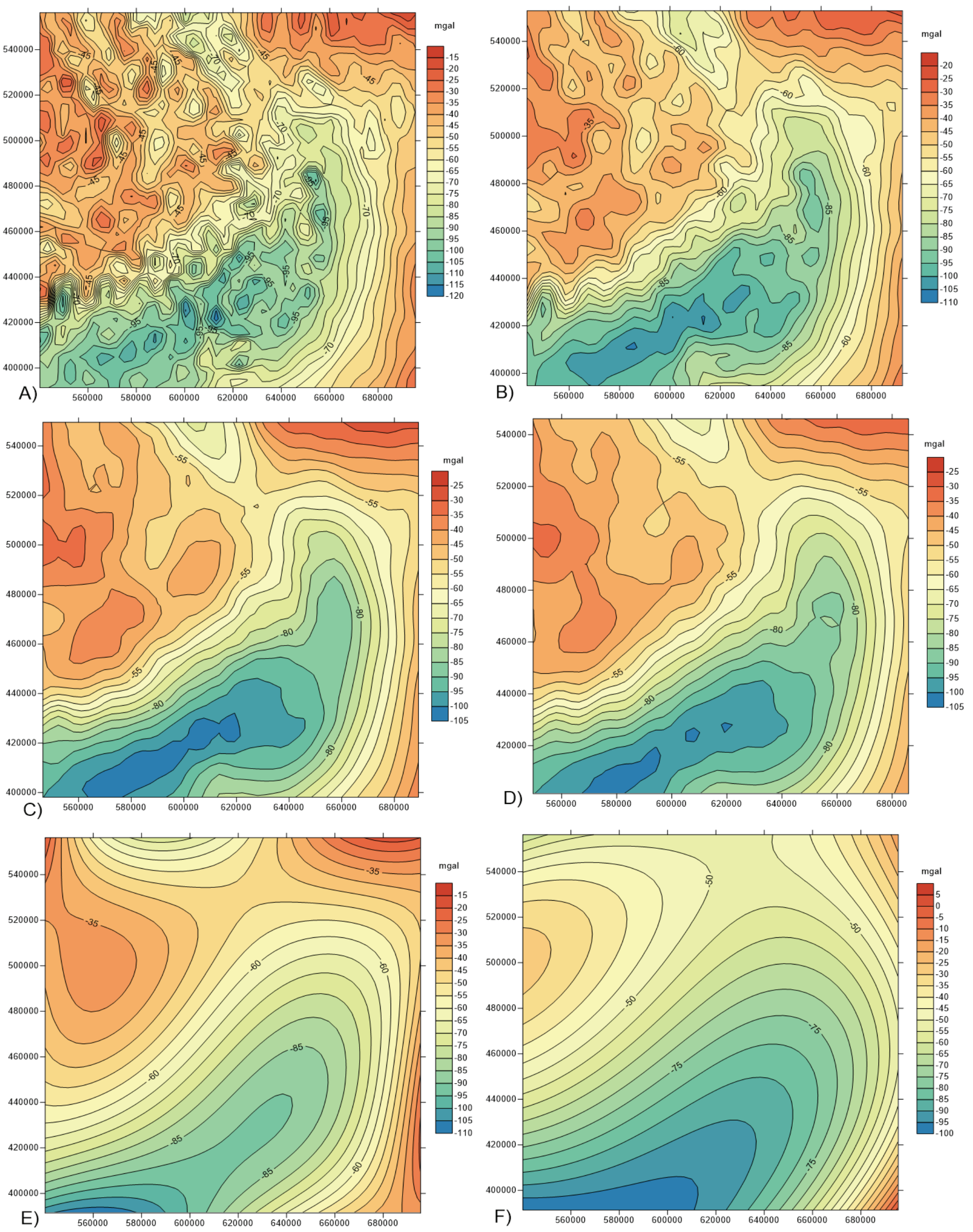

Figure 7. The Bouguer Anomaly in the studied area from BGI data. The representation of unfiltered data; B) Representation of the data averaged in moving windows of 9 values (3 lines * 3 columns); C) Representation of the data averaged in moving windows of 25 values (5 lines * 5 columns); D) Representation of the data averaged in moving windows of 49 values (7 lines * 7 columns); E) The tendency surface with 6th order; F) The tendency surface with 3rd order.

For tendency surfaces, we have developed programmes for calculating analytical expressions for the following types of surfaces:

- The tendency plan of the Bouguer anomaly has the following equation:

Z_{tend} = -188.707147163*X-0.1554708098*Y+27.0513680505;

- The 2nd degree:

$Z_{tend} = A+BX+CY+DX^2+EXY+FY^2$;

- The 3rd degree: $Z_{tend} = A+BX+CY+DX^2+EXY+FY^2+GX^3+HX^2Y+IXY^2+JY^3$; the coefficients being: A=-11938.42251; B=4797.3673020601; C=1487.185233; D=-652.9127963639; E=-438.9016750949; F=0.0000125275; G=45.8620878794; H=-31.7580106317; I=85.5197506216; J=-37.4263031660.

- The 6th degree: $Z_{tend} = A+BX+CX^2+DX^3+EY+FXY+GX^2Y+HX^3Y+IY^2++XY^2+KX^2Y^2+LX^3Y^2+MY^3+NXY^3+OX^2Y^3+PX^3Y^3$, the coefficients being: A=499438.5000; B=-373202.3671875; C=81600.5175781; D=-5520.4898071289; E=-19053.671875; F=91387.85546875; G=-28282.2334; H=2245.9517211914; I=-63199.002; J=13665.5058593750; K=619.84033; L=-186.4072189331; M=9255.7174072266; N=-3328.0280761719; O=342.1310119629; P=-7.7146945000, where X and Y represent the independent variables (in the coordinates system STEREO 70 in the directions W-E, respectively N-S) and Z represents the variable dependent on X and Y. The residual value is $Z_{rez} = Z_{obs} - Z_{tend}$ highlights the local aspects of anomalies. In Figs. 6-7, filtered data were presented. These data can be used to different depth of the case study.

CONCLUSIONS

The realization of a 3D geological model comprises many stages, as follows: Building the digital terrain model; Building the *a priori* geological model; Assigning physical properties to formations, taking into account geological constraints for each unit; Discretization of the lithological model in a 3D geometric grid; Specification of "fixed" *a priori* cells whose lithology cannot be altered; Making a table with the geological boundary cells between the formations; Calculating the response for the gravitational and/or magnetic fields for each observation site; Initialization of the density distribution, residual magnetization, magnetic susceptibility and geological constraints based on lithology; Calculating the geophysical effects of the model; Selecting parts of the model to be modified; Geological assessment of the modified model; Validation of the modified geological model, calculation of the geophysical responses of the modified model; Evaluation of the likelihood of the modified model.

Considering that we use large sets of multiparametric data with spatial and temporal distribution in the 3D geological/geophysical models, the input data must be filtered according to the model dimensions. Thus, filtering methods such as polynomial trend analysis, moving average analysis with different window sizes, and variance analysis of the correlation factor with a mobile window can yield very good results along with the spectral methods and analytical continuation of gravitational or magnetic field in superior or inferior semi space.

The generalization of tendency surfaces to hyper-surfaces adds more information, when we use more than two independent variables and a dependent variable.

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