GEOPHYSICAL AND GEOLOGICAL STUDY IN THE AREA OF THE CĂLIMANI – GURGHIU - HARGHITA VOLCANIC STRUCTURES

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Abstract. A vast bibliography is available on the volcanic structures in Călimani-Gurghiu-Harghita, from which we could extract tectonic and geological information that can be corroborated with geophysical data. The geomagnetic field maps were built on the data contained in the measurement catalogues in the archives of the Geological Institute of Romania. The data contained in these catalogues is not uniformly distributed, and high-density measuring areas (in areas of interest on valleys and accessible areas) alternate with areas with a very poor coverage (in areas of low interest and areas with a hard-accessible relief), leading to the need for mediations and filters made before interpolation. The gravimetric maps built on the published data and the data available at the International Gravimetric Bureau were filtered according to mobile mediation procedures and trend surfaces of different degrees. This paper is a preliminary geophysical and geological study in the project "The realization of 3D geological / geophysical models for the characterization of some areas of economic and scientific interest in Romania".

Keywords: gravity anomalies, geomagnetic anomalies, tectonics, volcanic structures.

Rezumat. Studiu geofizic şi geologic în zona structurilor vulcanice Călimani - Gurghiu – Harghita. Despre structurile vulcanice din Călimani-Gurghiu-Harghita există o vastă bibliografie, din care am putea extrage informaţii tectonice şi geologice care pot fi coroborate cu date geofizice. Hărţile câmpului geomagnetic au fost construite din datele conţinute în cataloagele de măsurare din arhivele Institutului Geologic din România. Datele conţinute în aceste cataloage nu sunt distribuite uniform. Există alternanţă de măsurători de densitate mare, în zone de interes pe văi sau căi accesibile cu densitate foarte mică de măsurători, în zone de interes scăzut sau relief greu accesibil. Acestea au condus la necesitatea medierii şi filtrării înainte de interpolare. Hărţile gravimetrice au fost construite din datele publicate sau datele disponibile la Biroul Internaţional Gravimetric au fost filtrate în acord cu procedurile de mediere mobilă şi suprafeţele de tendinţă de diferite grade. Această lucrare este un studiu geofizic şi geologic preliminar în cadrul proiectului „Realizarea modelelor geologice / geofizice 3D pentru caracterizarea unor zone de interes economic şi ştiinţific din România".

Cuvinte cheie: anomalii ale gravitaţiei, anomalii geomagnetice, tectonica, structuri vulcanice.

INTRODUCTION

From the multitude of tectonic and geological information, we present, in the first two figures, the tectonic and structural framework (Fig. 1) for an extended area that also includes the study area and the map of the Geoid with isobates at Moho discontinuity, extended on the entire territory of Romania (Fig. 2).

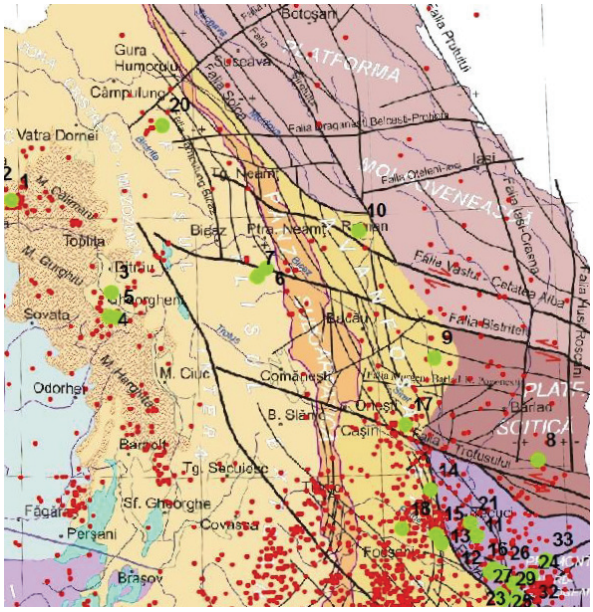

Figure1. Tectonic and structural features of Călimani-Gurghiu-Harghita Mountains as part of Eastern Carpathians (tectonics after VISARION 1998, seismicity marked by red and green dots, after DIACONESCU, 2017).

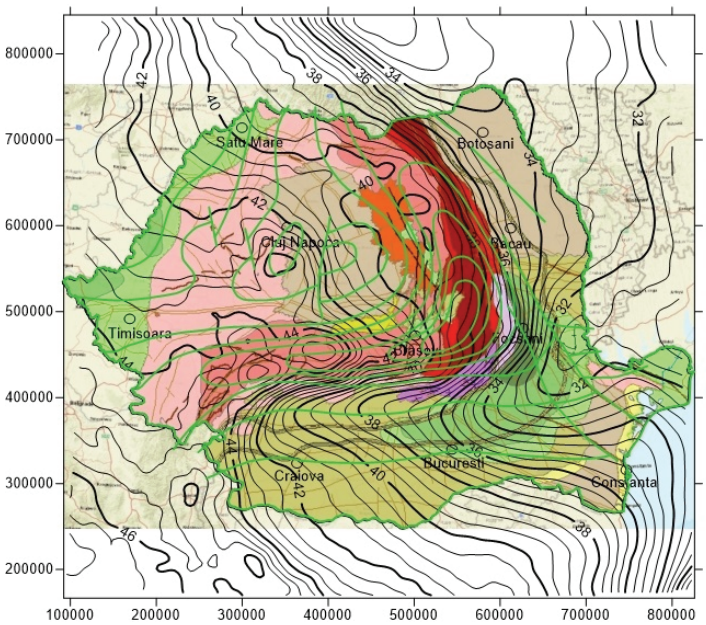

Figure 2. The geoid of Romania, in black (after ASIMOPOLOS-2017, with data from https://bgi.obs-mip.fr), superimposed over the map with isobates at Moho discontinuity, in green. (after RĂDULESCU, 1988).

GRAVITY AND GEODETIC RESULTS

Figure 3 presents the map of the residual Bouguer anomaly on the entire territory of Romania and figure 4 presents the map of the topographic surface, from https://bgi.obs-mip.fr.

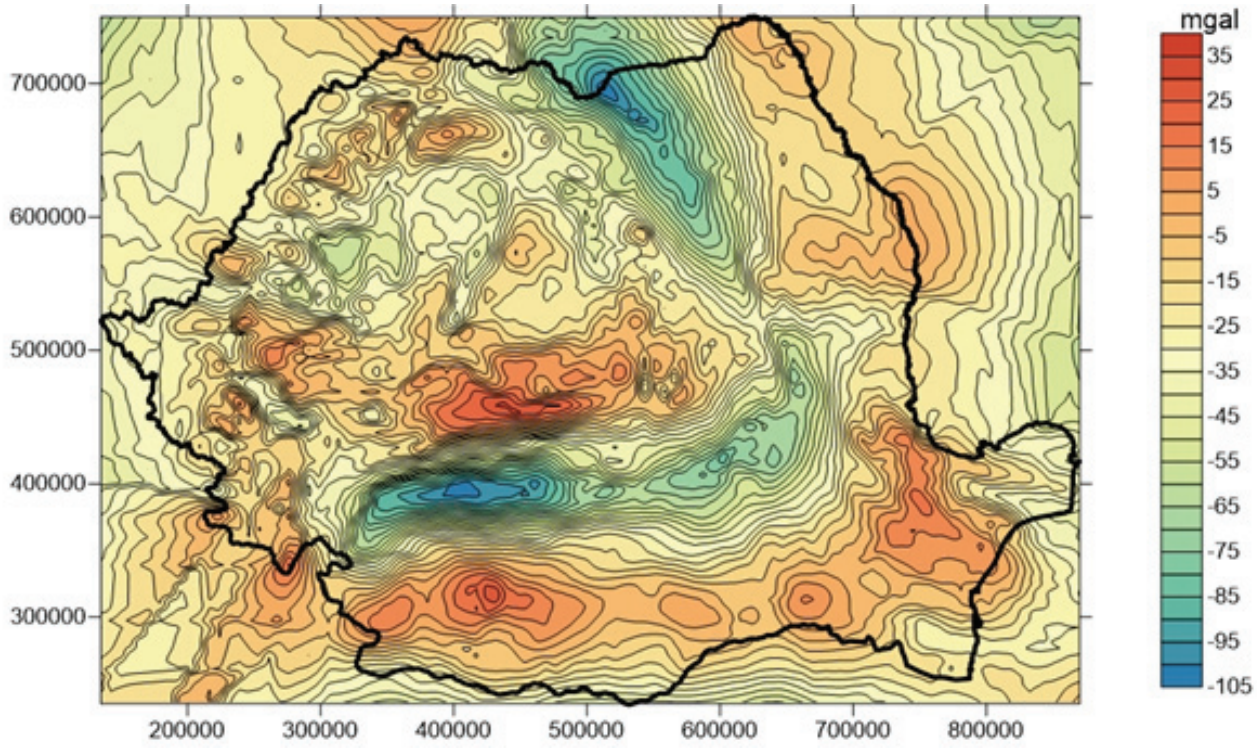

Figure 3. Map of the residual Bouguer anomaly. From the values of the Bouguer anomaly, the trend plane and the trend surfaces of orders 3 and 6 were extracted in turn (after ASIMOPOLOS 2017, with data from https://bgi.obs-mip.fr).

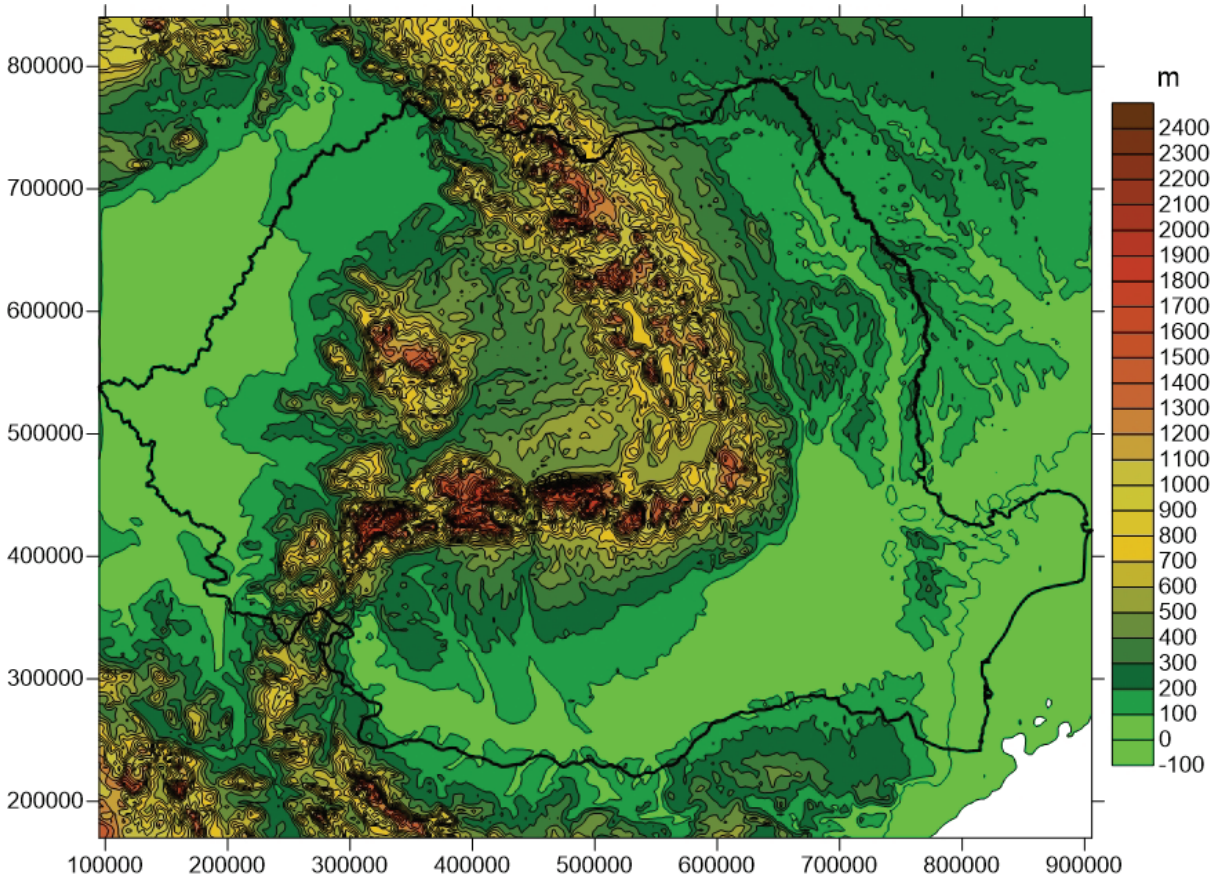

Figure 4. Map of the topographic surface, from ETOPO 1 data.

ETOPO1 is a 1 arc-minute global relief model of the Earth's surface that integrates land topography and ocean bathymetry. ETOPO1 is built from global and regional data.

GEOLOGICAL CONSIDERATIONS REGARDING THE NEOGENE MAGMATITES FROM THE CĂLIMANI-GURGHIU-HARGHITA MOUNTAINS

The presence of Neogene volcanites on the inner side of the Eastern Carpathians was determined by the subduction of a lithospheric plate with oceanic crust located in the West part of the Eastern European Platform. In the evolution of this subduction process, the sheets of the flysch and Carpathian molasses were created on the eastern side and replaced the vulcanites on the western side. The neogene, predominantly andesitic volcanism, is similar to other phenomena on the globe that have the same cause - subduction.

Volcanic activity took place from the Badenian to the end of the Pliocene, when the moments of paroxysm alternated with the phases of calm. As a general feature of the entire volcanic chain, we signal the presence of all types of vulcanites, from rhyolites to basalts, with the predominance of andesites.

In the volcanic chain on the western side of the Eastern Carpathians there are three sectors with different peculiarities, namely: the Oaş-Gutâi sector, the Bârgău-Rodna-Ţibleş sector and the Călimani-Gurghiu-Harghita sector

The Călimani-Gurghiu-Harghita sector is delimited to the north by Bistriţa Bârgăului and to the south by Valea Oltului, comprising the Călimani, Gurghiu and Harghita mountain massifs, in which the Neogene volcanites have the widest development, with a large area and heights exceeding 2000 m. There are also traces of glaciers in the Călimani Mountains. Fig. 5 presents the volcanic facies map of the Calimani-Gurghiu-Harghita volcanic range and fig. 6 presents the evolution in space and time of the main composite volcanoes.

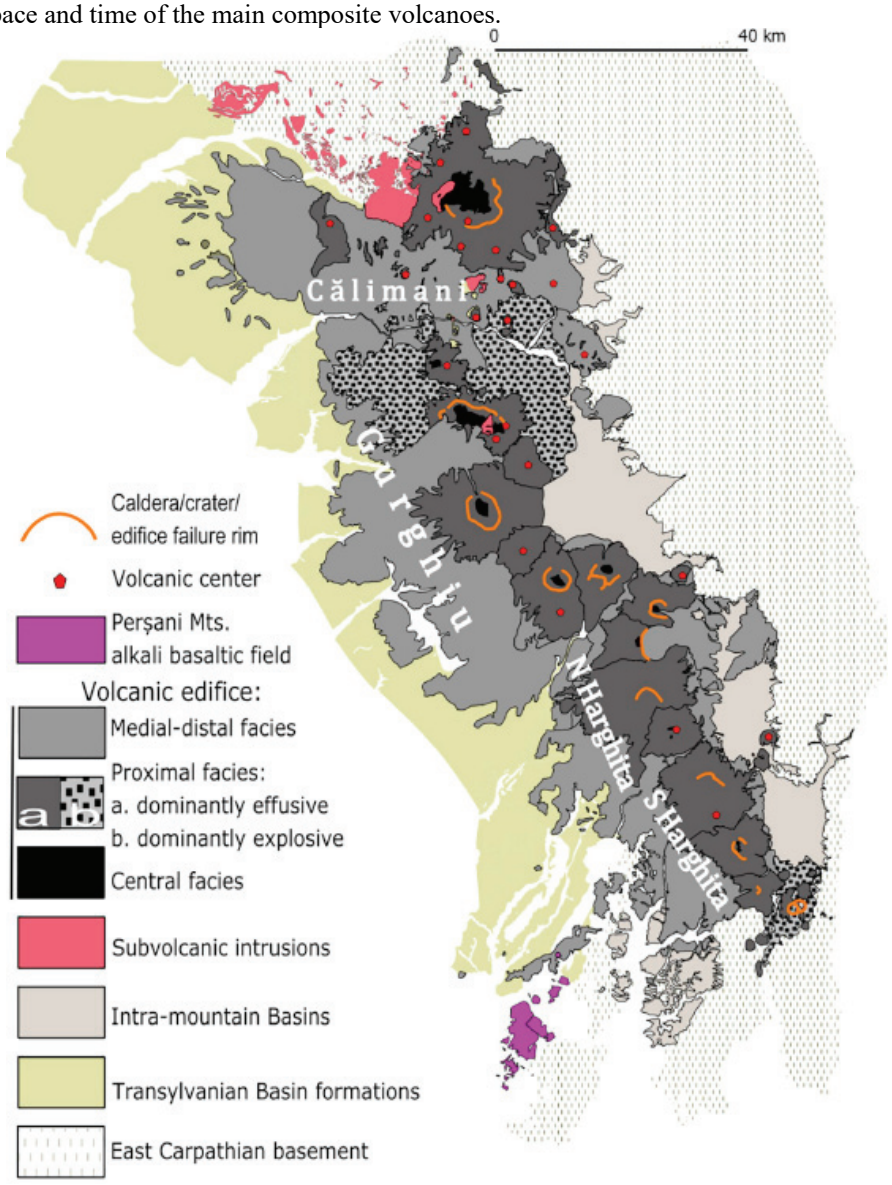

Figure 5. The volcanic facies map of the Călimani-Gurghiu-Harghita volcanic range. (modified from SZAKACS & SEGHEDI, 1995 and SEGHEDI et. al., 2019).

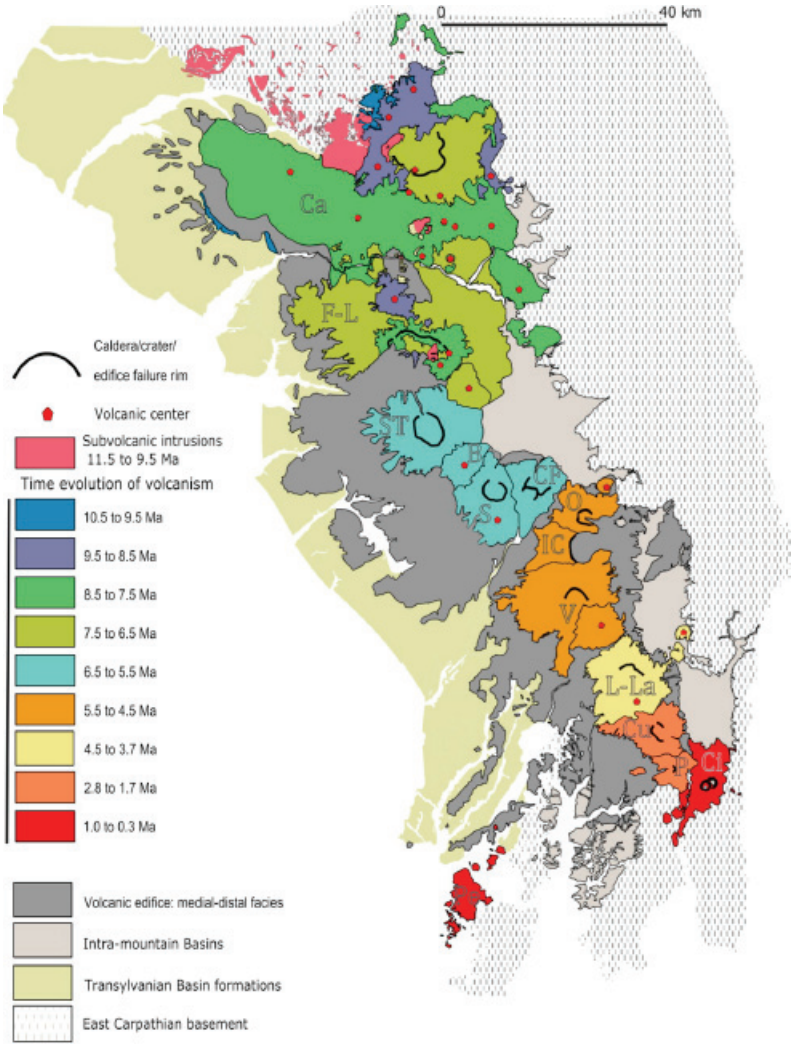

Figure 6. The evolution in space and time of the main composite volcanoes along the Călimani-Gurghiu-Harghita volcanic range (from SEGHEDI et. al. 2019), where: Ca – Călimani, F.I. – Fancel-Lapusna, S.T. – Seaca – Tatarca, B – Borzont, S-Sumuleu, C.F. – Ciumani-Fierastraie, O – Ostoros, I.C. – Ivo-Cocoizasi, V – Varghis, L – Luci-Lazu, Cu – Cucu, P – Pilisca, Ci – Ciomadul, Pe – Persani bazaltic volcanic field; intra-mountain sedimentary basins: Bi – Bilbor, Bo – Borsec, Gh – Gheorgheni, U.C. – Upper Ciuc, L.C. – Lower Ciuc, B – Brasov, Ba – Baraolt, D.M. – Ditrau Syenite Massive.

Volcanic mountains are well preserved being represented by craters such as: Călimani, Fâncel-Lăpușna, Seaca-Tătarca, Șumuleu, Ciumani and Fierăstrae. In the Harghita Mountains, volcanic craters generally have small dimensions, such as Astoroș and Harghita-Mădăraș, or they appear in the form of a plateau. In the south of the Harghita Mountains we find the closed volcanic apparatus in which the Sfânta Ana Lake and Tinovul Mohos were installed. This and smaller ones are considered to belong to a short late episode of explosive volcanic manifestations with the installation of acid lavas.

The foundation of the volcanites in the Călimani-Gurghiu-Harghita sector consists either of metamorphites, which can be covered on some parts of the sedimentary cover, or of Miocene and Pliocene deposits of the Transylvanian Depression.

The volcanic edifice comprises two parts that correspond to different stages of volcanic activity, at the bottom there is a volcanic-sedimentary structure with pyroclastic material accumulated subaerial or underwater, mostly masked by the products of the second stage. The volcanic-sedimentary formation consists of breccias and volcanic agglomerates trapped in a matrix of lapis lazuli, tuffs and bushes, with a thickness between 200 m and 500 m.

The products of the second stage are arranged over the volcanic-sedimentary formation, which constitutes the superstructure of the volcanic cones, which includes an alternation of pyroclastic products and lava flows characteristic of stratovolcanoes.

The oldest rocks in the suite of lava flows are considered the Drăgoiasa dacites from the east of the Călimani Mountains, followed in order by amphibolic andesites (with black homblende, then brown hornblende), amphibolic andesites with pyroxenes, andesites with pyroxenes and amphiboles and andes, basaltoid andesites are considered as last arrivals. Andesites with biolite and quartz and quartz andesites are also subordinated.

The age of Neogene Volcanites in the Eastern Carpathians results from the study of the relations of the volcanites with the sedimentary formations as well as on the basis of the determinations of absolute age. It was found that the oldest vulcanites are intercalated in the deposits of Badenian age, and the newest in the deposits of Pliocene age.

Determinations by radiogenic methods indicate ages between 10 M.a., for Piscuiatu quartz andesites in the Oaş-Gutâi sector and 3.92 M.a. for pyroxene andesites in the Harghita Mountains (SEGHEDI et. al., 2019).

From the determinations of absolute age it results that the volcanism in the Oaş-Gutâi sector started earlier than in the Călimani-Gurghiu-Harghita sector. This fact also emerges from the way in which the volcanic craters were preserved, which are much better preserved in the southern sector.

The Ciuc Depression is located in the upper basin of the Olt, being comprised between the eruptive massif Harghita to the west and the Ciuc Mountains to the east. Two transverse thresholds Jigolin and Racu separate it into three basins, lower, middle and upper. The filling of these basins consists of sedimentary deposits, in which the pyroclastic material has a significant weight. The thickness of the deposits is up to 500 m with several layers of coal. The age of the filling is estimated to be Late Pliocene-Pleistocene, with no paleontological evidence.

Gheorgheni Depression is located between the Harghita and Gurghiu Mountains to the West and the Hăghimaş and Giurgeu Mountains to the East, at the Mureş springs. The sedimentary deposits, which reach almost 1000 m in the center of the depression, are formed by volcanic agglomerates, tuffs and terrigenous material whose age is considered to be terminal Pliocene-Pleistocene, as in the case of the Ciuc depression.

There are five depressions in the Borsec - Bilbor area, the most important of which is the Borsec depression, which is 9 km long and has a filling of 70-130 m thickness. The filling consists of sands and gravels with clay intercalations. The sands are home to a level of coal up to 3 m thick, which has already been mined. The filling belongs to the late Pliocene-Pleistocene, being determined by paleontological methods.

GEOPHYSICAL CONSIDERATIONS REGARDING THE NEOGENE MAGMATITES FROM THE CĂLIMANI-GURGHIU-HARGHITA MOUNTAINS

The gravity data are from archive of International Gravimetric Bureau (https://bgi.obs-mip.fr) and were interpolated and filtered with algorithms from MATLAB (https://www.mathworks.com).

For the Northern part of volcanic structures, in figures 7 and 8 we present the Bouguer anomaly and the residual Bouguer anomaly in the Călimani - Gurghiu Mountains.

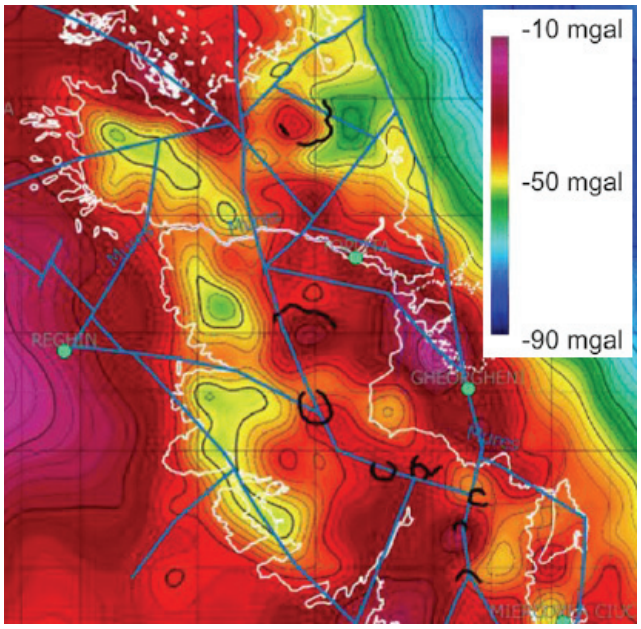

Figure 7. Bouguer anomaly in Călimani - Gurghiu Mountains (in mgal).

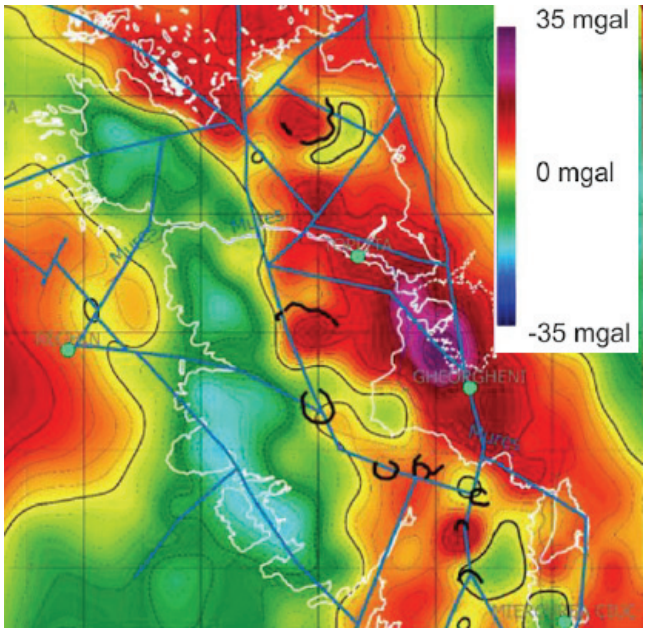

Figure 8. Residual Bouguer anomaly in Călimani - Gurghiu Mountains (in mgal).

For the Southern part of the volcanic structures, in figures 9 and 10 we present the Bouguer anomaly and the residual Bouguer anomaly in the Harghita Mountains.

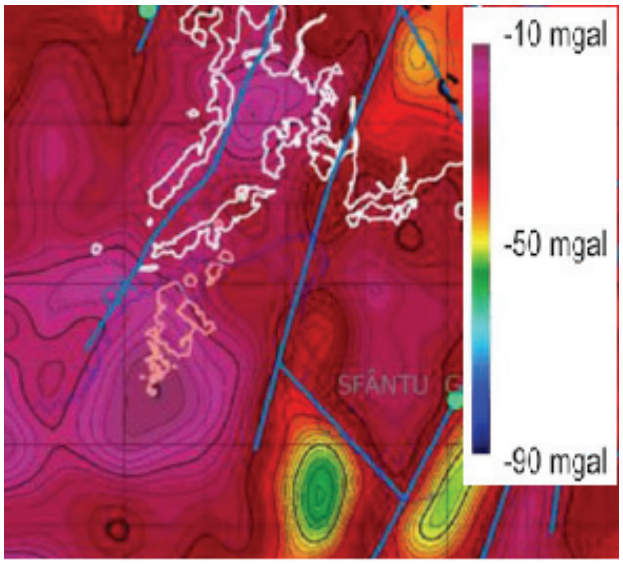

Figure 9. Bouguer anomaly in Harghita Mountains (in mgal).

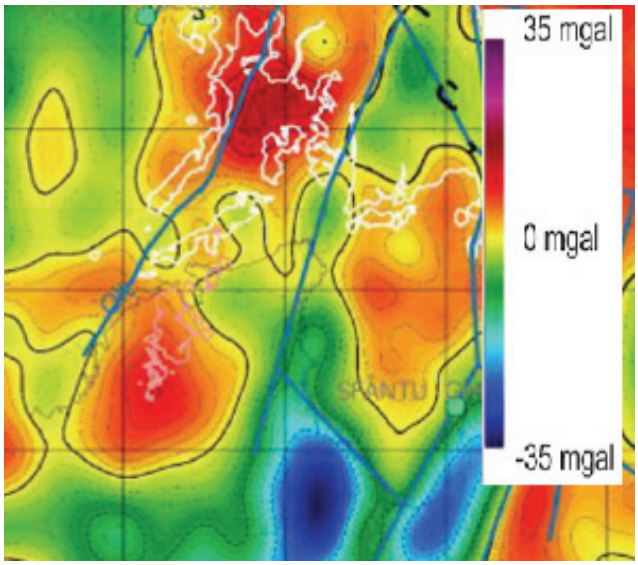

Figure 10. Residual of Bouguer anomaly in Harghita Mountains (in mgal).

The gravity anomalies (Bouguer and residual) map reflects gravity effects of large scale structures. They suggest thick geological bodies extending to depth all the way from surface. The strong negative anomaly eastwards corresponds to the folded and thickened crust of the Carpathian Orogen, that reflects the low density of sedimentary deposits. The strong positive anomalies westwards and in the intra-mountain basins system reflect the presence of high-density geological structures extending close to the surface.

The magnetic data originate from the archive of the Geological Institute of Romania (https://www.igr.ro/) and were interpolated and filtered with algorithms from MATLAB (https://www.mathworks.com).

For the Northern part of the volcanic structures, in figures 11 and 12 we present the total intensity anomaly of the magnetic field and the residual magnetic anomaly in the Călimani - Gurghiu Mountains.

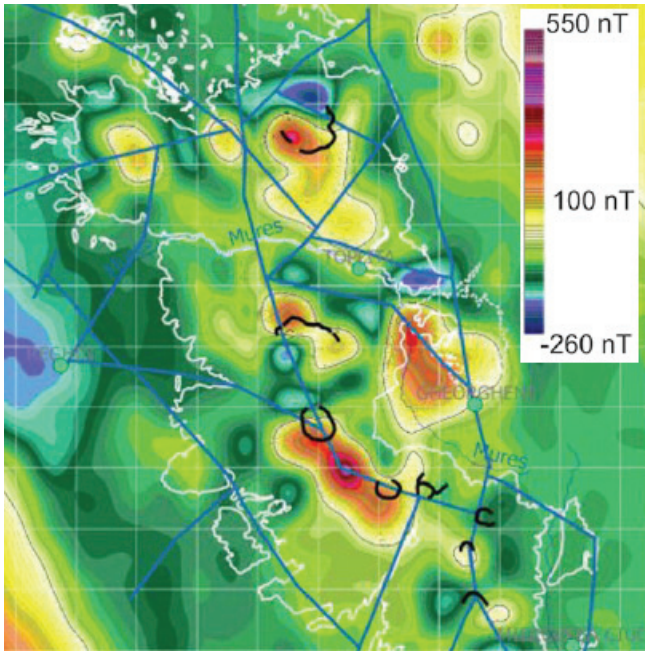

Figure 11. Total intensity anomaly of the magnetic field in the Călimani - Gurghiu Mountains (in nT).

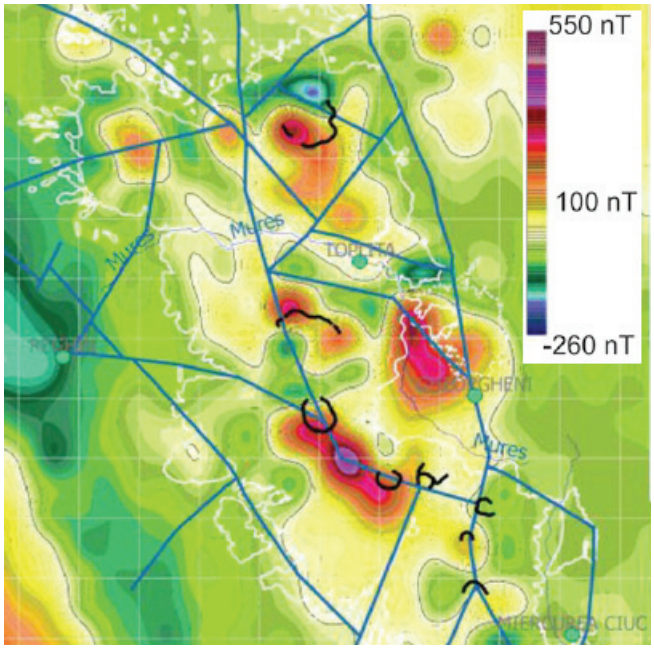

Figure 12. Residual magnetic anomaly in the Călimani - Gurghiu Mountains (in nT)

For the Southern part of the volcanic structures, in figures 13 and 14 we present the total intensity anomaly of the magnetic field and the residual magnetic anomaly in the Harghita Mountains.

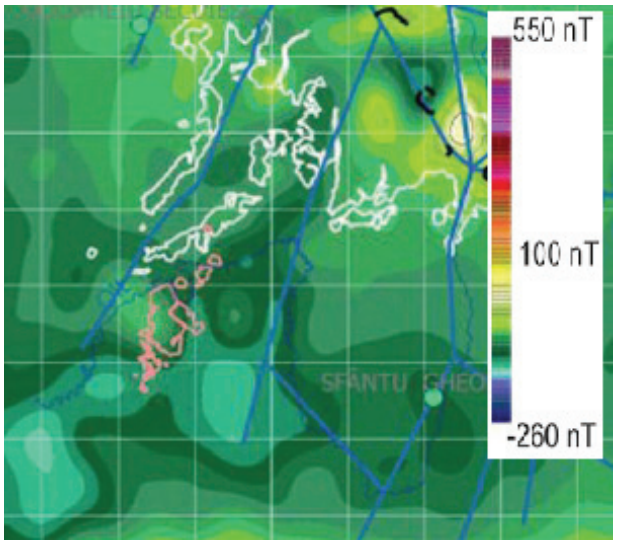

Figure 13. Total intensity anomaly of the magnetic field in the Harghita Mountains (in nT).

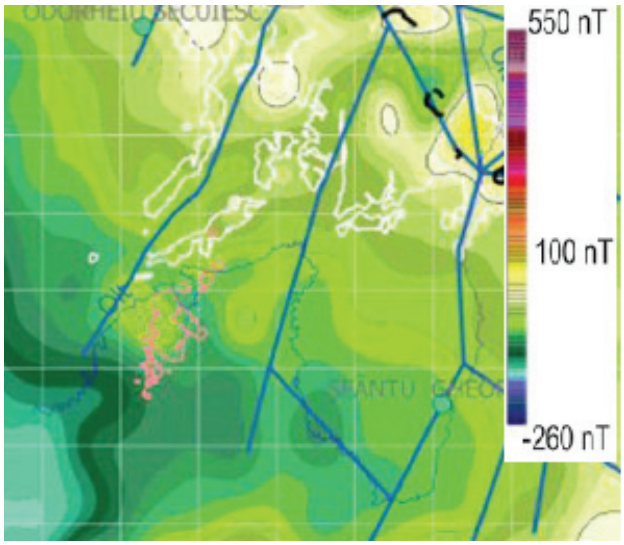

Figure 14. Residual magnetic anomaly in the Harghita Mountains (in nT).

The total magnetic intensity of magnetic field (Fig. 11 and Fig. 13) and the residual magnetic anomaly (Fig. 12 and Fig. 14) maps show that the high magnetic susceptibility bodies generating the anomalies are located in the shallow geological environment and extend to greater depth. The positive anomalies coincide with fault zones. The largest and intense magnetic anomalies are located in the northern and central part of the Călimani-Gurghiu-Harghita Mountains and diminish in size and intensity towards South.

CONCLUSIONS

The gravity anomalies (both Bouguer and residual) maps reflect the gravity effects of large scale structures. They suggest thick geological bodies extending to depth all the way from surface. The strong negative anomaly eastwards corresponds to the folded and thickened crust of the Carpathian Orogen, that reflects the low density of sedimentary deposits. The strong positive anomalies westwards and in the intra-mountain basins system reflects the presence of high-density geological structures extending close to the surface.

Both the total magnetic intensity of magnetic field and the residual magnetic anomaly maps show that the high magnetic susceptibility bodies generating the anomalies are located in the shallow geological environment and extend to greater depth. The positive anomalies coincide with fault zones. The largest and intense magnetic anomalies are located in the northern and central part of Călimani-Gurghiu-Harghita Mountains and diminish in size and intensity towards the South.

The spatial distribution of the volcanic craters indicates two trending systems: NNW-SSE and NE-SW. Also, NW-SE striking fault zone show volcanic craters that were active between 10.5 to 9.5 Ma and NE-SW faults mark the eruptive centres active between 9.5 to 8 Ma (SEGHEDI et. al., 2019)

Between 8 and 6.5 Ma, volcanic activity was along of NNW-SSE faults system. Volcanism migrated, in period from 6.5Ma to 0.03Ma, towards the SSE paralleling with fault systems associated with the intra-mountain basins.

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