Romanian Academy
“Sabba S. Ştefănescu” Institute of Geodynamics

PhD Thesis

- ABSTRACT -

PALEOMAGNETIC INVESTIGATIONS IN THE AREA OF THE EAST CARPATHIANS NEOGENE VOLCANISM

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PALEOMAGNETIC INVESTIGATIONS IN THE AREA OF THE EAST CARPATHIANS NEOGENE VOLCANISM

- ABSTRACT -

The main objective of this paleomagnetic study has been to document the geomagnetic field recorded by younger than 7 Ma volcanic rocks collected from the East Carpathians. The accordingly acquired information was aimed to constrain tectonic movements and to improve models which addressed the relationships between the volcanic activity and the tectonic evolution of that area, relying on contributions concerning the volcanic activity geochronology and on the acquisition of statistical data concerning the behavior of the geomagnetic field over the last 7 Ma.

In order to achieve the proposed objectives, samples of volcanic rocks (various types of andesites) have been collected from 68 sites (outcrops) in South Harghita Mountains, 89 sites in North Harghita Mountains and 39 sites in Gurghiu Mountains. From each sampling-site have been collected 6-10 paleomagnetic samples on the average, distributed over a significant area within the outcrop, two of them were designated as pilot samples and accordingly subjected to detailed demagnetizations in alternative field (AF) and to thermal demagnetizations. The measurements concerning the natural remanent magnetization and the behavior recorded during demagnetization have been conducted on a total of 422 distinct samples from South Harghita Mountains, on 466 samples from North Harghita Mountains and on 217 samples from Gurghiu Mountains. A total of 1105 samples have been demagnetized.

The collected samples analysis has been performed in the Bucharest University paleomagnetism laboratory, a facility jointly run by the School of Physics and by the School of Geology and Geophysics, and which benefits of state of the art scientific equipments for paleomagnetism and rockmagnetism investigations.

The investigated area covers Harghita Mountains and the southern part of Gurghiu Mountains, all of which belong to the East Carpathians. Harghita Mountains are further divided into North Harghita and South Harghita, based on certain geological and geophysical specificities.

The structure of the PhD thesis is as follows:

- Part I. PREVIOUS INVESTIGATIONS IN THE CARPATHIAN-PANNONIAN REALM,
- Part II. THEORETICAL AND EXPERIMENTAL ISSUES,
- Part III. ORIGINAL CONTRIBUTIONS.

Appendixes include:

- the list of figures,
- the list of tables,

- typical examples of orthogonal diagrams and of successive demagnetization curves obtained as a result of demagnetizations conducted in alternative magnetic field and in thermal field, all diagrams being categorized by volcanic structures,
- a pdf-format copy of the first published paper: Panaiotu, C.G., **Visan, M.**, Tugui, A., Seghedi, I., Panaiotu, A. G., 2012. "Palaeomagnetism of the South Harghita volcanic rocks of the East Carpathians: implications for tectonic rotations and palaeosecular variation in the past 5Ma", *Geophysical Journal International,* 189, 369-382; doi: 10.1111/j.1365-246X.2012.05394.

In **Part I. Chapter 1** there are indicated the significant contributions that paleomagnetic investigations have provided to various fields of geophysics, there are specified the new paleomagnetic techniques which have resorted to the latest scientific breakthroughs in the field of rockmagnetism, and there are discussed the previous paleomagnetic studies having addressed the Carpathian-Pannonian realm and which contributed to geochronological and tectonic reconstructions, including those concerning the Neogene volcanic activity in the area of the Călimani-Gurghiu-Harghita volcanic chain.

Previous paleomagnetic studies conducted in the 1970-ies have mainly addressed the central section of the Călimani-Gurghiu-Harghita (CGH) volcanic chain. Those investigations have included 22 sites in the Gurghiu Mountains (Pătraşcu, 1976) and 43 sites in the North Harghita Mountains (Pătraşcu, 1976), while in the South Harghita Mountains there have been investigated 3 sites in their northern section (Pătraşcu, 1976), and 2 sites in the southern one (Michailova et al., 1983). The paleomagnetism study published by Pătraşcu (1976) proposed a division of the volcanic areas into distinct domains as function of the recorded paleomagnetic polarities. Yet when the distribution of newly acquired K-Ar age data (Peltz et al., 1987, Pecskay et al., 1995, Seghedi et al., 2004) was correlated with the magnetic polarities time-scale (Lourens et al., 2004), it became obvious that those early paleomagnetic measurements could not provide the additional information necessary for documenting in detail the time-evolution of the volcanic activity. It consequently resulted that the concerned topic had to be addressed in the framework of new and more elaborate studies.

In **Part I. Chapter 2**, the geotectonic evolution models that addressed the Carpathian Mountains in the framework of the Alpine Europe, are discussed, together with interpretations concerning the processes involved in the evolution of the volcanic arc located in the investigated area, by including as well interpretations based on geophysical studies. In this section there is also provided a detailed geochronology of the Neogene volcanic activity in the East Carpathains, and details concerning the Călimani – Gurghiu – Harghita volcanic chain structure and petrography, by relying on the latest investigations conducted in that area and published in the scientific literature.

Figure 1 includes a geological sketch map of the East Carpathians Bend area and of the adjoining regions. The paleomagnetic declination orientations on average areas, as published by Panaiotu et al. (2004) and Dupont-Nivet et al. (2005), and the horizontal displacement velocities with respect to the Eurasian Plate, as derived from GPS measurements (van der Hoeven et al., 2005) are also indicated.

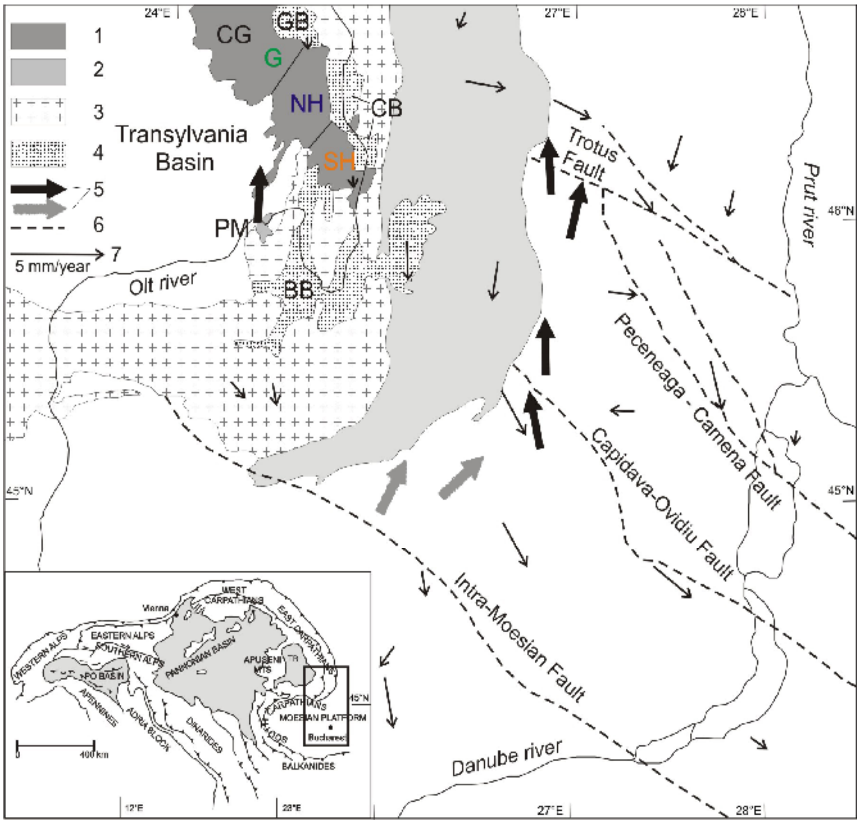

Figure 1. *Geological sketch map of the East Carpathians Bend area and of the adjoining regions, being also indicated the results obtained, prior to the present work, in terms of tectonic rotations and of currently occurring displacements* (modified after Fielitz & Seghedi 2005).

Symbols: 1, Miocene to Quaternary volcanic areas: Călimani-Gurghiu (CG), North Harghita (NH), South Harghita (SH) and Perşani Mountains (PM); 2, Moldavide nappes of the East Carpathians; 3, Dacides and other inner Carpathians nappes; 4, Miocene–Quaternary intramontane basins: Gheorgheni Basin (GB), Ciuc Basin (CB) and Bras¸ov Basin (BB); 5, area mean palaeomagnetic declinations (this study and Dupont-Nivet *et al.* 2005): no rotation (black arrows), significant rotation (dark grey arrows); 6, present day seismic active faults in the Moesian Platform; and 7, measured GPS horizontal velocities with respect to Eurasian Plate (van der Hoeven *et al.* 2005).

Călimani – Gurghiu – Harghita volcanic chain is the youngest section of the Neogene magmatic arc of the East Carpathians. It has developed as a result of an eruptive activity that over the time interval 11 - <0.05 Ma progressively migrated from the NE to the SW (Pécskay et al., 1995) (Fig. 2). Ensuing to the prevalently calc-alkaline volcanic activity, strato-volcanic edifices were built, displaying a generally concentric, yet at the same time asymmetric forms, generating a chain of adjoining and partly superimposed volcanoes (strato-volcanoes), surrounded by volcaniclastic deposits and/or isolated monogenetic domes or polygenetic dome-complexes (Szákacs & Seghedi, 1995, Lexa et al., 2010).

Along the direction of the volcanism migration, the magmatic edifices height and volume progressively decrease, the lowest limits in this respect being reached in the South Harghita Mountains. This situation outlines a gradual decline of the volcanic activity, in terms of both available magma volumes, and eruption rates (Szákacs & Seghedi, 1995, Lexa et al., 2010).

Along-arc magma generation was related to progressive break-off of the subducted slab and asthenosphere uprise. (Mason et al., 1998, Seghedi et al., 1998, Seghedi & Downes, 2011). The volcanism evolution has been controlled by the faults and fractures location along a trans-tensional corridor of NNW-SSE strike, which was positioned at the eastern boundary of the Dacia continental plate, the volcanic centers being concentrated along the western margin of that corridor. Such a fault-zone has been able to provide the pathways which favored the eruption of the magma that was generated in the upper mantle and in the lower crust (Fielitz &. Seghedi, 2005, Seghedi & Downes, 2011).

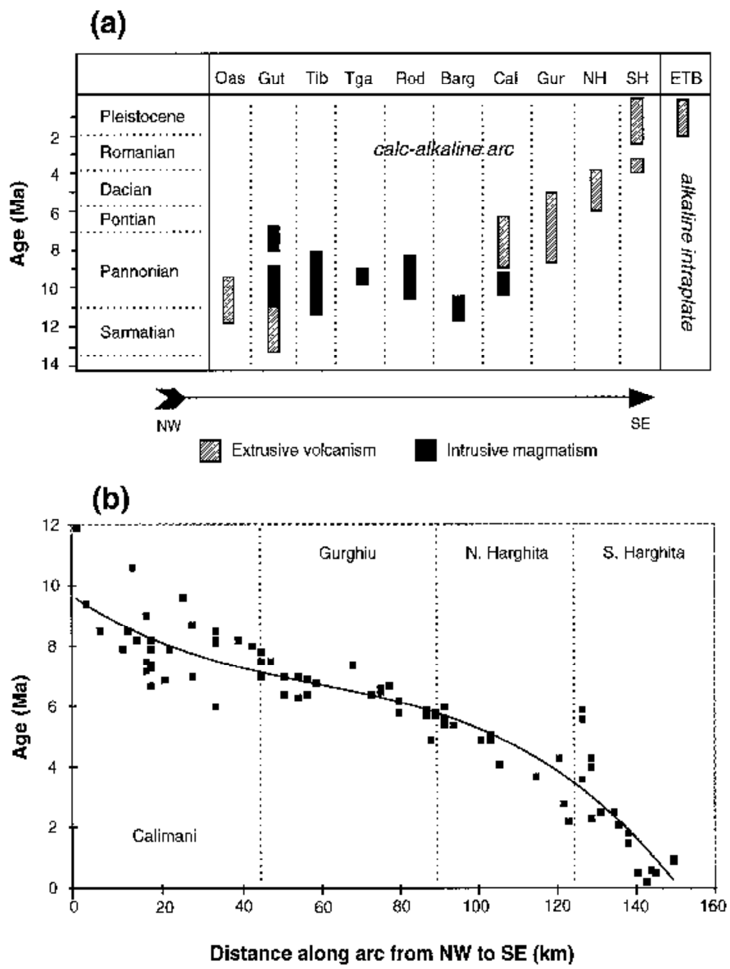

Fig. 2. K-Ar geochronology of the magmatic activity having developed in the East Carpathians Arc and in the Transylvanian Basin (*Mason et al., 1998)*: (a) Approximate time-intervals during which the volcanic activity has developed in each of the arc segments; (b) Diagram with the age of the calc-alkaline magmas in the CGH arc, plotted as a function of distance: along-arc distances are measured starting from the northernmost area of calc-alkaline volcanic activity, in Călimani Mountains.

Part II, with the title “Theoretical and experimental issues”, provides an outline of the paleomagnetism fundamentals and it includes four distinct chapters:

In the first chapter, the geomagnetic field main characteristics are discussed, and the main magnetic minerals, are described, as well as the types of remanent magnetizations in rocks.

The second chapter describes in detail the main paleomagnetic methods designed for the magnetic minerals identification, as well as the accordingly utilized techniques (measuring the magnetic susceptibility variation as a function of the applied field, measuring the magnetic susceptibility variation as a function of temperature, measuring the hysteresis properties, measuring the isothermal remanent magnetization (IRM), devising FORC diagrams, measuring the natural remanent magnetization).

The third chapter provides a description of the methods utilized for identifying and analyzing the natural remanent magnetization (demagnetization in alternating magnetic field, thermal demagnetization), and of the charts used for representing the demagnetization data, as well as of the analysis by which the remanent magnetization components are isolated.

The fourth chapter addresses the statistical approach utilized for analyzing the paleomagnetic directions and for determining the virtual geomagnetic poles in order to calculate the apparent rotations of the obtained virtual geomagnetic poles, as well as the methods for computing and assessing the paleomagnetic directions dispersion with respect to the geographic pole, and the inclination anomaly – all these being important parameters in the computation of the paleosecular variation. The criteria adopted for selecting those acquired paleomagnetic data which comply with appropriate quality standards are indicated and described. The standards of analysis have been retrieved from the recent high quality international studies that addressed the paleosecular variation at global level (Johnson et al., 2008), as well as from the global statistical models considered in studies of the terrestrial average field (TAF) for the last 5 Ma (McElhinny and McFadden, 1997, Tauxe and Kent, 2004).

Part III includes the results that have been actually obtained in the framework of the present study. The results are categorized as a function of the geological and geophysical characteristics, leading to the following division of the investigated area into distinct zones:

- **The paleomagnetism of volcanic rocks in South Harghita Mountains**
- **The paleomagnetism of volcanic rocks in North Harghita Mountains**
- **The paleomagnetism of volcanic rocks in Gurghiu Muntains.**

Volcanic rocks samples (various types of andesites) have been collected from 68 sites (outcrops) in the South Harghita Mountains, from 89 sites in the North Harghita Mountains and form 39 sites in the Gurghiu Mountains. A total of 1105 independent samples have been collected (fig. 3) by means of a portable core drilling machine and their orientation was established by magnetic and solar compass. At any time when circumstances allowed, the magnetic declination was also measured. In selecting the rock outcrops for sampling, the following criteria have been used: little amount of fracturing, no sliding or tilting undergone by the outcrop blocks, small extent of rock weathering, favorable conditions for field tests, absence of isothermal magnetizations.

In devising the sampling strategy, there have been taken into account the regional geological map Odorhei at the scale 1:200000 (Săndulescu et al., 1968), the CGH volcanic chain volcanological study conducted by Szakács & Seghedi (1995), as well as the more recent paper published by Seghedi et al. (2004).

The collected samples analysis has been performed in the Bucharest University paleomagnetism laboratory, a facility jointly run by the School of Physics and by the School of Geology and Geophysics, and which benefitted of state of the art scientific equipments for paleomagnetism investigations.

From the collected samples, standard cylindrical specimens for paleomagnetism (of about 11 cm^3) have been cut in the laboratory in order to be subsequently used in the investigations.

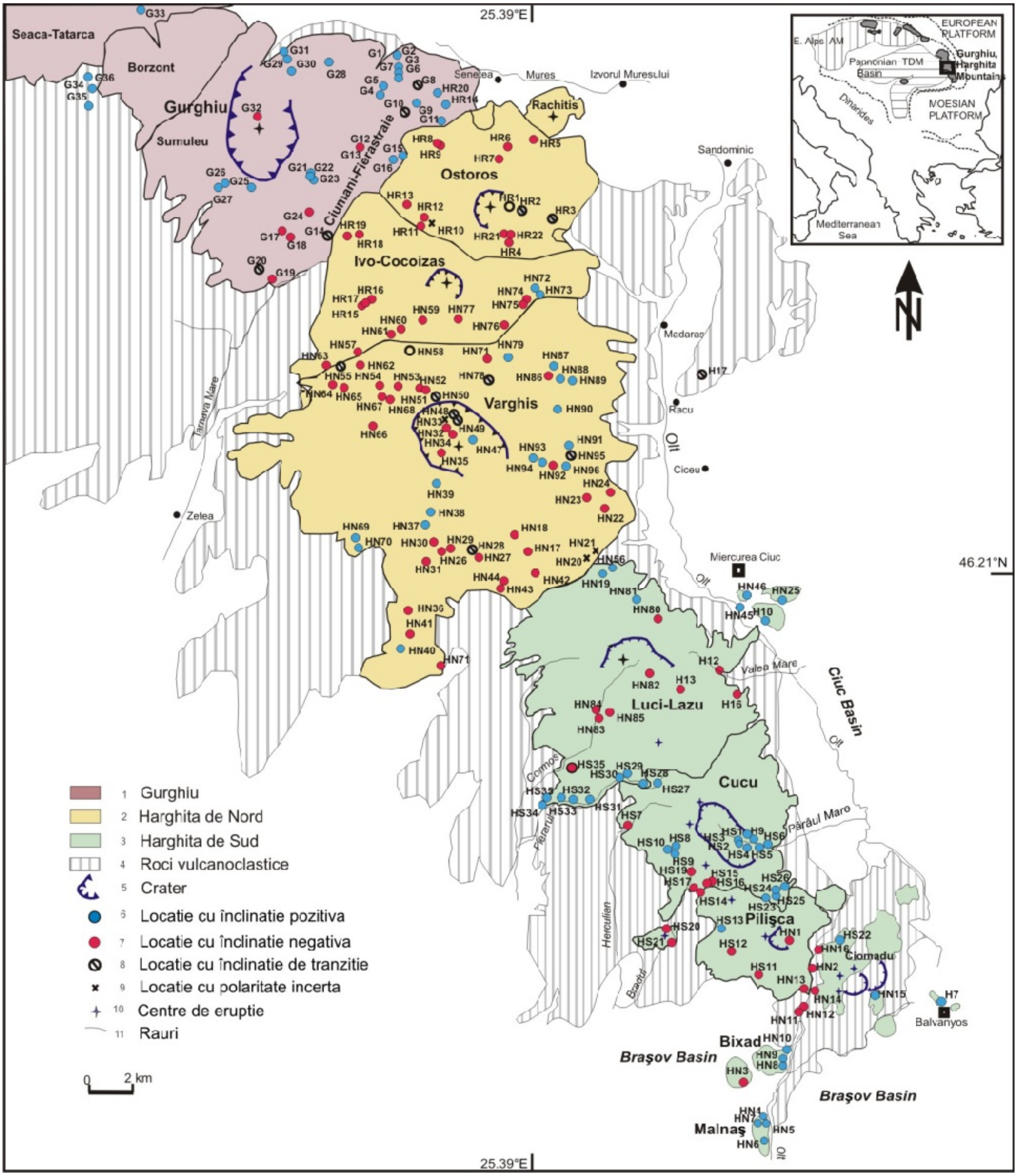

Fig. 3. Location of the paleomagnetic samples collection sites within the investigated volcanic area: Gurghiu Mountains, North Harghita Mountains and South Harghita Mountains. The geological sketch map is modified from *Szákacs and Seghedi, (1995*). Legend: 1. Volcanic structures in Gurghiu Mountains – southern part; 2. Volcanic structures in North Harghita Mountains; 3. Volcanic structures in South Harghita Mountains; 4. Volcaniclastic rocks; 5. Eruption craters; 6.Paleomagnetic sampling point exhibiting positive inclination; 7. Paleomagnetic sampling point exhibiting negative inclination; 8. Paleomagnetic sampling point exhibiting transitional inclination; 9. Uncertain polarities; 10. Eruption centers; 11. Streams.

The structure of the natural remanent magnetization has been investigated both by demagnetizing the samples in alternating magnetic fields, and by means of thermal demagnetizations for all specimens. The static method has been used for performing demagnetization in alternating magnetic field, to this purpose being employed a MAGNON instrument of 200 mT maximum field; the thermal demagnetization of the specimens was conducted at room temperature and at 700°C, by utilizing a non-inductive oven placed inside three magnetic shields. JR-6A Dual Speed Spinner Magnetometers have been used for measuring the remanence. Both the magnetometer and the oven were placed inside Helmoholtz coils which secured a controlled, lower than 500 nT magnetic environment.

For identifying the natural remanent magnetization and for outlining its structure, a main component analysis has been performed by using the Remasoft 3.0 (Chadima and Hrouda, 2006) software.

The individual components of the magnetization were identified in Zijderveld orthogonal projections (Zijderveld, 1967), by outlining the vertical and horizontal linear sections. The considered linear sections displayed smaller than 5° maximum deviations. The method consists in reconstructing the paleo-declination, the paleo-inclination and the intensity of the magnetization which was still recorded after each demagnetization step.

Magnetic mineralogy is dominated by magnetite or low titanomagnetite (Fig. 4). Most sites (95 per cent) have a S ratio above 0.80, indicating a mineralogy dominated by low coercivity magnetic minerals. Field dependence of magnetic susceptibility shows no or a very small variation in all specimens (Fig. 5). This behavior is compatible with the presence of magnetite and/or titanium-poor titanomagnetite (Hrouda et al. 2006).

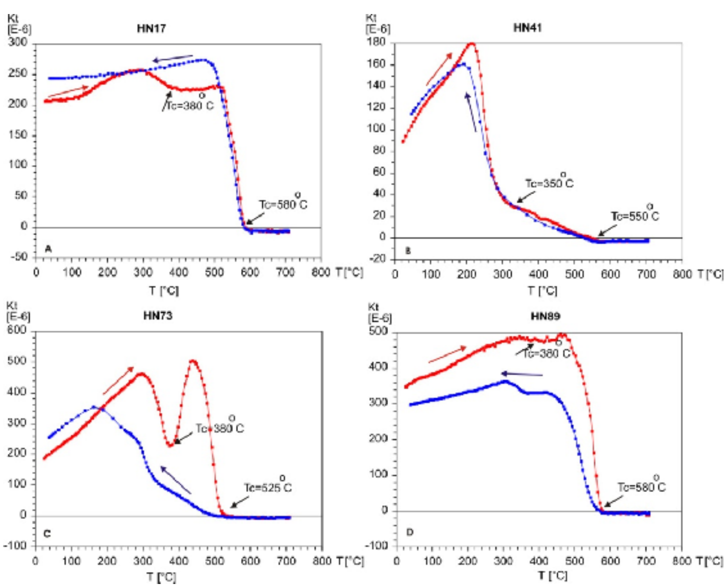

Figure 4. Representative temperature dependence of the magnetic susceptibility for selected specimens.

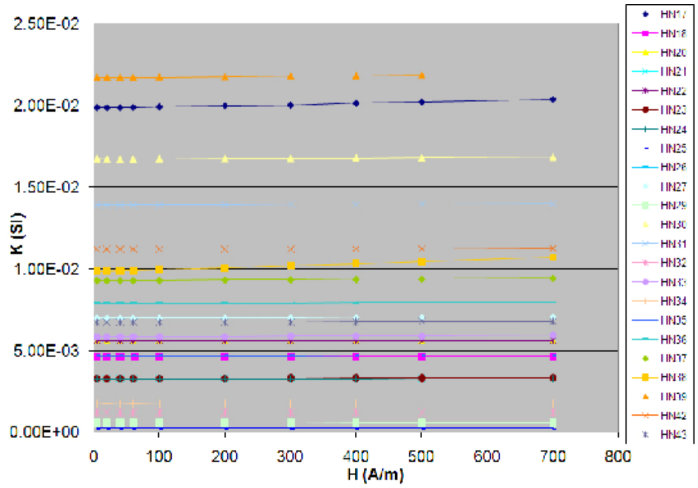

Figure 5. Field dependence of the magnetic susceptibility for the sampled rocks.

In Figs. 6, 7 and 8 the distribution of the average directions and of the Virtual Geomagnetic Pole (VGP) for the investigated areas is illustrated.

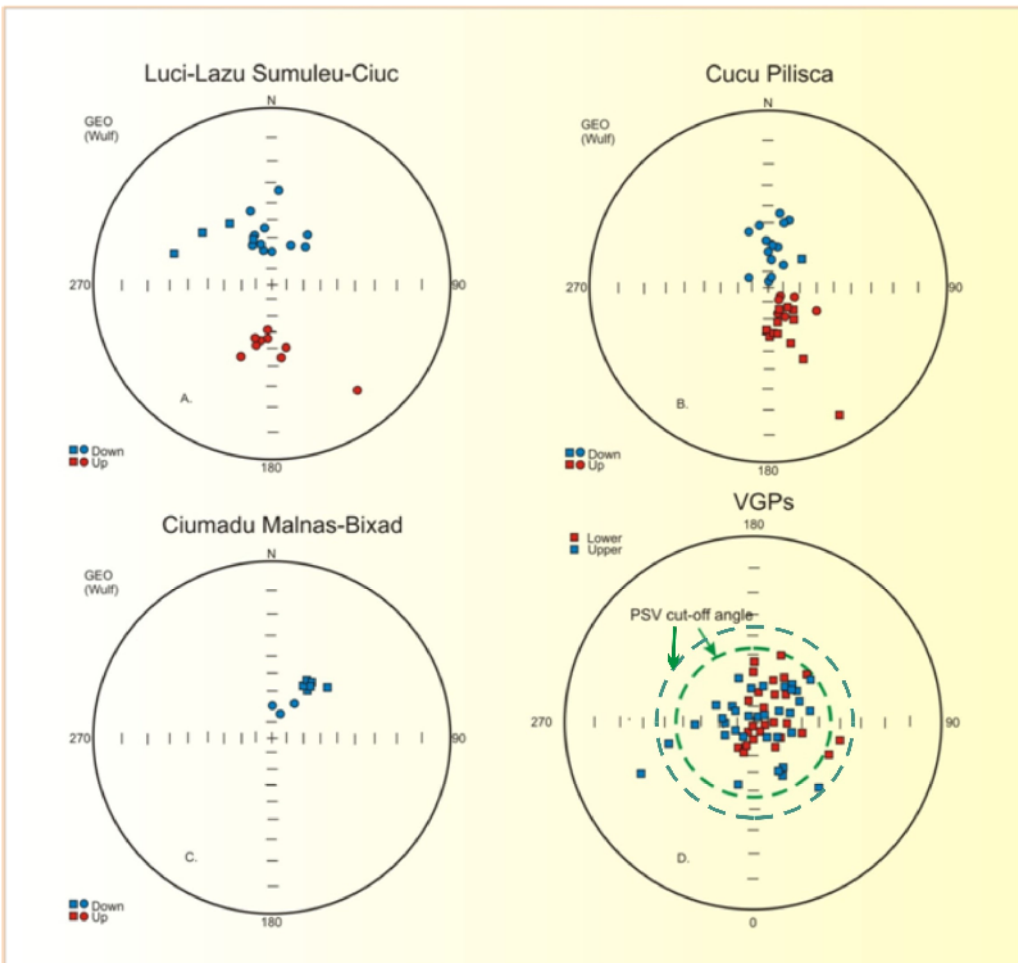

Fig.6. The distribution of the average directions and of the Virtual Geomagnetic Pole (VGP) for each of the sampling points in the South Harghita Mountains area: a) the volcanic structures Luci-Lazu (circles) and Şumuleu-Ciuc (squares); b) the volcanic structures Cucu (circles) and Pilişca (squares); c) Ciomadu volcanic structure and Balvanyos dome (circles), and Malnaş-Bixad intrusive domes (squares); d) The VGP distribution and the PSV limit-angles.

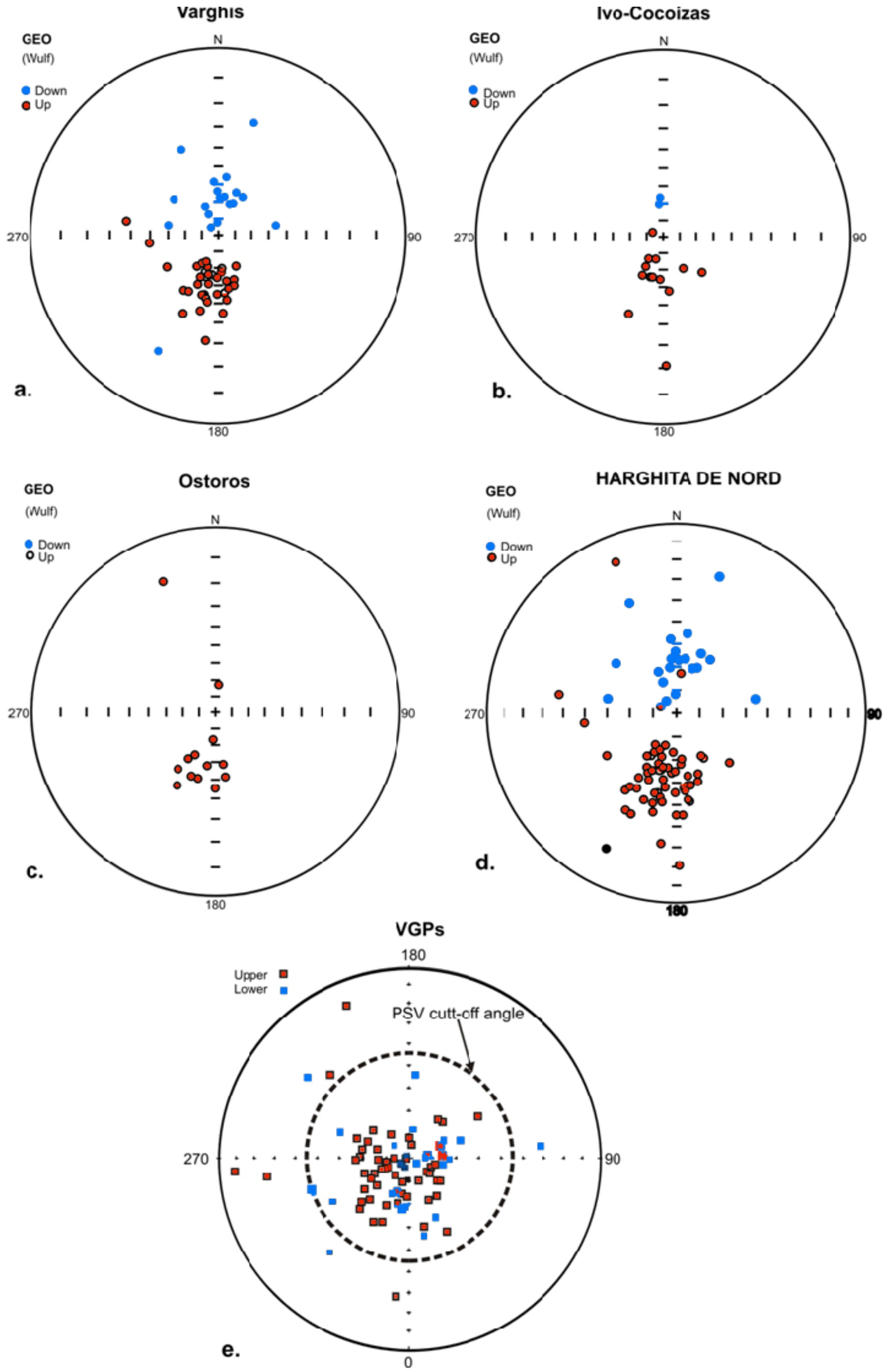

Fig.7. The distribution of the average directions and of the Virtual Geomagnetic Pole (VGP) for each of the sampling points in the North Harghita Mountains area: **a.** Varghiş volcanic structure; **b**. Ivo-Cocoizas volcanic structure; **c.** Ostoroş volcanic structure; **d.** The distribution of the average directions, by considering the entire North Harghita Mountains area, **e.** The VGP distribution and the 45^{o} latitude limit for the PSV.

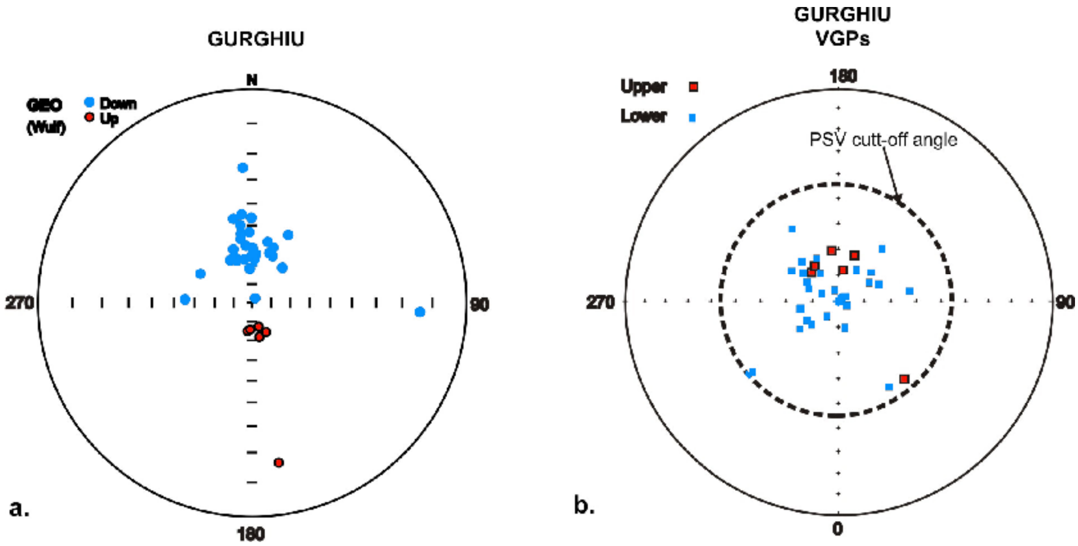

Fig.8. a. The distribution of the average directions and of the Virtual Geomagnetic Pole (VGP) for each of the sampling points in the Gurghiu Mountains (southern section) area; **b.** The VGP distribution and the 45^{o} latitude limit for the PSV.

The accordingly outlined main periods of volcanic activity - constrained by correlating the magnetic polarities with the K-Ar age determinations available for the volcanism of that region (Seghedi et al., 2004, Pécskay et al., 1995) - resulted to be as follows (Fig. 9):

- The Borzont, Şumuleu and Ciumani-Fierăstraie structures (in the southern section of the Gurghiu Mountains) are included in the C3An chron, with ages in the 6-6.7 Ma range; an exception are the 5 reverse polarity sampling sites identified within the Şumuleu volcanic structure: they might belong to the volcanic eruption stage associated to the Ivo-Cocoizaş and Ostoroş (North Harghita) structures, thus falling into the age interval which corresponded to the C3r chron.
- In the Ivo-Cocoizaş and Ostoroş (North Harghita) structures most polarities are reverse, that fact being in agreement with the associated K-Ar ages which correspond to the C3r chron. The two normal polarity sampling sites located close to the eastern border of that volcanic structure could belong to a particular eruption episode that was prolongation of the Vârghiş structure activity, and which neared the 4n subchron of the C3n chron. The corresponding ages range between 5.2-5.6 Ma;
- The Vârghiş (North Harghita) structure is included in the C3n chron and its age ranges between 4.2-5.3 Ma;
- The Luci-Lazu (South Harghita) structure is included in the C2Ar chron, its age ranging between 3.6-4.2 Ma;
- The Cucu (South Harghita) structure is included in the C2An chron and its age ranges between 2.5-3.5 Ma;

- The Pilişca – Malnaş – Bixad (South Harghita) structures are included in the chrons C2r, C2n, C1r, in the 1.6-2.5 Ma age interval. It is worth mentioning that only normal polarities were identified in all our sampling sites within the sub-volcanic domes of Malnaş and Bixad: most corresponding directions display just a small scatter, accordingly suggesting that the two domes have cooled during the same magnetic chron;
- The Balvanyos and Ciomatu structures are included in C1 chron, in the 1-0.2 Ma age interval.

The polarities distribution highlights the fact that in most volcanic structures, the main eruption period lasted for less than 1 Ma; accordingly, the time-interval suggested by the polarities distribution is shorter than the one inferred from K-Ar age determinations.

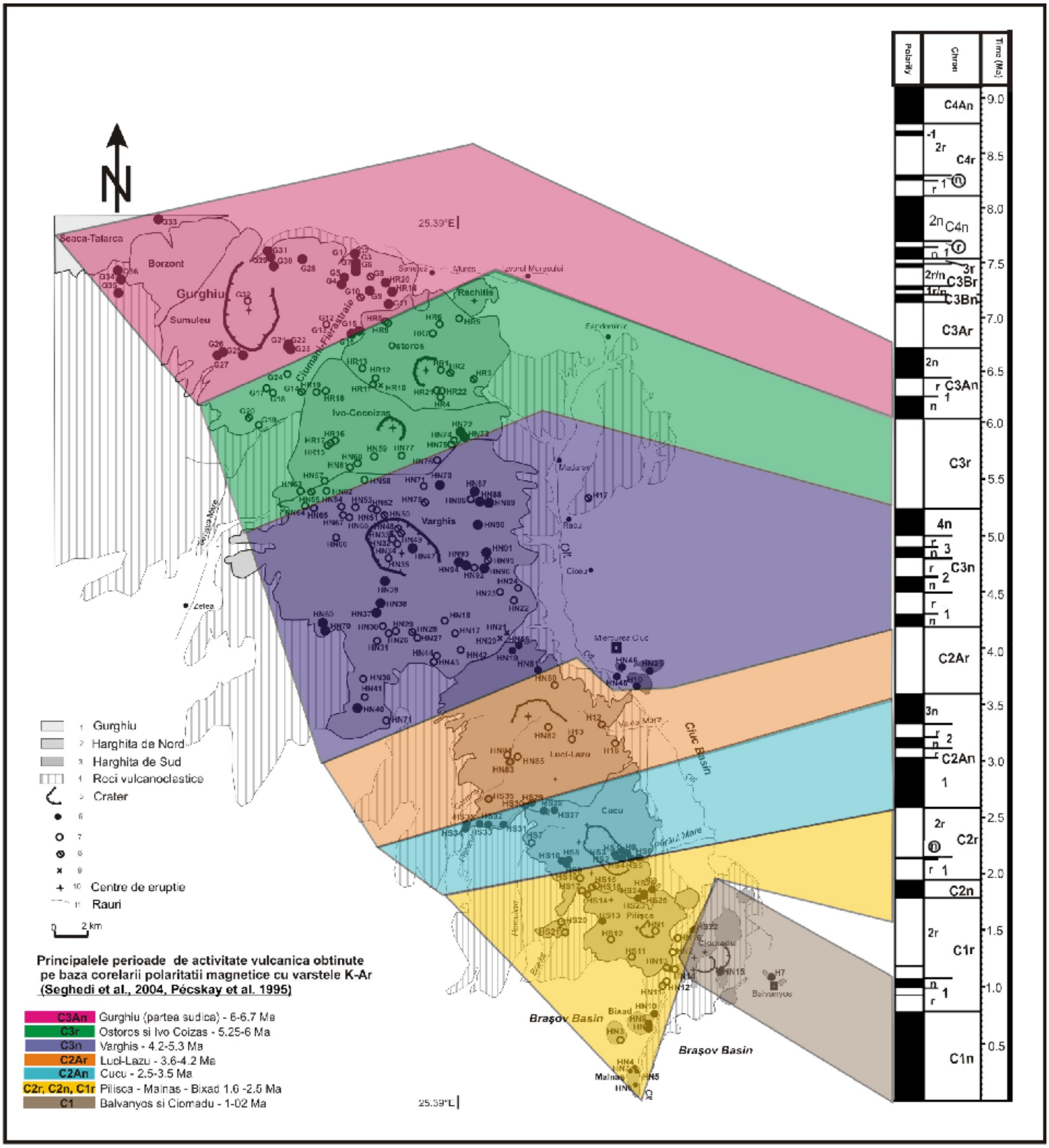

Figure 9. Correlation of the main periods of volcanic activity with the Geomagnetic Polarity Time Scale based on available K–Ar ages and on the geographic distribution of magnetic polarity. Geomagnetic Polarity Time Scale is after Lourens *et al.* (2004).

The obtained original results range in four broad categories of contributions:

1) Contributions to improving the model of the volcanism temporal evolution, by correlating the geographical distribution of the magnetic polarities with K-Ar ages of the magmatic rocks in the investigated areas. Based on this correlation, the main volcanic activity episodes experienced by the investigated areas could be identified. The geographical distribution of the magnetic polarities outlines the fact that in most volcanic structures, the main eruption period lasted for less than 1 Ma. In general, the time span suggested by the polarities distribution is shorter than the one inferred from K-Ar ages. Overall considered, the results are consistent with the currently accepted model of a progressive migration of the volcanic activity from north to the south (e.g. Seghedi et al., 2004), being at the same time emphasized the clear distinctions existing between the individual time steps of that migration (the corresponding durations being just about 1 Ma, occasionally even less).

2) Contributions to the investigation of the tectonic implications of the paleomagnetic data. The corresponding analysis has started from the average paleomagnetic poles derived for the investigated areas. Based on those data, and by computing a new reference pole for Europe, the latitudinal translations, as well as the amplitude of the rotations around vertical axes have been calculated (tab 1, fig. 10, fig. 11). For the entire considered area, Perşani Mountains (Panaiotu et al., 2004), Harghita Mountains and the southern part of Gurghiu Mountains, the apparent rotations and the northward displacements of the poles are smaller than the involved errors, or of the same order of magnitude. This fact indicates that in those areas of the Transylvanian Basin, neither significant rotations around a vertical axis, nor significant translations can be detected subsequently to the volcanic rocks emplacement. Younger than 5 Ma rotations (Dupont-Nivet et al., 2005) were identified only at the exterior of the Carpathians bend zone. The distribution of the rotations, both at the exterior, and at the interior of the southeast bend of the Carpathians is consistent with the bend area geological model, which indicates that during the last 11 Ma the crustal deformation has displayed maximum intensities around the Pliocene / Quaternary transition, the corresponding deformation being restricted to the SE Carpathians region (Cloetingh et al., 2004; Matenco et al., 2010; Merten et al., 2010). It is interesting to notice in this respect that the paleomagnetic declinations distribution is consistent with the present-day velocities derived from GPS measurements (van der Hoeven et al., 2005), this fact indicating a certain persistence of the bend area deformation style over the last 5 Ma.

Table 1. The paleomagnetic poles and the kinematic parameters derived for the investigated areas

Site	*N*	*Plat (°)*	*PLon (°)*	*A_{95} (°)*	*R (°)*	*PD (°)*
Gurghiu-South (6-6.3 Ma)	37	85.2	-124.3	6.7	3.7±6.9	3.4±5.1
North Harghita (4.3 – 6.0 Ma)	70	83.6	149.5	4.5	6.8±4.8	3.3±3.6
South Harghita (2 - 4.3 Ma)	53	85.5	310.1	5.6	6.9±6.3	-1.8±4.3
Perşani (0.6 – 1.2 Ma) (Panaiotu et al., 2004)	23	84.6	57.5	7.5	4.1±8.8	-5.4±5.7
Reference pole for Europe (Panaiotu et al., 2012)	18	89.1	185.1	1.7		

Note: N - number of computed VGP positions; Plon, Plat - the VGP latitude and longitude; A_{95} *– confidence angle; R, apparent rotation; PD, northward displacement of the pole.*

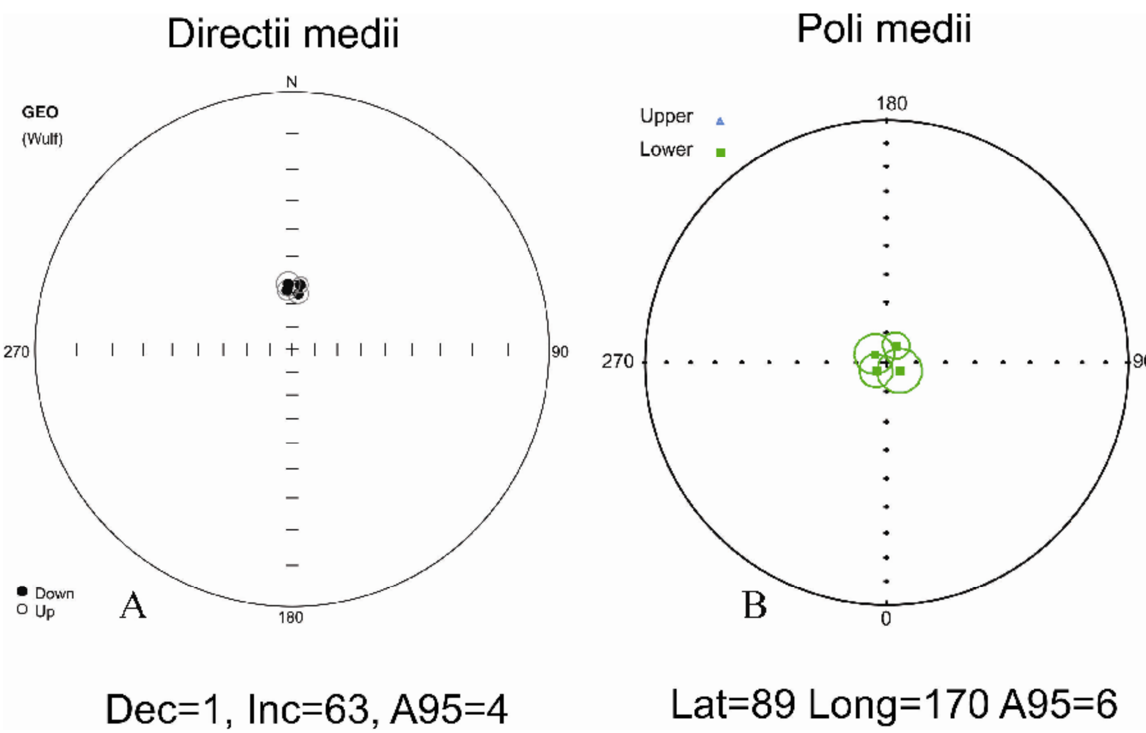

Figure 10. The distribution of the average directions and of the Virtual Geomagnetic Poles (VGP) for all the investigated areas

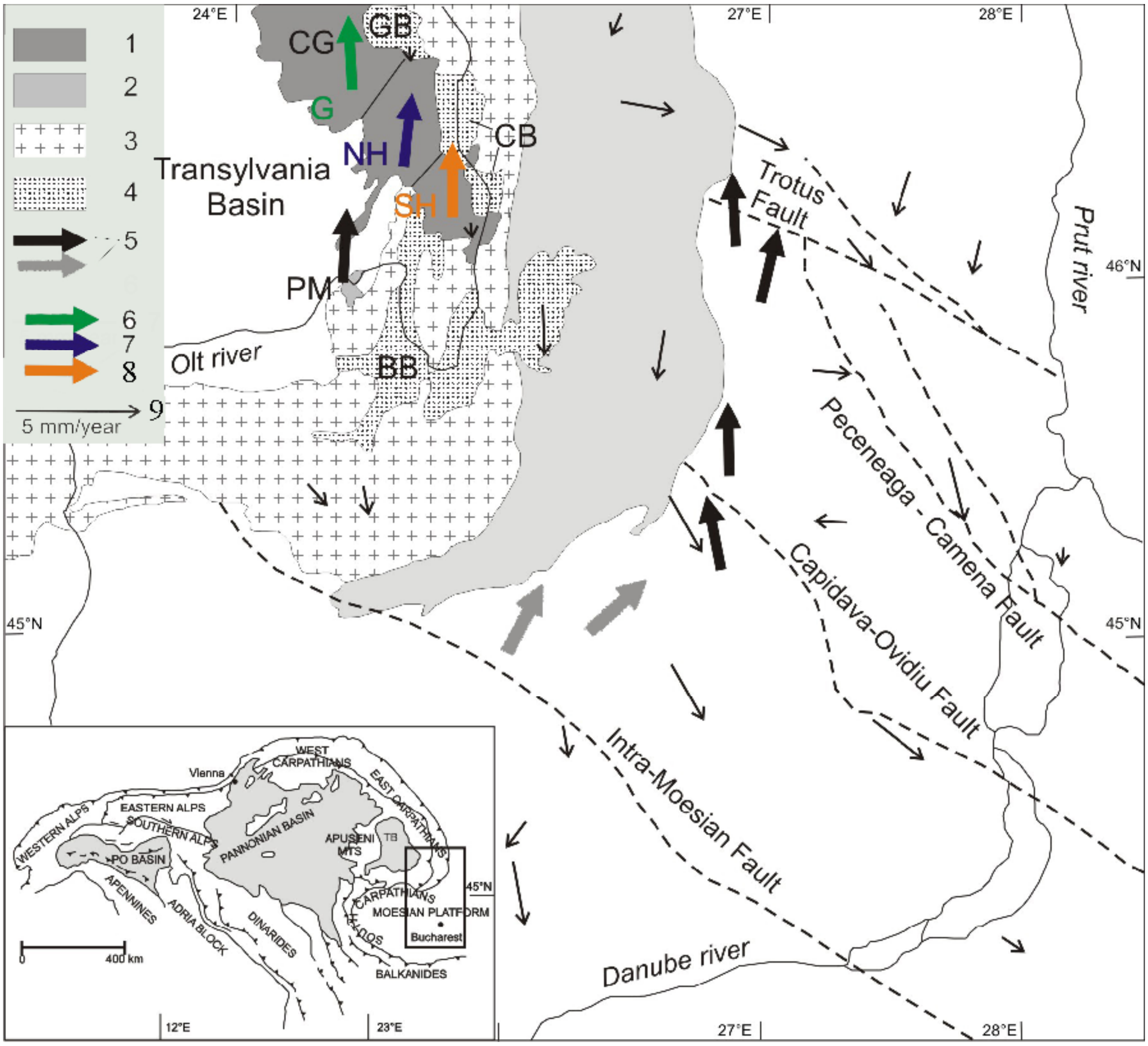

Figure 11. The distribution of the average areal paleomagnetic declinations derived in the framework of the present thesis for Călimani-Gurghiu (CG) Mountains, for North Harghita (NH) Mountains, and for South Harghita (SH) Mountains, plotted against a reference background which illustrates results previously obtained by other authors: paleomagnetic declinations in Perşani Mountains (PM) (*Panaiotu et al., 2004*), declinations derived by *Dupont-Nivet et al., 2005*, and horizontal displacement velocities with respect to the Eurasian Plate, derived from GPS measurements (*van der Hoeven et al., 2005*); the geological sketch map is modified after *Fielitz and Seghedi, 2005*.
Legend:
1. Miocene-Quaternary volcanic zones: (CG) Călimani-Gurghiu Mountains, (NH) North Harghita Mountains , (SH) South Harghita Mountains and (PM) Perşani Mountains;
2. The Moldavide nappes of the East Carpathians;
3. The Dacides and other internal Carpathian nappes;
4. Miocene-Quaternary intramontane basins: (GB) Gheorgheni Basin, (CB) Ciuc Basin, and (BB) Braşov Basin;
5. Average areal paleomagnetic declinations exhibiting no rotation (black arrows), and significant rotations (gray arrows);
6. Average areal paleomagnetic declinations in Călimani-Gurghiu (CG) Mountains;
7. Average areal paleomagnetic declinations in North Harghita (NH) Mountains;
8. Average areal paleomagnetic declinations in South Harghita (SH) Mountains;
9. Horizontal velocities with respect to the Eurasian Plate, derived from GPS measurements.

3) Contributions to the statistical study of the geomagnetic field on a global level. They are a result of analyses that addressed the paleosecular variation based on the virtual geomagnetic poles dispersion and on the inclination anomaly. In the framework of the present thesis, there have

been obtained the first paleomagnetic results in Europe which meet qualitative and quantitative standards similar to those of the currently available global-level paleosecular variation analyses (Johnson et al., 2008). The paleosecular variation analyses for the North Harghita and Gurghiu mountains are compatible with those included in the global data base (Johnson et al., 2008), whereas those for South Harghita Mountains exhibit larger dispersions. The obtained results might be an indication of a possible increase in the Virtual Geomagnetic Poles (VGP) dispersion, or, alternatively on the existence of certain regional differences between the paleosecular variation (PSV) data sets acquired at similar latitudes over the 2-4 Ma time interval. Nevertheless, both the paleosecular variation, and the inclination anomaly are still compatible with the geomagnetic field statistical model TK03 recently proposed by Tauxe and Kent (2003).

4) The magnetic mineralogy data base acquired in the framework of present study can be utilized in the future for the interpretation of regional aeromagnetic data and of detailed magnetic surveys.

So far, the results acquired in the framework of the present thesis have been further disseminated as follows:

1) In a paper published in an ISI rated journal:

Panaiotu, C.G., **Visan, M.**, Tugui, A., Seghedi, I., Panaiotu, A. G., 2012. "Palaeomagnetism of the South Harghita volcanic rocks of the East Carpathians: implications for tectonic rotations and palaeosecular variation in the past 5Ma", *Geophysical Journal International,* 189, 369-382; doi: 10.1111/j.1365-246X.2012.05394.

2) The data utilized in preparing the paper published in Geophysical Journal International have been selected and stored in the international data base for paleomagnetism and rockmagnetism Magnetics Information Consortium (MagIC) within EarthRef.org (The website for Earth Science reference data and models).

(http://earthref.org/MAGIC/search/#m006745dt20120714165038)

3) In a paper in the internationally indexed data base:

Barbu, M., Faur, L., **Visan, M**., "Paleomagnetic study of the Miocene volcanism in the southern part of the Gurghiu Mountains (Eastern Carpathians) ". *Society of Petroleum Engineers - 73rd European Association of Geoscientists and Engineers Conference and Exhibition 2011 - Incorporating SPE EUROPEC 201, Volume 7, 2011, Pages 5528-5530.*

4) In a paper which is in print in a scientific journal of the Romanian Academy:

M. Vişan, C.G. Panaiotu, I. Seghedi., "Paleomagnetic constraints for the timing of volcanism from south Gurghiu and Harghita Mountains". *Revue Roumaine de Géophysique*.

5) By the preparation – now in its final stage – of a new paper addressing the paleomagnetism of the North Harghita Mountains volcanic rocks.

6) By presentations delivered at the following national and international conferences:

- **1st International Symposium of Geology and Geophysics Students** - 22-24 April 2010: "New paleomagnetic results from the South Harghita volcanic area (Romania)" **Mădălina Visan**, "Sabba Stefănescu" Institute of Geodynamics, Teodora Merezeanu, Andrei Panaiotu, Cristian Panaiotu, University of Bucharest;

- **1st International Symposium of Geology and Geophysics Students** - 22-24 April 2010: "New paleomagnetic data in the eastern part of the North Harghita volcanic area" Tudor Alexandru Ienulescu, Gabriela-Teodora Trandafir, University of Bucharest, **Mădălina Visan**, "Sabba Stefănescu" Institute of Geodynamics;

- **73rd EAGE Conference & Exhibition incorporating SPE EUROPEC 2011,** Vienna, Austria - "Paleomagnetic Study of the Miocene Volcanism in the Southern Part of the Gurghiu Mountains (Eastern Carpathians)" **- Madalina Visan,** Barbu Mihai, Panaiotu Cristian, Luchiana Faur.

- **National Scientific Symposium Bucharest, May 20, 2011 - Madalina Visan**, Panaiotu Cristian: "New paleomagnetic results from the Harghita volcanic area (Romania)".

- **National Symposium of Geology and Geophysics GEO 2013, May, 2013 - Madalina Visan**, Panaiotu Cristian: "Palaeomagnetic study of some Neogene magmatic rocks from the Gurghiu and Harghita Mountains (Romania)"**.**

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