Integrated study of the post-collisional Miocene-Quaternary volcanic forms in the East Carpathians using geological and geophysical constraints (InstEC - Project code: PN-II-ID-PCE-2012-4-0137)

2013-1st stage

Budget 2013
In LEI

Salaries	56378,00
Inventory	18000,00
Mobility	19892,00
Overhead (23,16%)	16068,00
Total	113338,00

THE STRUCTURE OF RESEARCH ACTIVITIES

The research was following several objectives/activities in correlation with the research plan:

A. ACTIVITIES RELATED TO BUILDING A GIS DATABASE

1. BUILDING UP THE GIS COMPATIBLE COMPUTER DATABASE (I)

1.1. DOCUMENTATION ACTIVITIES

The main area to be investigated using geological and geophysical studies in the INSTEC project is defined in Fig. 1 by the yellow polygon. However geological-petrological data investigation intends to cover all the area of Neogene magmatism in Romania, including Oaş and Gutâi Mountains volcanic structures. Also information from Neogene magmatic rocks in the Apuseni Mts. Understanding of all Neogene magmatic area in Romania will be used for comparing reasons and geodynamic interpretation at regional scale.

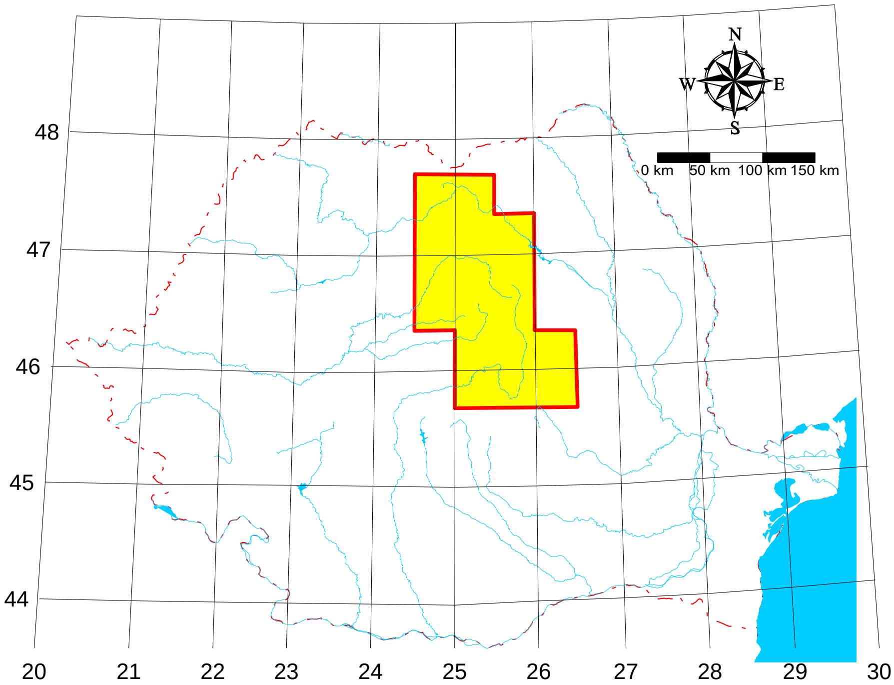

Fig. 1. – Location of the study area for integrated geological and geophysical data

INSTEC geological and geophysical target area covers a wide part of the Eastern Carpathians where previously prospecting/geological and/or geophysical research works were performed. Not all the results of these studies are published, and some of them are considered as confidential and may be consulted within special circumstances.

In order to be able to consult them, we have contacted the National Agency for Mineral Resources (NAMR), and started the procedures for obtaining the permission to use the unpublished data.

According to the Romanian legislation, any use of the information authorised by NAMR is only possible through the IGAR Office of Special Documents.

1.2. STRUCTURING DATABASE

As previously mentioned in the application form, the geophysical database mainly aims at providing gravity and geomagnetic data needed in the modelling and interpretation process. The data will allow us to:

- check-up current hypotheses regarding the structure and dynamics of volcanism in the Eastern Carpathians,
- build up gravity and geomagnetic interpretive numerical models, helping for constructing new models of the volcanism in the Eastern Carpathians.

The basic structure of the geophysical database can be seen in Fig. 2.

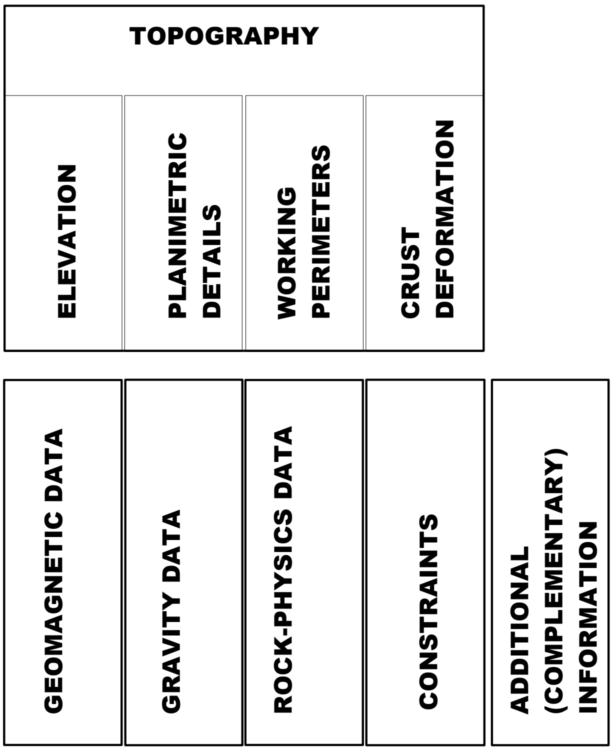

Fig. 2. - Structure of the geophysical database

On the other hand, the need for a GIS compatible database requires a spatial organization of information in close correlation with the geographic area to which it belongs.

The 1:100.000 scale Gauss map sheet was chosen as a storing base-unit. Fig. 3 shows the spatial organization of the geophysical database, as well as the Gauss code of the 1:100.000 map sheets.

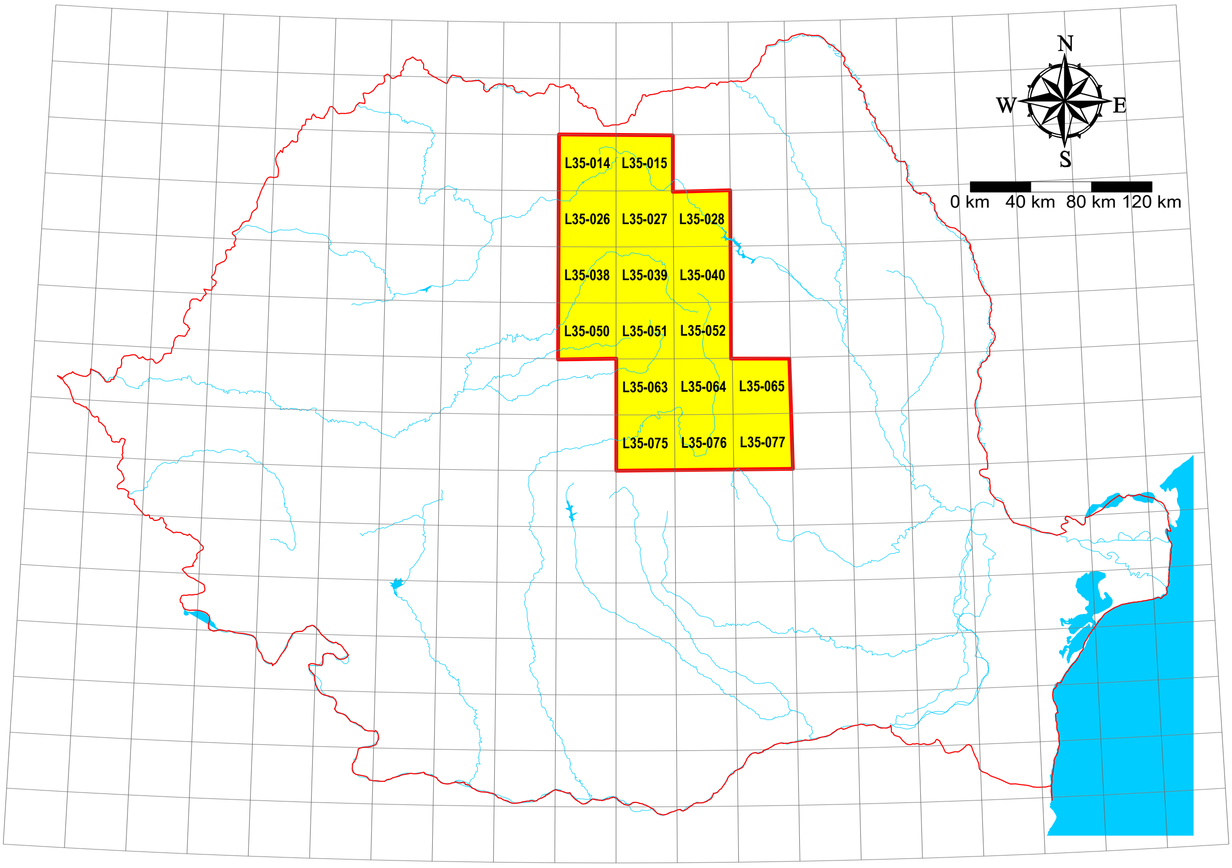

Fig. 3. – Spatial organization of the geophysical database (1.100.000 scale Gauss map sheets)

All the information will be stored in files named in relation with the appropriate Gauss code.

Each file‘s ID will have a code describing the type of information stored, as well as the corresponding 1:100.000 map sheet Gauss code. For example, **dh_L35-014** is the file containing the altitude information of L35-014 map sheet, while **dg_L35-014** is the file containing the Bouguer anomaly of the same area.

1.3. ORGANISING DATABASE

In a GIS compatible database, each file contains the horizontal coordinates and elevation of the observation points, to which one or more attributes that describe the additional information will be added.

The horizontal coordinates can be defined either as geographical coordinates (latitude and longitude) or as STEREO70 rectangular coordinates (Xstereo –northing and Ystereo - easting).

The simplest files are the DTM (digital terrain models) files. There is an example of such a file:

ID	latitude (degrees)	longitude (degrees)	Xstereo (meters)	Ystereo (meters)	Height (meters)

where Xstereo and Ystereo are the Stereo 1970 horizontal coordinates, and the height defined in the national 1978 Black Sea height system.

The gravity data files may contain also additional information such as:

ID	latitude (degrees)	longitude (degrees)	Xstereo (meters)	Ystereo (meters)	Height (meters)	dg (mgals) (2.20 g/ccm)	dg (mgals) (2.67 g/ccm)

where dg is the Bouguer anomaly computed for different reference densities.

The geomagnetic data files contain an attribute referring to the geomagnetic epoch too:

ID	latitude (degrees)	longitude (degrees)	Xstereo (meters)	Ystereo (meters)	Height (meters)	Geomag epoch	F (nT)	DF (nT)

where F is the geomagnetic total field and DF the geomagnetic anomaly.

1.4. BUILDING UP THE DTM

The achievement of DTM represents the first step in the construction of any GIS compatible database, by offering the structural frame for storing any kind of other type of gIS compatible data.

1.4.1 DTM on WGS 84 ellipsoid

The first DTM model has been constructed base on the global model of elevations: ETOPO 1.

(http://www.ngdc.noaa.gov/mgg/topo/)

ETOPO1 is a 1 minute arc global relief model of Earth's surface. Figure 4 and 5 show images of 2D and 3D terrain model built using ETOPO1 information for the INSTEC area.

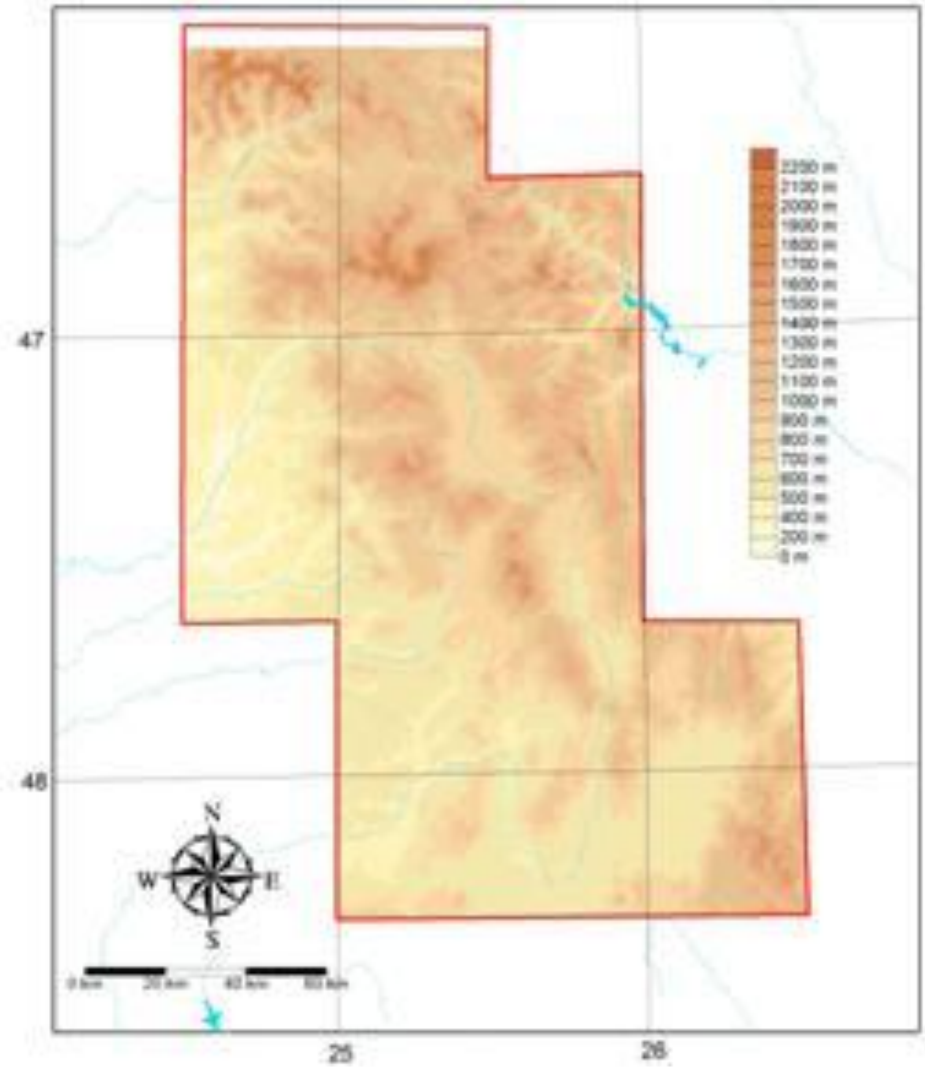

Fig.4. Regional digital terrain model on WGS 84 ellipsoid as derived from ETOPO 1 model

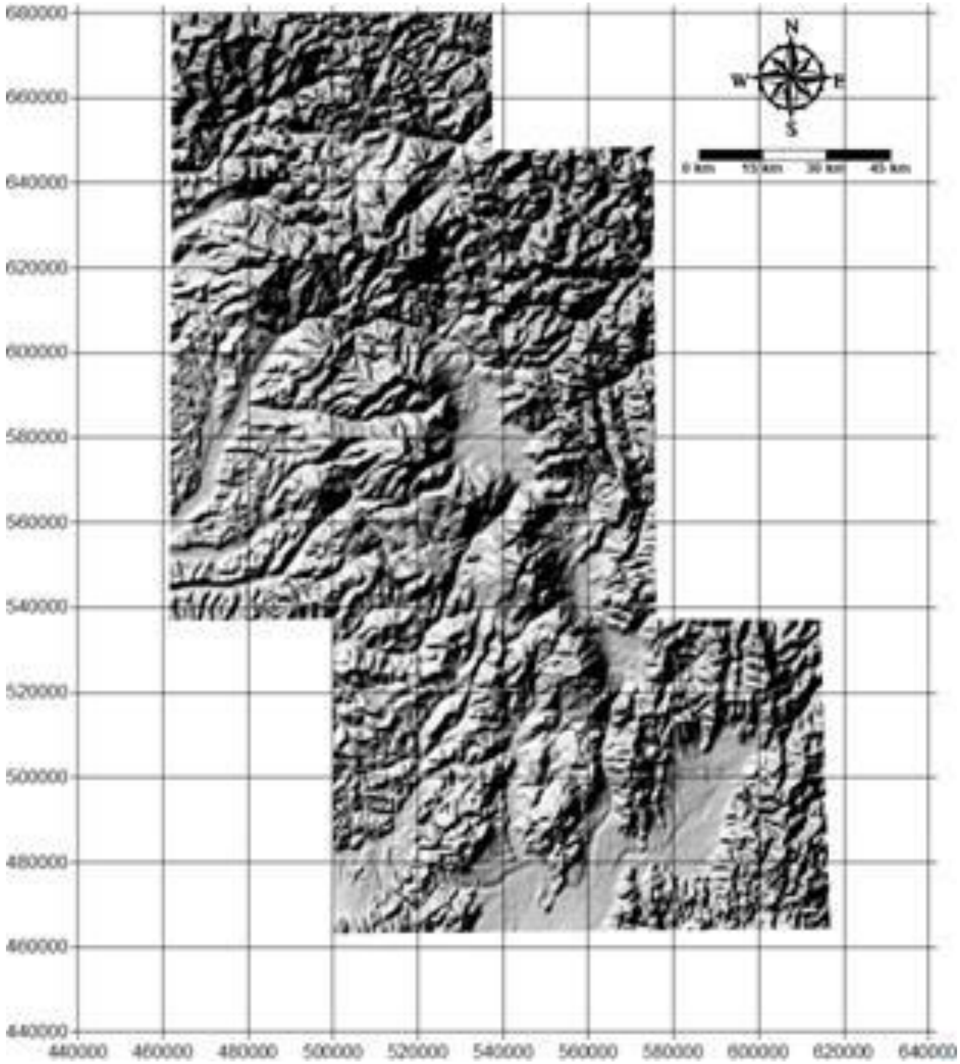

Fig.5. 3D regional digital terrain model on WGS 84 ellipsoid derived from ETOPO 1 model

1.4.2. DTM on Krassovski ellipsoid

Using ETOPO 1 model may cause some problems because of its poor (1 minute) resolution (1-2 km) and the vertical datum reference level, different from that one used for gravity observations. In Romania the points of the (aero) magnetic and gravity works were projected in Gauss-Kruger system and 1978 Black Sea height system.

Figures 6 and 7 shows a comparison between the resolutions of ETOPO 1 model and 1:100.000 Gauss- Kruger map sheets.

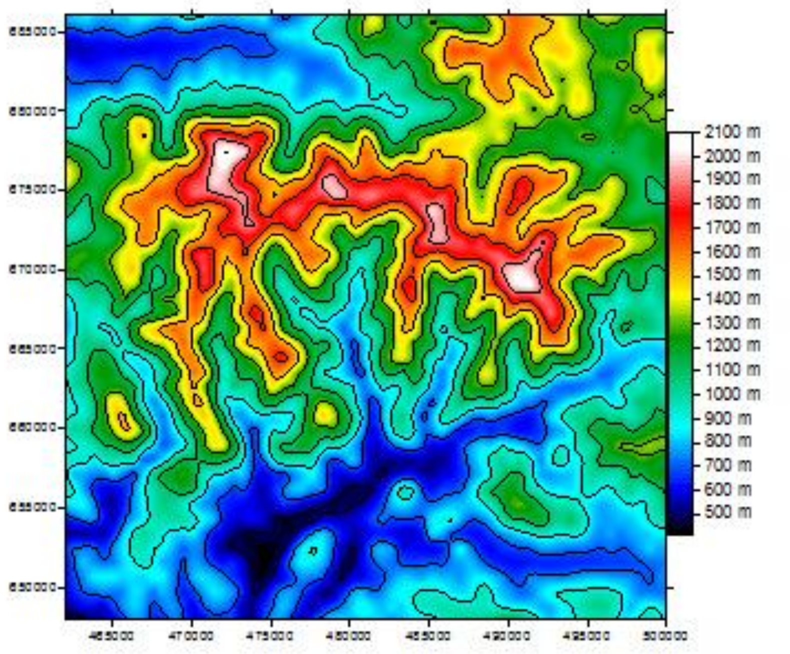

Figure 6. Terrain model for L35-014 map sheet on WGS 84 ellipsoid as derived from ETOPO 1

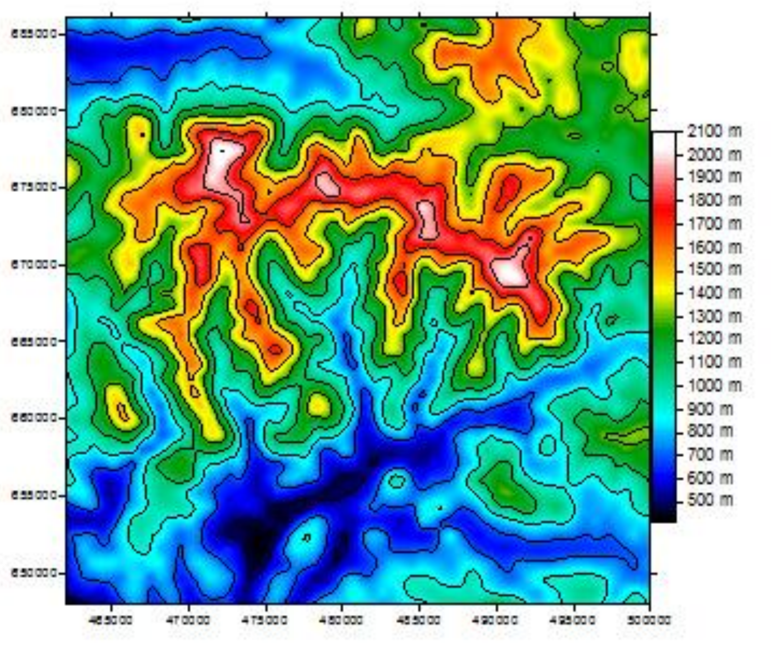

Figure 7. Terrain model for L35-014 map sheet on Krasovski ellipsoid and Gauss – Kruger projection

The appropriate advanced processing and interpretation of geophysical information require similar positioning systems with those employed during data acquiring. Especially the height system plays an important role.

This is why it has been decided to build up a DTM by digitizing the 1:100.000 Gauss-Kruger map sheets. These models have also a better resolution. Figure 8 illustrates two models with different resolutions for L35-014 map sheet.

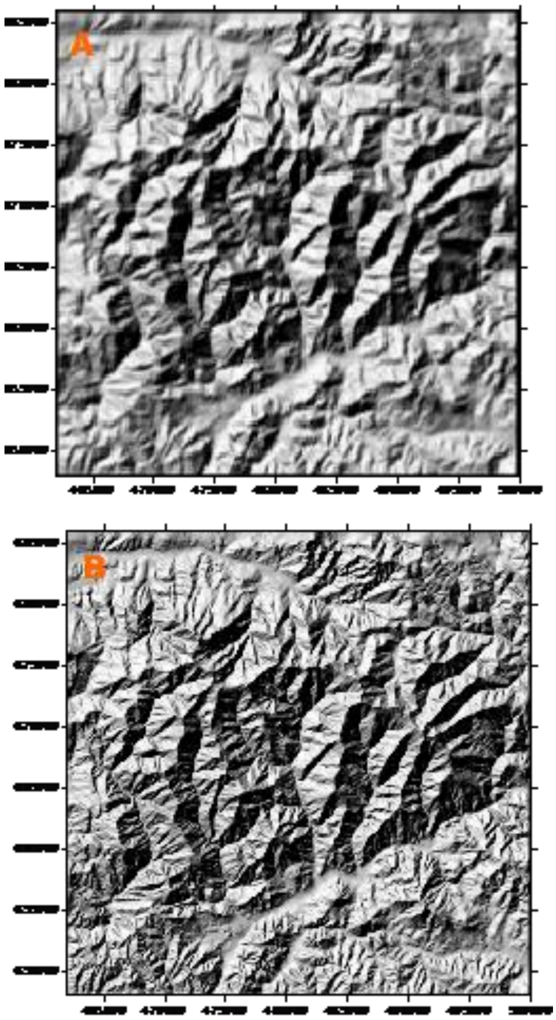

Fig. 8. L35-014 map sheet: the effect of model resolution. Models created with A. a cell grid of 200m x 200m; B. a cell grid of 50m x 50m.

1.4.3. Topography data transfer on electronic support

The published maps have been scanned and digitized, and information referred in the stereographic projection system STEREO 1970 by the help of the commercial computer application DIDGER (©Golden Software).

The following operations are necessary:

- scanning the information provided on the paper support

- setting-up the frame for the transfer to STEREO 1970 system

- digitising altitude information

- digitising planimetric details

All the above-mentioned operations are time-consuming and must be carefully implemented, especially in the mountain areas.

This is why the last stage is represented by the validation of the data.

The state-of-the-art in the achievement of the DTM is shown in Figure 9. The study area was almost fully covered, the only exception being L35-052 map sheet which will be validated till the end of 2013.

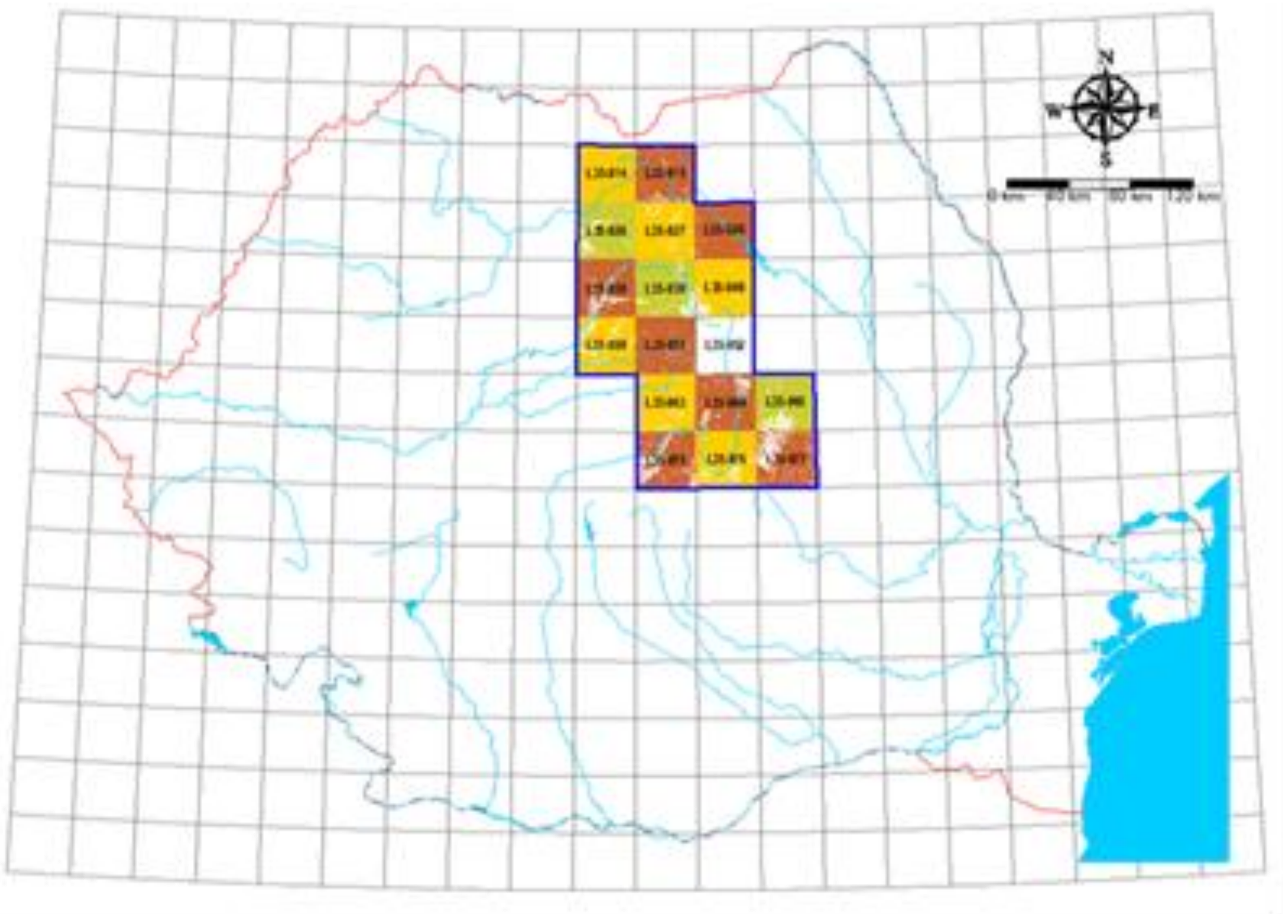

Figure 9. Current state of topographic data transfer on electronic support

1.5 MAGNETIC MINERALOGY DATABASE – METHODOLOGY

Database of magnetic mineralogy achieved in this stage of the project is a compilation of data obtained from magnetic susceptibility and paleomagnetism measurements on Neogene volcanic rocks.

The study area corresponds to Harghita Mountains and to the southern part of the Gurghiu Mountains, Eastern Carpathians. Over 190 points were processed.

Rock samples core of 2.5 cm diameter have been extracted by the help of a portable drilling device. The orientation of the core samples has been determined by employing a Brunton compass and a solar compass where possible.

Paleomagnetic determinations were conducted in the Paleomagnetism Laboratory of the Bucharest University by the courtesy of Professor Cristian Panaiotu.

The magnetic mineralogy database contains:

- **Localization of outcrops – Latitude (^{o}), longitude (^{o}) and altitude (m)**. Strategy of outcropping was established taking into account the works of Szakács, Seghedi (1995) and the National Geological Map of the Romania, scale 1:200.000 (Sandulescu et al., 1968). Location of the sampled outcrops has been determined with a portable GPS Magellan Explorist 600.
- **Magnetic susceptibility**, **K (SI)** – The observations on the magnetic susceptibility of the rock samples were performed by employing the MFK1A (AGICO) device with an accuracy of 2x10-8SI.
- **Natural remnant magnetization** (**NRM) [A/m]-** NRM determinations have been conducted by the help of the spin magnetometer JR-6A (AGICO) credited with an accuracy of $2x10^{-6}$ A/m.

The vector **natural remnant magnetization** is given by: amplitude MR (A/m), declination (Dge), inclination (Ige).

Magnetic polarities were extracted from orthogonal demagnetization Zijderveld diagrams; N = normal polarity, R = reverse polarity, T = transition direction between the two polarities.

The current WMM values in each sampling point (D_deg, D_min, I_deg, I_min, F_nT) were obtained using the EMM2010 program. This program is offered by NGDC (National Geophysical Data Center) of NOAA and is dedicated for calculating the Earth's magnetic field with a spatial resolution higher than conventional models because it includes the contribution of crustal magnetic field. It highlights wavelength magnetic anomalies of at least 56 km. (http://www.ngdc.noaa.gov/geomag/EMM/downloads/emmSPHDownload.html)

- **External magnetic field strength** was calculated by transformation F nT in F_A / m.
- **Induced magnetization (MI [A/m] = k(SI)*F_A/m.)**
- **Koenigsberger ratio (Q) (Q = NRM/MI)**

B. ACTIVITIES RELATED TO DATA SYNTESIS

At this stage we focused on the following objective:

2. ANALYSIS AND CRITICAL DISCUSSION OF THE CURRENT MODELS ASSOCIATED TO GEODYNAMIC EVOLUTION OF THE EAST CARPATHIANS IN CONNEXION WITH MIOCENE-QUATERNARY MAGMATIC ACTIVITY (1).

2.1. GEODYNAMIC MODELS FOR THE EAST CARPATHIANS (1)

Geodynamic reconstructions in the Carpathian-Pannonian Region (CPR) are the result of manifold geological and geophysical approach. The progress in the geodynamic reconstructions is reflected in the succesive models realized up to now. The initial models were generated by using mainly geological information, whereas the recent ones includes increased petrological and geophysical data. The first models discussed geosynclinal theory. An important step in the knowledge was the introduction of the global theory of plate tectonic developed at the beginning of the 70th (ex. Dickinson, 1971). According to this new theory, the early geodynamic models for the CPR adopted the model of circum-Pacific areas, so that all the mountain areas at the border of European Plate were interpreted as a result of the collision between an "island arc" and the European continent. "Island arc" were defined by their characteristic structural elements: (1) oceanic plate; (2) through; (3) folded basement; (4) calc-alkaline magmatic arc; (5) a backarc basin. The items (3), (4) and (5) have been considered in some models characteristic for CPR, at that time assimilated as an arc-type, or even "island arc" type (ex. Bleahu et al., 1973; Rădulescu, Săndulescu, 1973; Boccaletti et al., 1973) (Fig. 10).

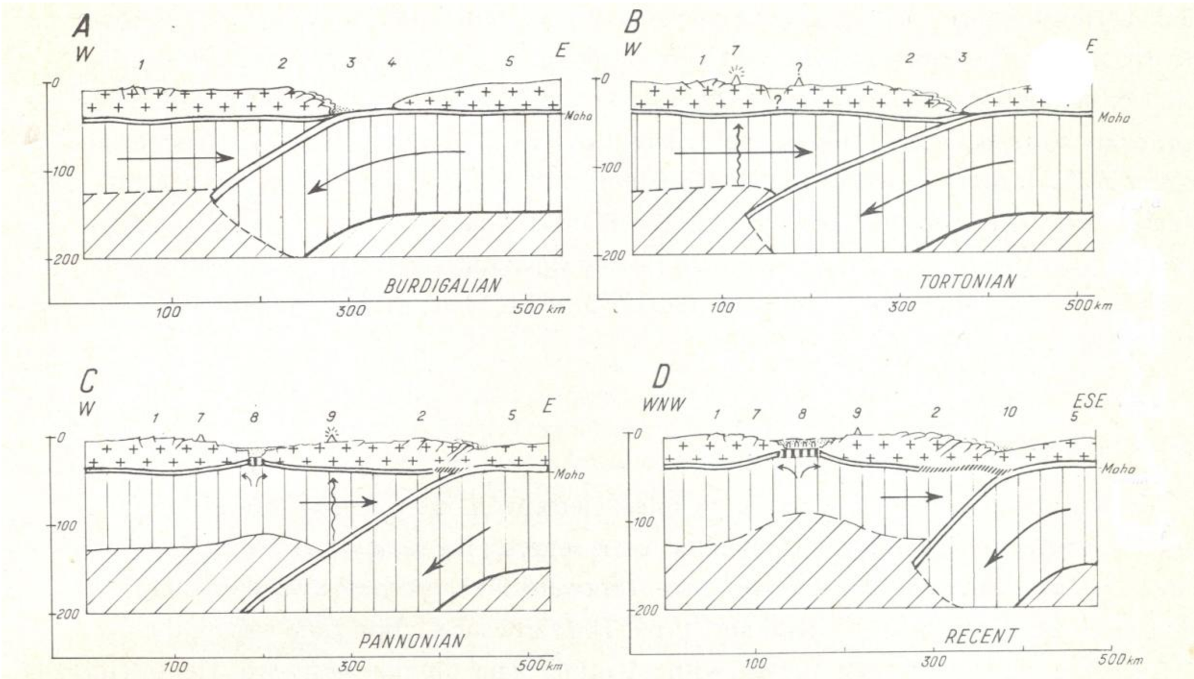

Fig. 10. – Interpretative geological cross-sections along the East Carpathians (acc. Boccaletti et al., 1973) that suggests the tectonic plate model for Burdigalian-recent times. Symbols: crosses: continetal crust; vertical lines: upper mantle; oblique lines: asthenosfere; 1: Apuseni; 2: East Carpathians; 3: through; 4: oceanic crust; 5: East Carpathian platform; 7: calc-alkaline rocks in Apuseni Mts.; 8: Transilvaniya basin as back-arc type; 9. calc-alkaline rocks in the East Carpathians (Călimani-Gurghiu-Harghita volcanic chain); 10: Areas with active sedimentation and negative Bouguer anomaly.

The following research studies evolved following two shemes: tectonic reconstruction (1) and reconstruction of magmatic processes (2) in this way enhansing the previous simplistic models with complex models that highlight the special pecularities of the Alpine-Carpathian-Hymalaian belt, as difeent from the circumpacific one (e.g. Prelevic, Seghedi, 2013).

(1) The geotectonic reconstructions proved that the basement of the Intra-Carpathian area is composed of several continental blocks (terranes), recognized in the literature as ALCAPA, Tisia (Tisza) and Dacia (e.g., Balla, 1984, Csontos *et al.*, 1992; Schmid et al., 2008). ALCAPA block is situated in the northen part of Pannonian Basin, since Tisia and Dacia are sucessively developed in the southern part of the Pannonian Basin, including Apuseni Mts and Transylavania Basin. ALCAPA block is separated by the Tisia block by a major tectonic

dijunction known as Mid- Hungarian Line, active probably since Cretaceous times and a place of numerous tectonic deformations (e.g., Csontos *et al.*, 1992; 2002).

Tisia and Dacia blocks were characterized by a different geologic history during the Mesozoic times, as reflected also by the paleomagnetic data (Pătraşcu *et al.*, 1994). The welded crustal Tisia-Dacia entity is a result of Early-Middle Cretaceous collision, as suggested by the crustal thickening and tectonic nappe generation in Apuseni Mts. (e.g., Balintoni 1997; Dallmeyer *et al.*, 1999), South and East Carpathians (e.g., Săndulescu, 1984, Berza *et al.*, 1994). Geological data suggests that Alcapa and Tisia blocks were derived from the northern margin of Adria (=Apulia) block (e.g., Săndulescu, 1994; Schmidt *et al.*, 2008). Geodynamic evolution of these blocks during the Neogenea implied translation and rotation of the mentioned blocks (e.g., Csontos, 1995; Fodor *et al.*, 1999; Csontos et al., 2002).

Recent tectonic reconstruction of CPR (e.g., Csontos, 1995; Fodor *et al.*, 1999; Huismans *et al.*, 2001; Ustaszewski et al., 2008) suggests that Tisia was translated toward the east during Early-Middle Miocene, along the Alcapa block(Fig. 11).

Such complex tectonic processes generated an impressive active force of movement of the tectonic blocks that implied rotation, collision and acccretion suggesting the probable implication of the subduction accompanied by rotation of the lithospheric blocks presently attched to the European Plate (e.g., Royden, 1988; Săndulescu, 1988; Royden & Burchfiel, 1989; Csontos *et al.*, 1992; Csontos, 1995). Paleomagnetice data prove a clockwise rotation of ~20^{o} during Eocen- EarlyMiocene times (Pătraşcu *et al.*, 1994; Panaiotu, 1998), period when ALCAPA suffered ~30^{o} counterclockwise rotation processes (Márton, Márton, 1996).

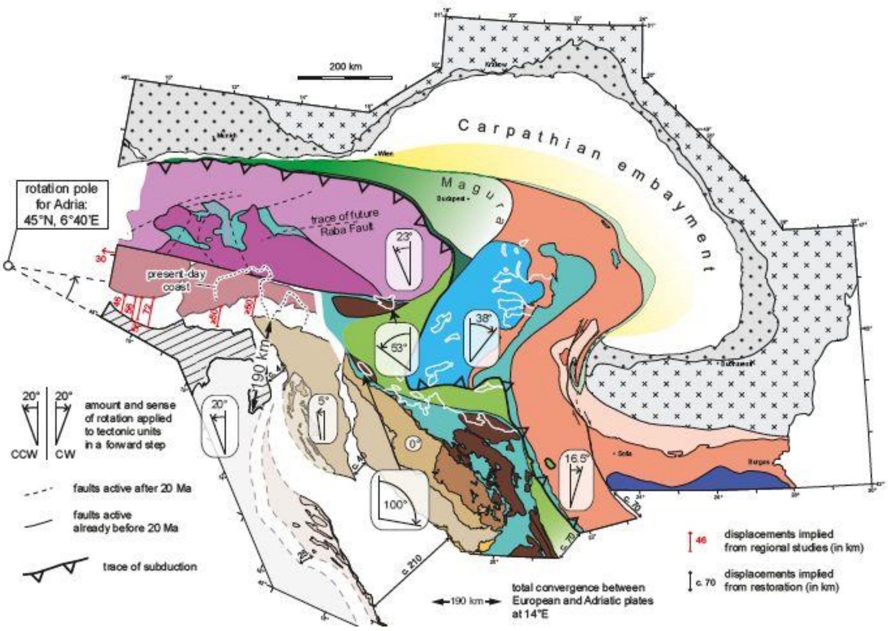

Fig.11. - Restoration of tectonic units in the Alps, Carpathians and Dinarides domain for the Early Miocene. Colours and patterns of tectonic units after Ustaszewski et al. (2008)

Starting to Middle Miocene Tisia and Dacia blocks have been implicated in rapid clockwise rotation (~60^{o}). These rotations started at ~ 14 Ma, diminished at 13 Ma up to 28^{o} and stoped at ~12 Ma (Panaiotu, 1998, 1999). Between 14-12 Ma, only the nord-estern part of ALCAPA was rotated, as couterclockwise between 50^{o}-20^{o} (Panaiotu, 1998, Márton *et al.*, 2000). Important clockwise rotation of Tisia (along Dacia) (Apuseni Mts.) generated during Badenian – Early Pannonian times, at the upper crustal levels normal faulting perpendicular on the rotation axis (e.g., Csontos *et al.*, 2002). These faulting was reeponsible for a series of basin generation of core-complex type toward NW-SE direction, visible along the western margin of the Apuseni Mts. (e.g., Royden, 1988; Săndulescu, 1988; Balintoni, Vlad, 1998). Similar graben type basins were detected in the adjacent Pannonian Basin (e.g., Balla, 1984, 1987; Csontos, Nagymarosy, 1998; Csontos et al., 2002). This type of extensional basins is syncronous with major rotation and coincides with sedimentation and magmatic processes strating with Early Badenian (e.g., Balintoni, Vlad, 1998; Roşu *et al.*, 2004; Seghedi *et al.*, 1998, 2004). A schematic geodyanmic evolution is given in the în Fig. 12, after Csontos *et al.* (2002; figura 12c) and Seghedi *et al.* (2004; figura 2b). Upper figure (Csontos *et al.*, 2002) presents the geodynamic situation at the end of major rotations (Panonian times). Lower figure after Seghedi *et al.*, (2004) sugest that the Apuseni Mts. magmatism, as part of Tisia, is in direct connection with the major clockwise rotations between 15.5 - 11 Ma, when the core-complex type extension was associated with graben type basins. In this time interval contemporaneous clac-alkaline magmatic activity developed in the front of Alcapa and Tisia blocks (Pécskay *et al.*, 1995a,b; 2006), in direct conexion with similar type of core complex lithospheric extension as for Tisia (e.g. Nemčok *et al*., 1998; Seghedi *et al*., 1998, 2001, 2004; Seghedi, Downes, 2011). The collision of Tisia block during Upper Miocene (~11 Ma), was considered as a result of the end of subduction retreat with implication of East European Platform megablock (e.g., Csontos, 1995; Maţenco, 1997; Zweigel, 1997).

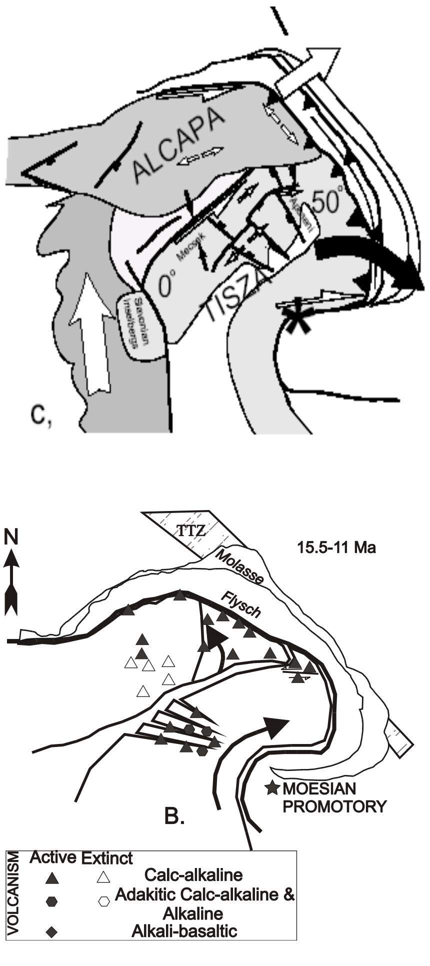

Fig. 12 – Simplified sketches of geodynamic evolution of CPR during Middle-Upper Miocene. This figure reproduces the Fig. 12c from Csontos et al. (2002), suggesting the geodynamic situation resulted during main rotation and translation toward the east (corresponding to Pannonian time). It can be observed the differential rotation processes corresponding to the central and eastern part of Tisia, and also the graben basin opening in the western Apuseni Mts. The lower figure reproduce figure 2b in Seghedi et al. (2004), showing the distribution of the magmatism inside Tisia block (Apuseni Mts.) as being in close relationship with peak rotation period between 15.5 - 11 Ma, concomitant with graben generation. In the same time interval the figure is showing the presence of a contemporaneous calc-alkaline magmatism in the front of Alcapa and Tisia blocks.

Starting to Upper Miocene up to the present times the stress indicators suggests the prevalence of a compresive stess in the southernmost part of the Transylvania basin and its margins toward E-W and NW-SE, followed by an important isostatic uplift (e.g. Huismans *et al*., 2001; Ciulavu *et al*., 2002; Sanders *et al.*, 2002).

Between the mentioned internal blocks and the European platform the Carpathian nappes were compressed with ca. 160-260 km (e.g. Morley, 1996; Behrmann *et al*., 2000; Maţenco et al., 2007; Ustaszewski *et al*., 2008). The contraction processes finished at ca. 11 Ma, but this episode is controversial, since assume subduction processes of a lithospheric material not yet specified.

(b) The studies generated after 1995 concerning the age of the magmatic rocks deny their generation as a result of a direct subduction process, as suggested in the previous studies, taking into account the supposition that the calc-alkaline magmas should be exclusively related with direct subduction processes. In the East Carpathians the volcanism postpone the generation of nappe tectonic units and it is subsequent in Upper miocen-Quaternary times, and in consequence is post-collisional (Mason *et al*., 1996, 1998, Seghedi *et al*., 2011) as generated during contemporaneous extension tectonic processes (Fielitz, Seghedi, 2005). Călimani-Gurghiu-Harghita (CGH) chain represents an important volume of calc-alkaline products joined in its southern part by small volume basaltic Na-alkaline and potassic alkaline associations (Szakács, Seghedi, 1995; Seghedi *et al*., 2004, 2011; Seghedi, Downes, 2011; Lexa et al., 2010). This pattern suggests a continuous N-S rejuvenation in the 11Ma-recent interval (ex. Pécskay *et al*., 2006). In fact all the magmatic occurrences along the East Carpathians including Oaş-Gutâi volcanic areas, " subvulcanic zone" area(Gröger *et al*., 2008; Pécskay *et al*, 2009) and CGH volcanic chain, strongly evidenced in topography, were generated close to the collision zone of the Carpathians as a result of post-collisional complex tectonic deformations. Such processees facilitated a development of a complex fracture system, extremely active during the magma generation at the surface (Fielitz, Seghedi, 2005). At that time the contemporaneous magmas were acting as a lubricant for tectonic processes (Seghedi, Downes, 2011).

This is a clear demonstration that calc-alkaline magmas were generated not as a direct product of subduction processes, but as a result of adiabatic deccompression processes and lithospheric partial melting during post-collision stage. To generate such kind of magmas it was necessary that the lithospheric mantle to conserve former subduction components (fluids, sediments) (e.g. Seghedi et al., 2004). The presence of a high thermal flux superimposed to CGH volcanic area (e.g., Tari et al, 1999; Demetrescu et al., 2001) is suggestive for acceptance of asthenosphere upwelling, that could be explained by oblique collision and progressive breakoff from N-S, appropriate volcanic activity migration in time and space in the same direction (Mason et al. 1998; Seghedi et al., 1998; Wortel, Spakman, 2000). The volcanic areas of South Harghita and Persani Mts. is the most controversial since of its unusual tectonic setting that produced up to now a numerous geodynamic models (e.g. Cloething et al., 2006; Ismail-Zadeh et al., 2012 şi referinţele incluse) and of its very complex magmatic rock petrology (e.g. Downes et al., 1995; Seghedi et al, 2011) that imply the connexion with Vrancea seismic area.

C. FIELDWORK ACTIVITIES

This material speaks of the third objective of the project:

3. THE IDENTIFICATION AND DESCRIPTION OF THE MAIN TECTONIC ALIGNMENTS THAT WERE ASSOCIATED WITH MAGMATIC ACTIVITY, BASED ON GEOLOGICAL AND GEOPHYSICAL DATA - FIELDWORK

3.1. GEOLOGICAL STUDIES IN THE PERȘANI MOUNTAINS

Fieldwork was performed in the Perșani Mountains in order to identify the volcanic structures, to constrain the processes that influenced the types of eruption and in order to identify the tectonic elements which favored the transportation and extrusion of magmas. The working methodology was based on detailed mapping of the volcanic area and on describing the structural, textural and compositional features of the magmatic deposits, and the spatial relation between them. A first result was the discovery of 6 new volcanic structures that were previously unknown. They consist in 6 craters associated with phreatomagmatic deposits (tuff rings and maars), 4 lava flow fields and 3 strombolian scoria cones. A part of the new cartographic image is shown in figure 13, as an interpretative tectonic and volcanologic sketch.

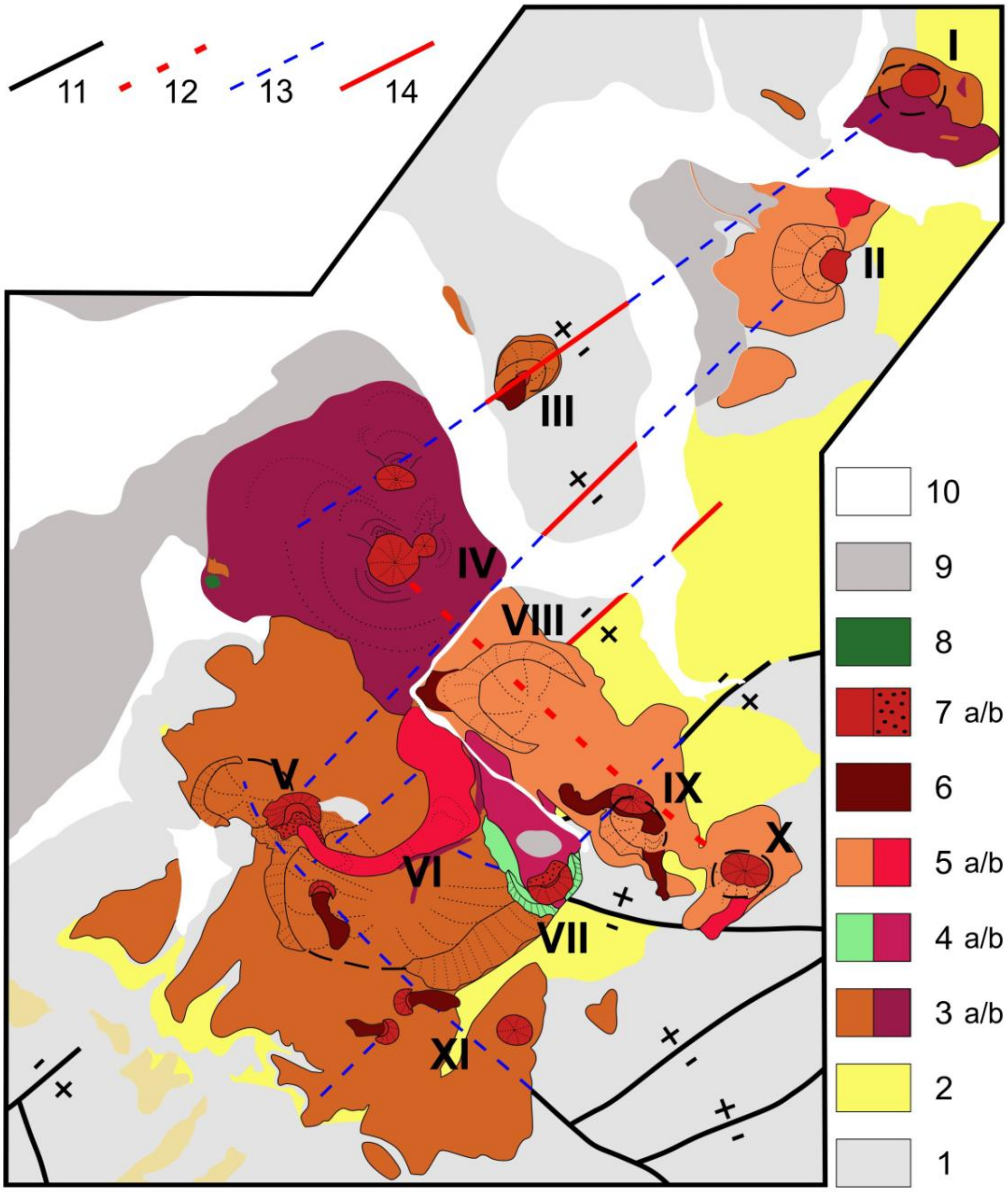

Fig. 13. – Tectonic and volcanologic interpretative sketch of the alkali basalt volcanic field from the Perșani Mountains. Legend: 1-Ante-pleistocene geological formations, 2-miocene tuffs, 3a-phreatomagmatic deposits 1.2Ma, 3b-lava flows 1.2Ma, 4a-phreatomagmatic deposits 800Ka, 4b-lava flows 800Ka, 5a-phreatomagmatic deposits 600Ka, 5b-lava flows 600Ka, 6-undated lava flows, 7a-strombolian scoria cones, 7b-strombolian debris deposits, 8-travertine, 9 – Pleistocene sedimentary deposits, 10 – quaternary sedimentary deposits, 11-faults, 12-presumed faults, 13-extension of faults, 14-faults derived from topographic profiles. I- Racoş volcano, II- Mateiaş volcano, III

Turzun volcano, IV- Măguricea volcanic structure, V- Gruiu volcano, VI- Bârc volcanic structure, VII- 636 volcanic structure, VIII- Bogata 1 volcano, IX- Bogata 2 volcano, X- Bogata 3 volcano (Pietrele).

The volcanic structures are disposed on NW-SE and NE-SW oriented alignments, which suggest a tectonic control. Two normal fault systems which coincide with this lineaments have been observed, the volcanoes being located especially at their intersection. The NE-SW trending faults are the most common, leading to the subsidence of basement compartments. These appear as depression-like structures, filled by volcanic material. The compartment that has subsided the most coincides with the volcanic field of Bogata valley, where lava flows from Măguricea, Gruiu, 636 and Bogata converge. As for Turzun volcano, which is considered to be one of the oldest structures, it can be observed that the volcanic deposits are slightly affected by faults, suggesting that the faults were active not only prior and during the eruption, but also afterwards. We can already conclude that the faults were the access routes for magmas towards the surface, and that the multitude of intersections between the two mentioned tectonic systems have controlled the monogenetic nature of volcanism. For mechanical reasons, it was easier for eruptive centers to migrate, than for magmas to erupt from the pre-existing vent areas.

Fieldwork data indicates that, with only a few exceptions, the eruptions followed the same general pattern, with each volcano passing through 3 phases. The first phase was explosive phreatomagmatic, generated by the interaction of magma and groundwater from basement Miocene tuffs, conglomerates and Cretaceous limestone. Sometimes, shifts from a phreatomagmatic to phreatic character and vice-versa can be observed. This was induced by varying amounts of magma and water that came into contact. Tuff ring and maar crater structures are developed in this first phase. The second phase is explosive magmatic, generating strombolian scoria cones. The third phase is effusive and characterized by the emplacement of successive lava flows fields, which either dislodge portions of the scoria cones (as in Gruiu and 636), either seep from the base of the cones. In this last case, observed at Măguricea, Bogata 3 (Pietrele), Trestia, Comana and Racoș, the morphology of the volcano is not evidently affected.

The exception from this pattern are the structures of Bârc valley (the widest tuff ring structure, with no strombolian phase and with lava flows infiltrated in the intra-crater phreatomagmatic deposits), Bogata 1, Comana Nord and Comana Vest (similar in behavior with the previous example), NV Gruiu (which only shows the first phase) and the volcanoes from Trestia valley (with no phreatomagmatic structures, showing only strombolian and sometimes effusive behavior).

3.2. GEOLOGICAL STUDIES IN THE SUBVOLCANIC AREA FROM THE RODNA-BÂRGĂU MOUNTAINS

Structural fieldwork studies have been performed, focused on the tectonic evolution of the Upper Miocene intrusions from the western extremity of the Rodna-Bârgău area. Petrographic and tectonic observations were also made on the Paleogene sedimentary deposits and metamorphic rocks which host the intrusions. The structural relations between the intrusions and host rocks were described and measured.

The Eastern Carpathians, as we know them today, have been shaped during the Miocene-Pliocene tectonic events (Săndulescu, 1984; Huismans et al. 1997; Maţenco et al. 2003). This is due to the fact that the Middle Cretaceous to Paleogene continental accretion was followed by a similar event in the Middle Miocene. This second accretion resulted in the Moldavides being thrust over the East European Platform (Săndulescu, 1984, 1988; Csontos, 1995). This event generated transpressive – transtensive crustal movements (Tischler et al. 2006), witch lead to local crustal extension (in the Median Dacides and in the east side of the Transylvanian Basin). In areas such as Rodna and Bârgău, isostatic balance has been achieved through the movement of individual tectonic compartments (Sanders et al. 1999). All these Middle to Upper Miocene processes lead to the emplacement of the magmatic intrusions from Rodna and Bârgău, as well as in neighboring areas (Pécskay et al. 1995a,b; Pécskay et al. 2009). This was preceded by a rhyolitic explosive event that happened in the Transylvanian Basin and generated the Dej tuff (Szakacs, 2000). Afterwards, controlled by the same tectonic regime dominated by tectonic exhumation (Sanders et al. 1999), a dominantly extrusive magmatism was developed from the Călimani towards the Perșani Mountains in the south, and towards the north-west from Oaș to Gutâi (Fielitz, Seghedi 2005; Seghedi et al. 2005;

Kovacs et al. 1995; Szakacs, Seghedi, 1995, 1996; Seghedi et al. 1998; Mason et al. 1998; Downes et al., 1995).

In the Rodna-Bârgău area, according to the stratigraphy described in the 1:50000 scale maps (Rebra, Rodna Veche, Ineu, Pietrosul Rodnei sheets), the Paleocene deposits are missing, thus confirming the post-Austric exhumation which affected the Rodna Massif (Gröger, 2006). This was followed by subsidence in the Bârgău area, as the Eocene deposits that overly the metamorphic and Cretaceous basement suggest. Sedimentation continues generally uninterrupted until the Middle Miocene.

To the south-west of the Bârgău area, the Burdigalian molasses deposits formed during the Pienides thrust event can be found (Săndulescu 1984, 1994). At the end of the Burdigalian a transpressive – transtensive regime is initiated along the Dragoș Vodă and North-Transylvanian fault systems; this generates the Rodna asymmetric horst and also affects the neighboring areas and Pannonic Basin (Györfi et al. 1999).

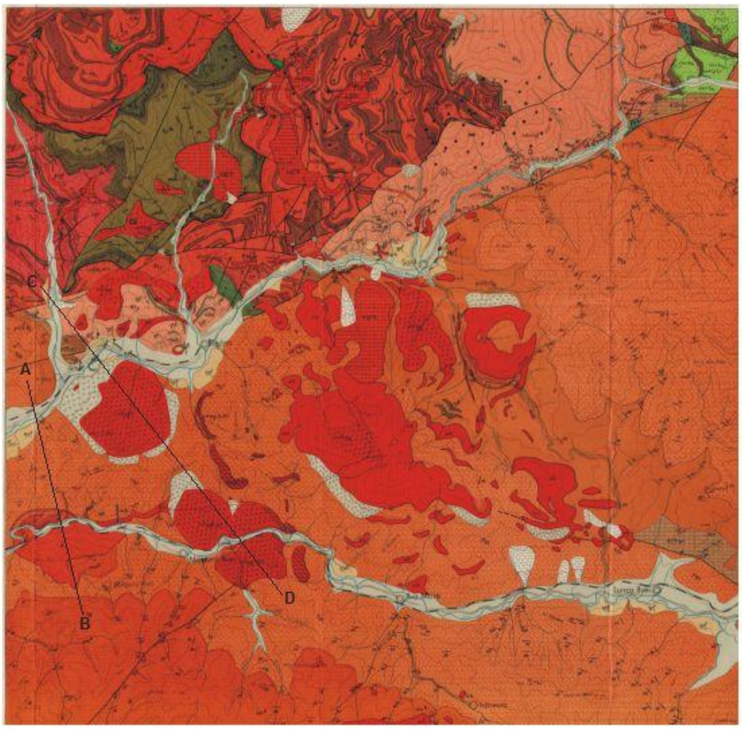

Fig. 14. - Rodna Veche geological map, 1:50000 scale, (Kraütner et al., 1978) showing the orientation of the A-B and C-D geological profiles. Legend according to the geological map of Romania, edited by the Geological Institute of Romania.

This tectonic regime was also active during the Upper Miocene, when then transtensive component became dominant on a large extent, from the Rodna-Bârgău region to the Pannonian Basin (Györfi et al. 1999; Ciulavu, 1999; Gröger, 2006; Tischler et al. 2006). This results in local extensions, which favour the generation, transport and emplacement of magmas (Pécskay et al. 1995a,b; Pécskay et al. 2009), the intrusions being emplaced in a relatively short time interval, between 11,5 and 8 Ma. The intrusions pierce through all the basement formation, starting with the Rodna metamorphic unit, until the Upper Miocene sedimentary deposits (Figs. 14, 15, 16). Their spatial distribution and relation with the host rocks suggests that an extensional regime was involved. At this moment, a relevant statistical analysis is not yet possible, due to the fact that more cinematic indicators need to be measured.

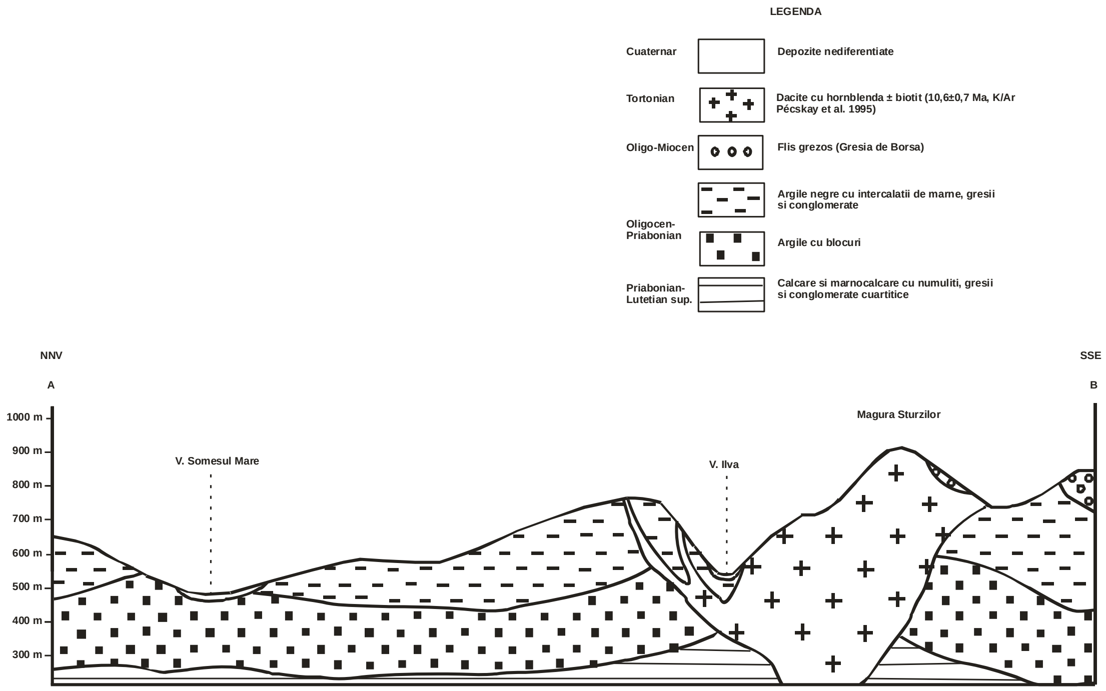

Fig. 15 - Interpretative geological profile A-B (see Fig. 14), showing the intrusive structure from Măgura Sturzilor

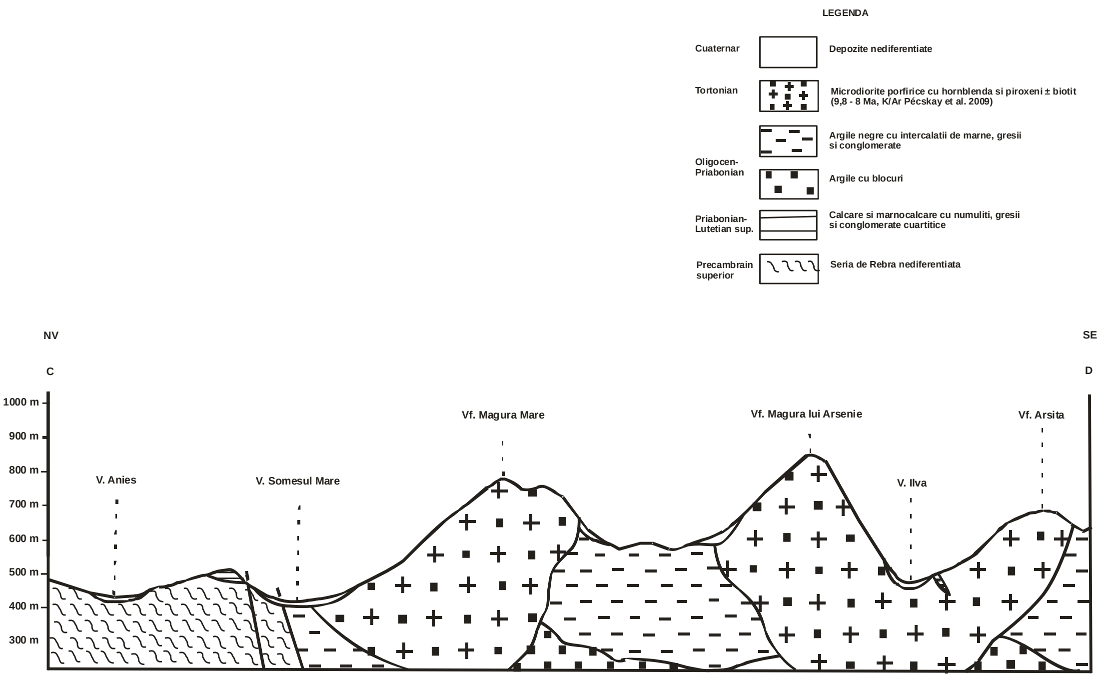

Fig. 16 - Interpretative geological profile C-D (see Fig 14), showing the Măgura Mare and Măgura lui Arsenie – Arşiţa intrusive structures

In this stage, we can state the following:

– the tectonic elements that facilitated magma transportation are preferentially oriented, following NW-SE, NE-SW and E-W trends. NW-SE and NE-SW trends are the outcome of the Dragoș Vodă and North-Transylvanian Fault systems, while the third direction observed in the southern parts of the studied area (Valea Vinului and Cormaia Transilvană) follows parallel faults. These were active for short time periods, while the extensional setting was active. Afterwards, the intrusions and host rocks were subjected to transpressive stress (Cormaia valley basin).

– most of the magmatic bodies are surrounded by smaller, secondary intrusions (Sturzilor, Arșița, Lunca Ilvei – Șanț), which is characteristic for fan-like opening of fractures during extension processes.

3.3. GRAVITY DATA AQUISITION

3.3.1. WORKS LOCATION

High accuracy gravity determinations have been performed within base-stations belonging to the national geodynamic monitoring network along the transect Rastoaca - Tg. Secuiesc (Sânzieni) as well as on the dedicated gravity network for monitoring the geodynamic active zone in the bending area of East Carpathians.

The location of the observation points is shown in Fig.17

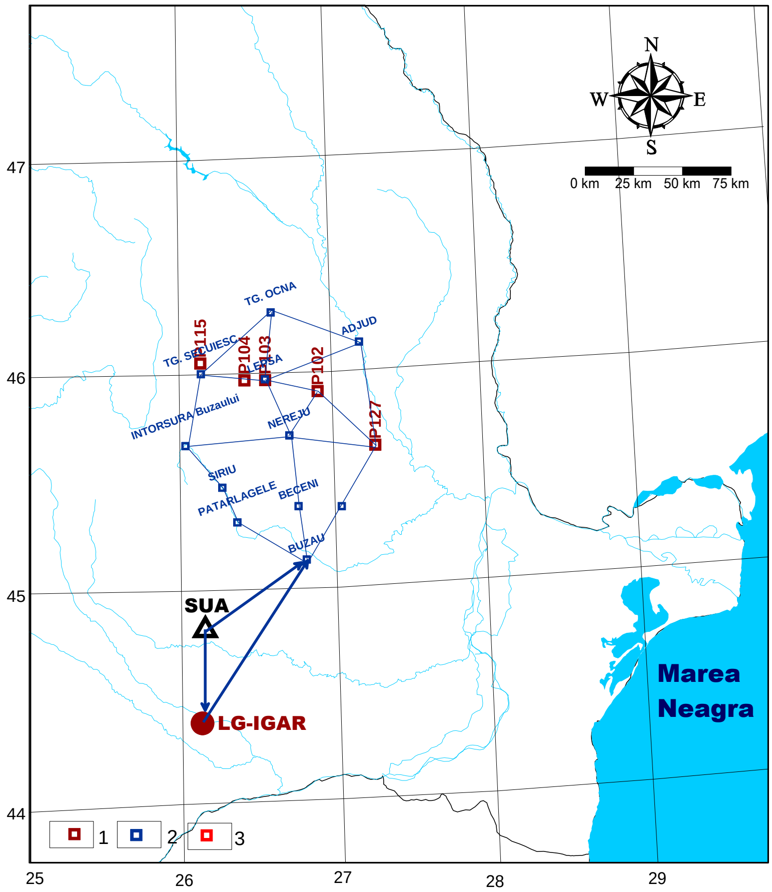

Fig. 17 - Location of measurement points and the design of the gravimetric ties 1, Răstoaca – Sânzieni transect; 2, Vrancea dedicated network; 3 additional locations, LG-IGAR - GRAVITY LAB inside the Institute of Geodynamics ; SUA- central gravity base station of Surlari Observatory.

3.3.2. FIELD OBSERVATIONS

3.3.2.1. Metrological considerations

All gravimetric observations were made using the CG5 Autograv Scintrex gravity meter # 40387 own by DDGT. The gravity meter was purchased in 2008, but returned to the manufacturing company in August 2011, for an overhaul.

Fig.18 - Scintrex CG-5 AUTOGRAV gravity meter

The main technical characteristics of the instrument are:

- assisted by an embedded processor with a Scintrex operating system,
- measuring range of 8000 mgal without prior adjustment,
- 1 μgal accuracy,
- possibility to work automatically under a pre-determined time,
- measurement frequency 6 Hz,
- readings are displayed on a ¼ VGA liquid crystal display ¼ VGA directly in mgal,
- automatic corrections: tilt up to ± 10 msec arc,
- earth tides,
- temperature,
- seismic filter,
- removal of manifestly erroneous readings based on advanced statistical criteria,
- quartz spring system placed in vacuum in a thermostatic chamber,
- unaffected by variations in terrestrial field up to ± 0.5 mT,
- long-term drift compensated automatically up to <0.02 mgal / day,
- supply system that provides 1 day energy independence,
- storage of about 200,000 readings in a flash memory of 12 MB,
- internal clock powered by a lithium battery,

- built-in GPS receiver connectable to an external antenna,
- possibility to download recorded data via RS-232 or USB ports in different formats:
- *.SGD (Scintrex proprietary format)
- *.TXT (ASCII with headers)
- *.XYZ (ASCII as worksheets)
- *.SMP (only for primary values), etc.

Sensitivity of the gravity meter is ± 1 µgal.

Repeatability (as indicated by the manufacturer): ± 5 µgal.

Tests conducted after 2011 overhaul seem to confirm these constructive parameters, even though for longer cycles, repeatability seems to be slightly below the range stated by the manufacturer.

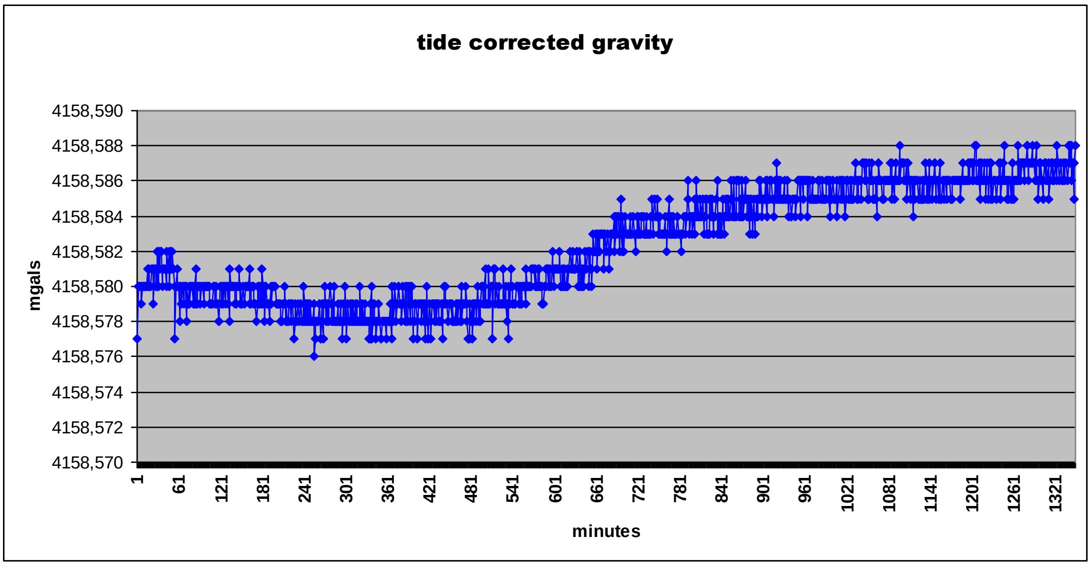

Fig. 19 - Reproducibility of readings at fixed point within 24 hours. Gravity determinations were done in the DDGT laboratory. There is a slight increase probably due to a residual effect of drift.

Figure 20 illustrates a test with residual effect removal, which improves the performance of the instrument. The instrument tilt records after two mutually perpendicular axes (Tilt X and Tilt Y) during these testing are presented.

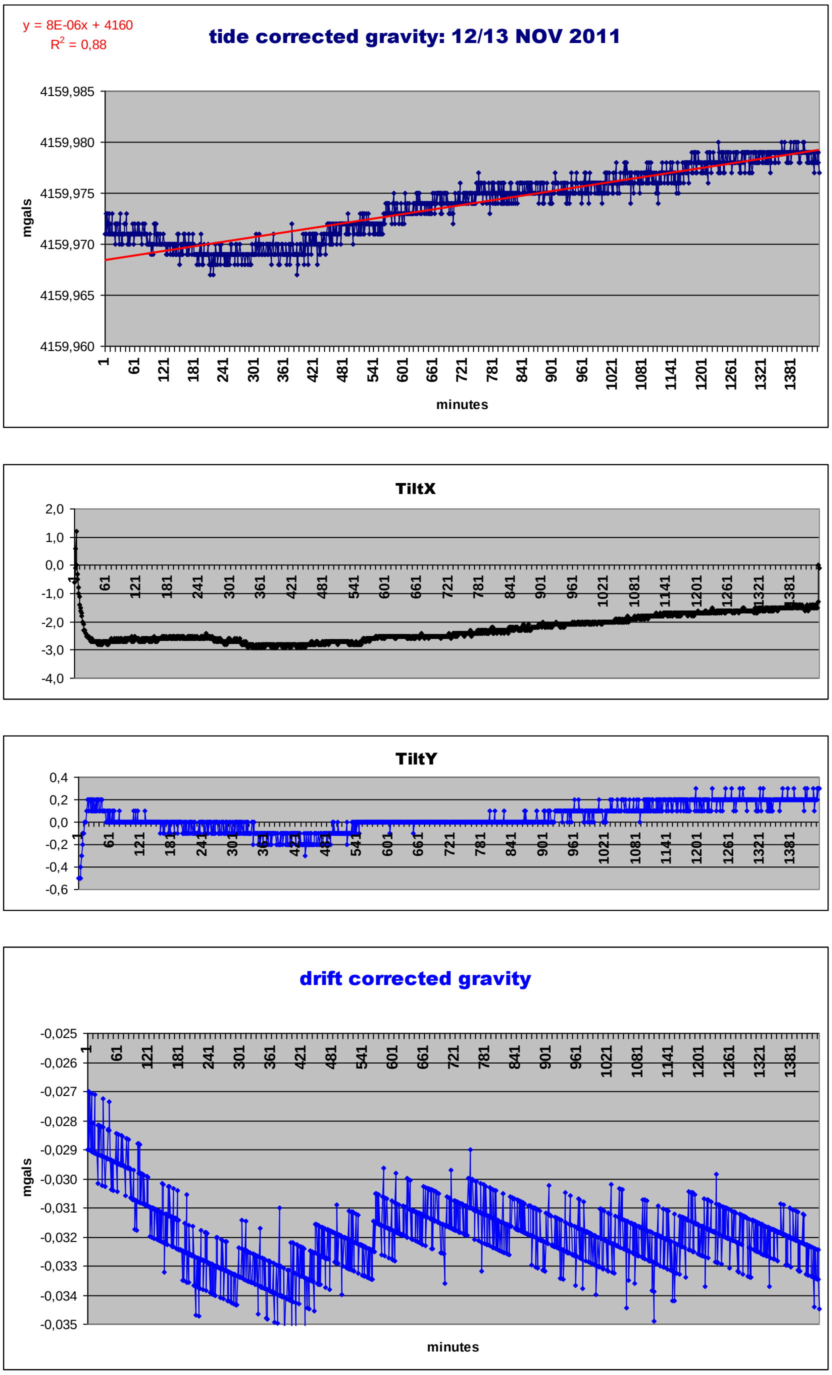

Fig. 20 - Improving the reading reproducibility of Scintrex CG-5 gravity meter by introducing the additional drift correction. Tilt X-inclination along Ox, Tilt Y – inclination along Oy. Tests conducted in DDGT gravity lab.

Following the tests it has concluded that the instrumental error of CG-5 gravity meter # 40387 exceeds the threshold of ± 5 µgal, the instrument exhibiting instrumental errors up to 10 µgals.

For this reason, repeated observations showing deviation of the results in two distinct measuring cycles greater than ± 10 µgal were repeated.

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