B. I. G.
156557

Romanian Journal of
STRATIGRAPHY

continuation of

DĂRI DE SEAMĂ ALE ŞEDINŢELOR INSTITUTULUI DE GEOLOGIE ŞI GEOFIZICĂ
COMPTES RENDUS DES SÉANCES DE L'INSTITUT DE GÉOLOGIE ET GÉOPHYSIQUE
(4. Stratigrafie)

Founded 1906 by the Geological Institute of Romania

INSTITUTUL GEOLOGIC AL ROMÂNIEI
BIBLIOTECA
156557

ISSN 1220-5664

Vol. 76
Supplement No. 4

Xth. CONGRESS RCMNS BUCURESTI • 1995

IUGS, REGIONAL COMMITTEE ON MEDITERRANEAN NEOGENE STRATIGRAPHY

4 – 9 September

GUIDE TO EXCURSION B3 (POST–CONGRESS)

TIME-SPACE EVOLUTION OF NEOGENE-QUATERNARY VOLCANISM IN THE CĂLIMANI-GURGHIU-HARGHITA VOLCANIC CHAIN

by

Alexandru Szakács, Ioan Seghedi

I.G.R. 45 N 24° E

Institutul Geologic al României
Bucureşti – 1995

Institutul Geologic al României

GEOLOGICAL INSTITUTE OF ROMANIA

The **Geological Institute of Romania** is now publishing the following periodicals:

Romanian Journal of Mineralogy
Romanian Journal of Petrology
Romanian Journal of Mineral Deposits
Romanian Journal of Paleontology
Romanian Journal of Stratigraphy
Romanian Journal of Tectonics and Regional Geology
Romanian Journal of Geophysics

They supersede "Dări de Seamă ale Şedinţelor", "Memorii" and "Studii Tehnice şi Economice", whose apparition goes back to 1910. Beside regular volumes, each series may occasionally contain Supplements (for abstracts and excursion guides to congresses and symposia held in Romania) and Special Issues (for larger papers of special interest). "Anuarul Institutului Geologic al României" will appear also in a new form, containing both the annual activity report and review papers.

Editorial Board: Gheorghe Udubaşa (chairman), Tudor Berza, Florian Marinescu, Marcel Mărunţiu, Grigore Pop, Vlad Roşca, Mircea Săndulescu

Managing Editor: Anatol Rusu

Executive Secretary: Felicia Istocescu

Editorial Office:
Geological Institute of Romania
Str. Caransebeş No. 1
RO - 79 678 Bucureşti - 32
Tel. (+40) 1 665 66 25, 665 75 30
Fax (+40) 1 312 84 44
e-mail GIRBHR@ROEARN.ICI.RO

The editor has changed the name as follows: Institutul Geologic al României (1910–1952), Comitetul Geologic (1953–1966), Comitetul de Stat al Geologiei (1967–1969), Institutul Geologic (1970–1974), Institutul de Geologie şi Geofizică (1975–1993), Institutul Geologic al României (since 1994).

ROMANIAN JOURNAL OF STRATIGRAPHY supersedes "Dări de Seamă ale Şedinţelor", Series 4/Stratigrafie – the last volume with this title being No. 74.

Scientific Editor: Grigore Pop

Advisory Board: Florian Marinescu

The manuscripts should be sent to the scientific editor and/or executive secretary. Correspondence concerning advertisments, announcements and subscriptions should be sent to the Managing Editor.

©GIR 1995
ISSN 1220–5664
Classification index for libraries 55(058)

Printed by the Geological Institute of Romania
Bucharest

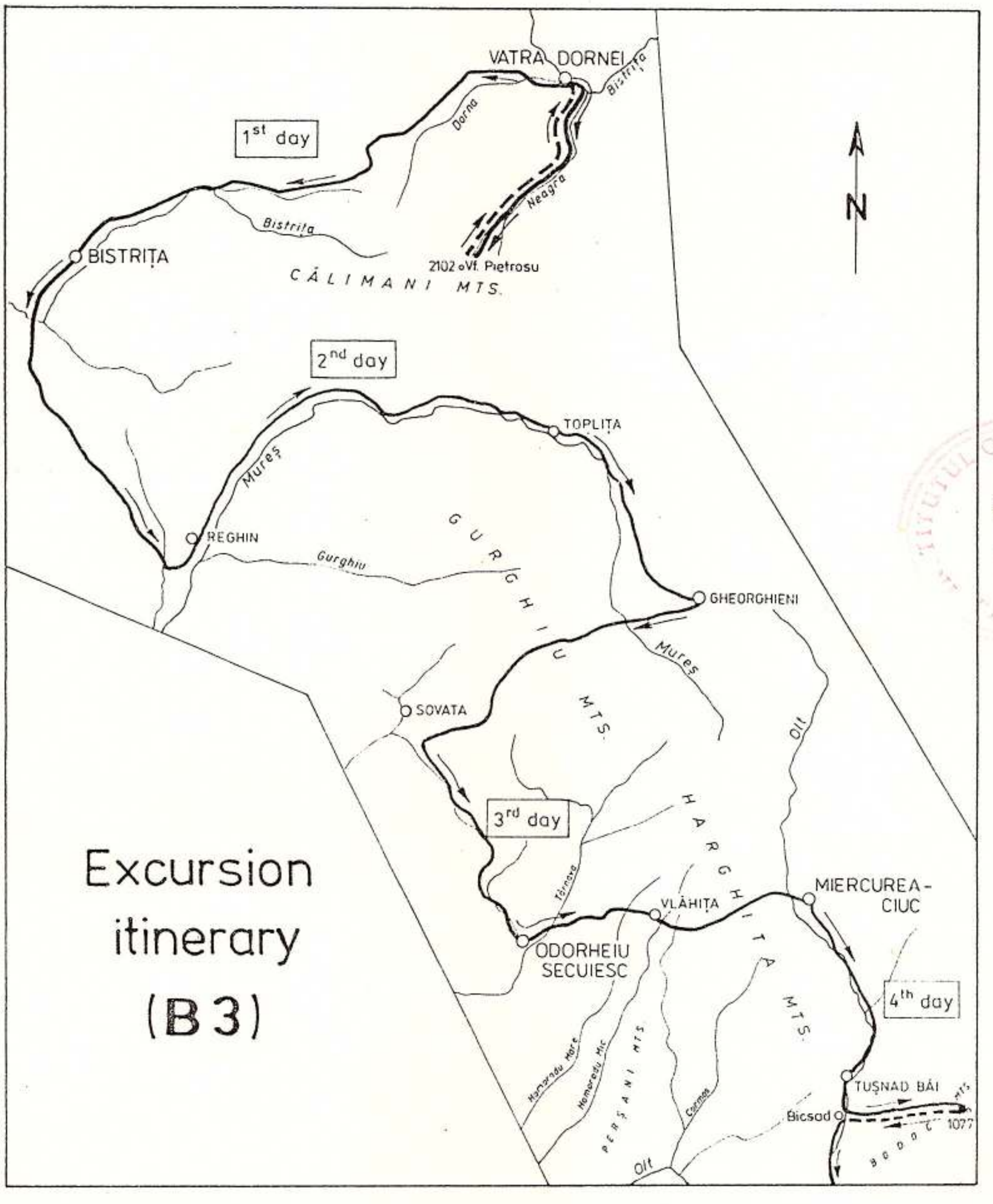
Institutul Geologic al României

GUIDE TO EXCURSION B3 (POST-CONGRESS)

TIME-SPACE EVOLUTION OF NEOGENE-QUATERNARY VOLCANISM IN THE CĂLIMANI-GURGHIU-HARGHITA VOLCANIC CHAIN

by

Alexandru Szakács, Ioan Seghedi



INSTITUTUL GEOLOGIC AL ROMÂNIEI BIBLIOTECA
156557

IGR Institutul Geologic al României

Institutul Geologic al României

CĂLIMANI-GURGHIU-HARGHITA VOLCANIC CHAIN

Introduction

The Călimani - Gurghiu - Harghita volcanic chain (CGH hereafter) forms the southernmost portion and the largest occurrence area of the Carpathian Neogene/Quaternary mostly calc-alkaline volcanic arc developed in Romania along the inner part of the Carpathian orogenic belt.

Unlike other Neogene volcanic areas in Romania, much more eroded (Oaş-Gutâi and Apuseni Mts.), the fresh looking morphology of the CGH volcanic zone allowed the early recognition of individual volcanic edifices and prominent features including the unique crater lake Sf. Ana at the southern end of the chain.

The chain display a roughly median position between the East Carpathians structural units (Upper Cretaceous to Paleogene "Transcarpathian Flisch " Unit in the north, the "Crystalline-Mesozoic Zone" Unit in the east, the "Cretaceous Flisch" Unit in the southeast) and the Neozoic Transylvanian basin molasses (fig.1).

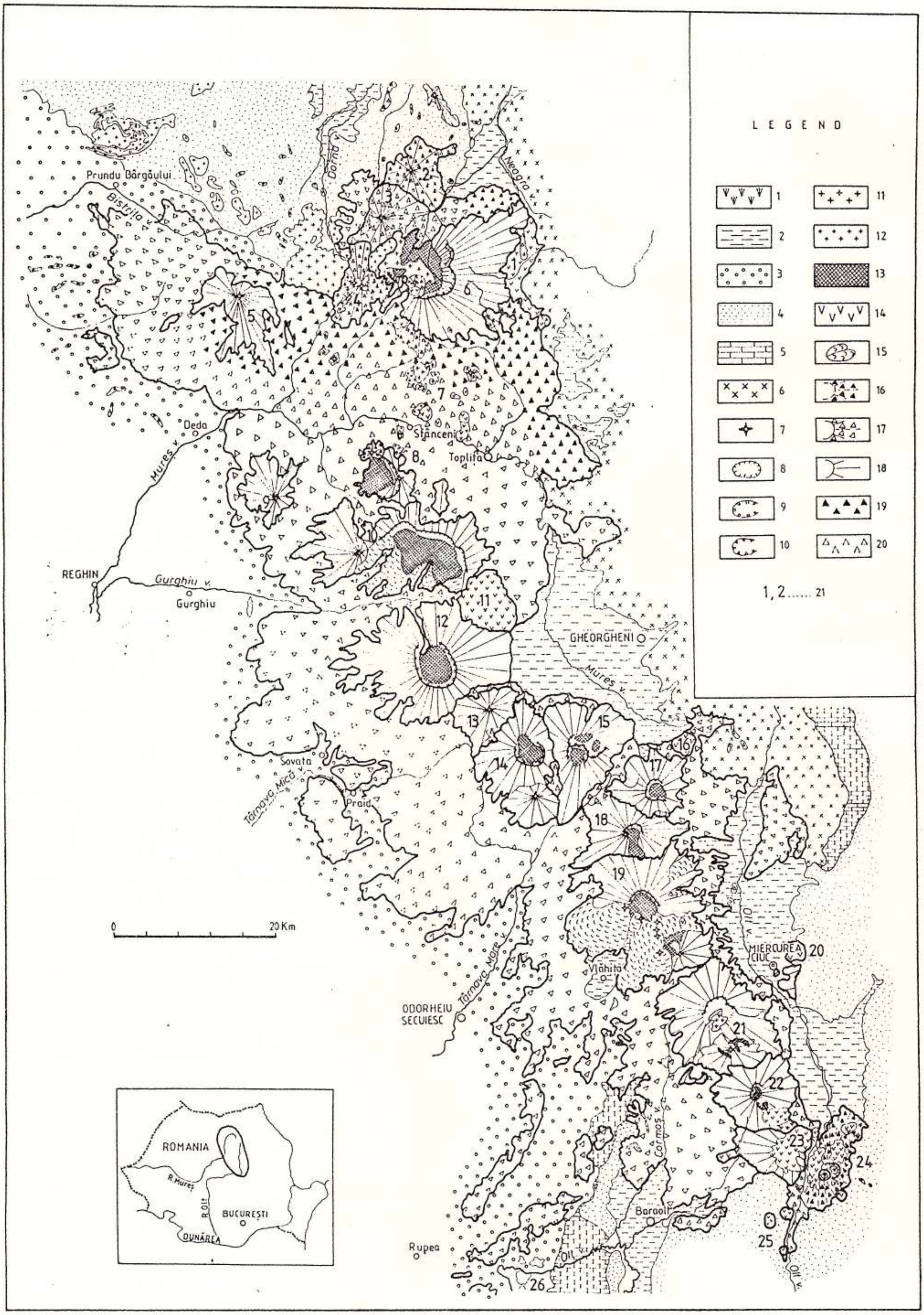
Generalized structural models attempting to account for the broader-scale constitution of the CGH chain have been proposed by Rădulescu et al. (1964a, 1973). In this "two compartment" model the lower part is constituted by a complex volcano-sedimentary formation and the upper compartment by well preserved composite volcanic apparata. Increasing amount of geological data, achieved mainly in the last decade, suggest that the volcanic structures belonging to the CGH consist of a central volcanic zone with subvolcanic intrusive bodies in its infrastructure, an intermediate zone, corresponding to volcanic cone (mainly consisting of lava flows) and a peripheral mainly volcaniclastic zone. Effusive-explosive volcanic activity prevailed at all stratovolcanic edifices building up a chain of adjoining and partially overlapping composite edifices with well developed peripheral volcaniclastic aprons.

Geotectonic setting

Its general location with respect the major lithospheric tectonic units of the Carpathian system and the western margin of the Eurasian plate (i.e. behind the Carpathian accretionary prism) as well as its main geochemical signatures (i.e. their calc-alkaline affinity) led the first applicants of the plate tectonic concept to the Romanian territory (Radulescu, Săndulescu, 1973, Bocaletti et al., 1973, Bleahu et al., 1973) to unanimously consider the subduction-related character of the East Carpathian volcanic arc (fig.2). Westward subduction of the oceanic crust of an easterly "basin" or ocean, whose sparse, obducted remnants are discontinuously recorded within the inner flysch nappes of the East Carpathins, occurred beneath an inferred Transylvanian microplate or an assemblage of several microplates. Recently, the subducted crust involved in the generation of the Neogene volcanic arc is thought as belonging to a "marginal basin" of the Euroasian plate with thinned crust or a narrow oceanic-type crust (Rădulescu et al., 1994).

There are, however, some problems with both timing and spatial relationships, especially along the CGH portion of the arc.

Institutul Geologic al României



Institutul Geologic al României

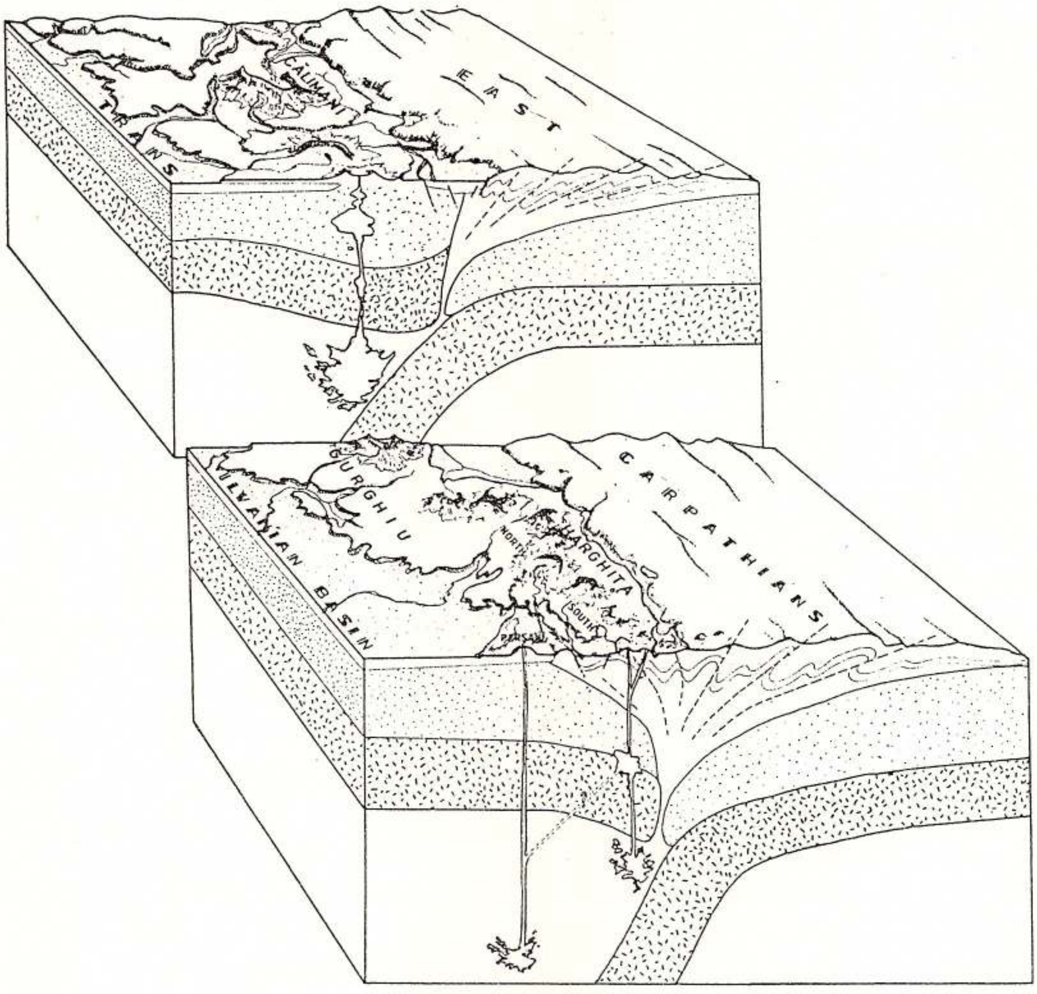


Fig. 2 – Hypothetical block diagram showing the inffered present-day tectonic setting of the CGH volcanic chain.

←

Fig.1 – Volcanological map of Călimani-Gurghiu-Harghita Mountains (East Carpathians); 1. Quaternary swamp or lake deposits; 2. Tertiary postvolcanic and synvolcanic sediments; 3. Tertiary prevolcanic molasse sediments of Transylvanian basin; 4. Cretaceous-Tertiary sediments of the Flysch zone of East Carpathians; 5. Late Paleozoic-Cretaceous sediments of East Carpathians; 6. Precambrian-Paleozoic metamorphic and plutonic rocks of Crystalline-Mesozoic Zone of East Carpathians; 7. Neck; 8. Crater; 9. Caldera-like depressions; 10.Collapse calderas (caldera fault); 11.Porphyritic intrusive rocks; 12.Fine porphyritic intrusive rock; 13.Volcanic core complexes; 14.Extrusive domes; 15.Lava flows; 16.Pyroclastic cone; 17.Stratovolcanic cone; 18.Effusive cone; 19.Coarse pyroclastic rocks-proximal facies; 20.Mudflow, debris avalanche, debris flow and ephemeral stream epiclastic volcanic rocks; 21.Volcanic edifices and areas: CĂLIMANI MTS.-1. Drăgoiasa; 2.Lucaciul; 3.Tămăul; 4.Rusca-Tihu; 5. Moldovanul; 6.Călimani; 7. South Călimani vocanic field; GURGHIU MTS.- 8. Jirca; 9.Obârşia; 10.Fâncel-Lăpuşna; 11.Bacta; 12.Seaca-Tătarca; 13.Borzont; 14.Şumuleu; 15.Ciumani-Fierăstraie; NORTH HARGHITA MTS.-16. Răchitiş; 17.Ostoroş; 18.Ivo-Cocoizaş; 19.Vârghiş; SOUTH HARGHITA MTS.-20.Şumuleu Ciuc; 21.Luci-Lazu; 22. Cucu; 23.Pilişca; 24.Ciomadul; 25. Bicsad-Malnaş volcanic field.

Institutul Geologic al României

The principal deformational events occurred in the East Carpathians in the Mid-Cretaceous and Early Miocene (Săndulescu, 1984, Rădulescu et al., 1994) without being accompanied by significant volcanism. On the other hand, mostly calc-alkaline volcanism largely developed in times (10 Ma onwards) when the compressional structure of the East Carpathians has already been accomplished, i.e. in a postcollisional structural environment. The spatial problem is related to the southern segment of the CGH chain (Harghita Mts.) where the parallelism between the Carpathian accretionary prism and the volcanic range is no more respected: the South Harghita segment obviously crosscuts the intensely folded inner flysch zone (Szakács et al., 1993). Crust thickness is typically higher here (c.a 40 km) as compared beneath the other segments (c.a. 30 km)(Stănică et al., 1986, 1990).

These circumstances warn one that no classical subduction model is to be routinely applied to explain the peculiar relationships between tectonic processes and magmatism in the East Carpathians where the subduction signature-bearing volcanic arc developed in a post-collisional tectonic setting , and is apparently a delayed effect of the active subduction processes.

Volcanic edifices, structures and environments

The axial part of the chain consists of a number of adjoining and partially overlapping volcanic edifices of various sizes, structures and compositions.

Most of the edifices can be characterized as composite volcanoes. The term "stratovolcano" is not a suitable one because most of these structures are lacking pyroclastics as significant cone-building components. They are the result of complex eruptive histories including several cone-building phases interrupted by destruction phases (either caldera-formation, edifice failure or erosion).

The largest and most complex of them is the big Călimani edifice which occupies the northern two thirds of the Călimani Mts. (Seghedi, 1987). In the western half it is built up on a basement of partially uncovered intrusive complex belonging to the southern extension of the "subvolcanic zone". A series of NNE trending older stratocones (Lucaciul, Tămăul, Rusca-Tihu) with their corresponding volcaniclastic aprons form the western half of the structure. The younger Călimani Caldera edifice partially overlap both these edifices as well as the strongly elevated intrusive basement (over 1900 m high in the Bistriciorul- Struniorul summit). It is topped by a c.a 8 km wide collapse caldera structure formed on a mostly lava-constructed volcano. Intracaldera stratocones (e.g. Negoiul Românesc), and dykes, caldera-rim (Pietricelul) and flank (Drăguşul) domes are post- caldera features as well as a large monzodioritic resurgent central intrusion, exposed about 11 km^2 in the interior of the caldera (fig.1).

The southern one third of the Călimani Mts. consists of a field of small-scale fracture-controlled edifices (mostly lava domes) dispersed among volcaniclastics that represents the southern peripheral volcaniclastic aprons of the main volcanic edifices.

An effusive lava center is located far west from these structures with fluid andesitic lava flows overtopping volcaniclastics, well exposed on the Scaunul (God's Chair) summit.

The northern part of the Gurghiu Mts. is dominated by the big amphitheater-shaped Fâncel-Lăpcsna Caldera structure (fig.1) c.a. 10 km across(Rădulescu et al., 1964b), whose origin is uncertain. At its northern flank the remnants of an older volcano displaying an unroofed intrusive core-complex, lava flows and a strombolian cone (Jirca) is found. The very large size of the caldera is not accounted for by the volume of the surrounding massive volcanics as it is the case with the Călimani Caldera. Therefore, widespread pyroclastics have to be taken into account. One possible candidate are the unwelded amphibole andesite pumice and ash

Institutul Geologic al României

flow deposits occurring on large surfaces in both southern Călimani and northern Gurghiu Mts., including the intern caldera rim. No systematic investigation of this problem has yet been achieved. An andesitic dome complex (Bacta) is adjoining to the southeastern part of the caldera. In the western part an unnamed lava volcano overlies the peripheral volcaniclastics of northern Gurghiu Mts., but even its lava field extension has not been outlined accurately.

Other composite volcanic structures in the southern part of Gurghiu Mts. include Seaca-Tătarca with its surprisingly uniform quasicircular "caldera" rim and relatively simple (or poorly known?) structure and shape suggesting rather a shield, Şumuleu with some "crater-rim" domes and well exposed core-complex and a large southern flank lava center, and the double cratered Ciumani-Fierastraie edifice. All of them are typically lava-built composite volcanoes with insignificant pyroclastics recorded in their cone structures. They are surrounded by coalescent volcaniclastic aprons that, due to their similar ages, cannot be separated according to their particular source volcanoes.

The North Harghita volcanoes form a NNE trending row of partially overlapping edifices. The northernmost one (Răchitiş) is a simple aphanitic dacitic dome volcano. Ostoroş, the next, is a rather small sized typical East Carpathian edifice with an obvious enlarged "crater", core-complex, rim domes, consisting of andesitic lavas, and very minor pyroclastics. Aphanitic lava flows, similar to Răchitiş rocks, are present on the northern flank and at the southeastern foot. It is uncertain whether this latter belongs to Ostoroş or the adjoining Ivo-Cocoizaş structure. Ivo-Cocoizaş edifice is strongly eroded with a well exposed core complex, a morphologically not so obvious amphitheater "caldera" and with a shield-like outer topography. Its lavas range from basaltic andesites to acid andesites, but rhyodacitic rocks are found in boreholes (Stanciu et al.,1985). The southern half of the edifice is overlain by the next edifice (Vârghiş) lavas to a considerable extent.

The rest of North Harghita is occupied by the large and complex Vârghiş edifice. Its oldest parts are exposed in the caldera interior and in the Harghita Băi area (southeast of the main summit) where we assume the presence of an independent but later partially buried smaller edifice, whose core complex and its eastern flank are only visible. A large, mostly lava- built cone with a large (c.a. 4 km wide) southward-open caldera forms the largest part of the edifice. Fluid, aphanitic andesitic-dacitic lava flows with well preserved surface pressure ridges (visible on aerial photos) are recorded on the eastern flank as well as a small amphibole-biotite-pyroxene lava dome. "Caldera" formation is not related to nighter huge lava outpouring nor a large ash-flow eruption. It is likely the result of one (or more) edifice failure and related debris avalanche event(s), therefore is not a true caldera but a "horseshoe depression". Postfailure activity concentrated along a north- south fracture where several lava-centers such as Harghita Ciceu and Szilas Vesze, built up a late-stage acid andesite lava range whose southward oriented flows and tongues have obvious topographic expressions (fig.1). Small volume pyroxene andesite pyroclastics are found in the "caldera" interior whereas a thin intercalation of amphibole-biotite pyroclastic level is found below the western "caldera"-rim. A well developed core complex with intrusive bodies and related hydrothermalism is an obvious feature of the "caldera" interior.

A peripheral dome complex of amphibole-biotite-pyroxene andesite composition constitutes the craterless Şumuleu-Ciuc edifice at the southeastern margin of the Middle Ciuc Basin near Miercurea Ciuc.

Luci-Lazu is the northernmost South Harghita volcano, with a typical shield morphology of its upper parts. Some andesitic domes complicate the eastern flank whereas a younger-phase effusive center (Lazu) overtop the structure in the south. An amphitheater-shaped depression

Institutul Geologic al României

hosting the Luci swamp is open southward. The andesite-dominated volcaniclastic apron developed toward southwest forms the basal part of the western South Harghita volcaniclastic assemblage and it is tentatively assignable to Luci-Lazu volcano suggesting that it experienced an early steeper composite cone stage, despite its today's shield morphology.

The Cucu volcano edifice consist of a "primitive" amphibole- pyroxene andesite lava pile overtopped by more acid biotite bearing lava flows and lava domes, some of them reaching the dacitic composition. Three crater remnants, identified recently (Karátson et al., 1992) together with the internal flanks of the domes form an unusual rectangular-shaped depression containing the common core-complex assemblage.

Pilişca volcano is constituted of a steep amphibole-biotite lava dome complex built up over the erosional remnants of an older pyroxene andesite and basaltic andesite cone on which strombolian spatter is recognised. No obvious crater-like depression is present.

The most well preserved volcano is the southeasternmost one (Ciomadul) consisting of a viscous dacitic lava dome and flow complex and a twin-cratered pyroclastic cone. The lava domes are clustered in the northern and western part of the edifice whereas isolated domes are present to south (Köves Ponk), southeast (Dealul Mare) and northwest (Baba Lapoşa) (Szakács, Seghedi, 1986). The remnants of further two isolated domes (Puturosul and Bálványos) are found farer to east.

The volcanic chain terminus is marked by a cluster of three volcanic bodies of which one is an amphibole-biotite-pyroxene andesite lava dome (Murgul Mare) and the others are shoshonitic near-surface intrusions (Murgul Mic and Luget).

The lithologic, structural and morphologic features of both volcanic edifices and deposits are typical for subaerial continental arc type calc-alkaline volcanism. No obvious feature suggesting subaqueos activity has yet been encountered. Deposition of the volcanic products - effusive and volcaniclastic - was subaerial excepting for local lacustrine subaqueous environments.

Time and space evolution

Magmatism began at the northwestern periphery of the Călimani Mountains (Pécskay et al., in press), consisting of intrusive activity as the southeastern extension of the subvolcanic zone of Bârgău Mts. (ca. 12.0 - 9.5 Ma). The oldest volcanics are located at the eastern part of the Călimani Mountains (9.3 Ma) and are represented by dacitic rocks (Peltz et al., 1987). Coeval period of volcanic activity was observed for the Călimani and Gurghiu Mts. between 8.4 - 6.8 Ma (fig.3). The K-Ar ages suggest that volcanic activity started roughly at the same time in Călimani and Gurghiu, but lasted ca. 1.5 Ma longer along the later segment. There is slight overlapping between the final volcanism in the Gurghiu Mts. and the onset of North Harghita volcanicity (6.3-5.9 Ma). It is notable that the southern part of North Harghita Mountains and the northernmost South Harghita volcano (Luci-Lazu) were simultaneously active (fig.3). Following a period of waning activity lasting about 1 Ma, volcanism continued in the rest of South Harghita. It was observed a southward migration for the three main volcanoes (Cucu, Pilişca, Ciomadul), ranging from 2.8-0.2 Ma. Ciomadul is the youngest volcano of all the Carpathians and Eastern Europe. A recent ^{14}C age of a charcoal piece found in Ciomadul pyroclastics has given 10,700+ yr. BP (Juvigné et al., 1994).

Institutul Geologic al României

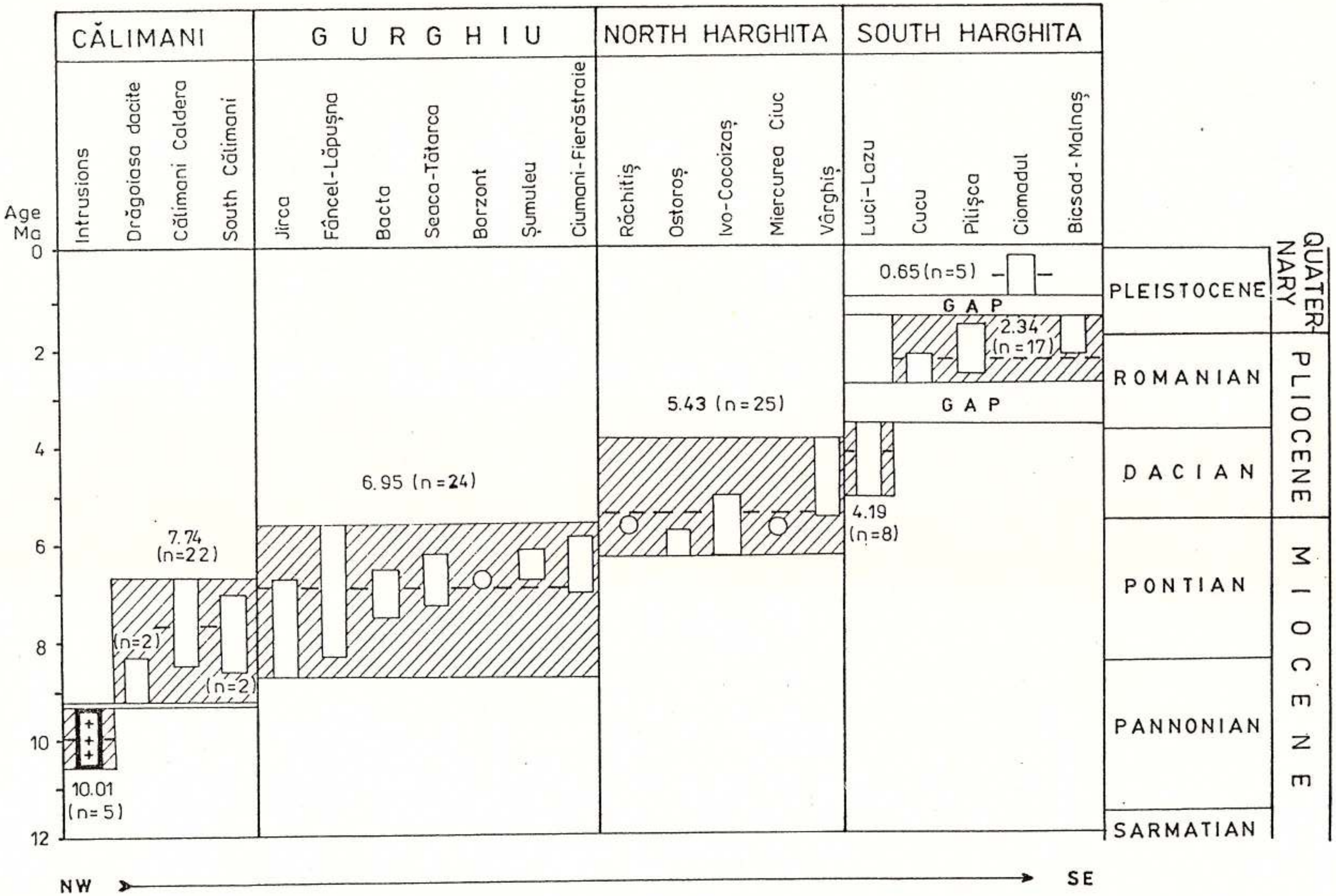


Fig.3 – Time-space evolution of the volcanism along the CGH volcanic chain as resulted from K-Ar data. Volcanic edifices and areas are shown individually.

Institutul Geologic al României

Petrography

CGH lavas vary from basalts, through basaltic andesites, to andesites and dacites. They are typically porphyritic. Plagioclase, magnetite and ilmenite are ubiquitous in all rock types. Clino- and ortopyroxene are common in basalts, andesites and some dacites. Amphibole is present from andesitic composition onwards, but sparsely occurs in basaltic andesites too. Quartz occurs in dacites and in shoshonites located at the southern end of the CGH. Groundmass accessories include apatite and zircon. Sphene is a rare phenocryst phase in some rocks, particularly those from the youngest volcanic centers in the south of the chain. Biotite occurs in the more evolved and more K-rich rocks. A few aphyric rocks which contain mainly rare plagioclase phenocrysts occur in several volcanic centers (Călimani, Răchitiş, Ostoroş, Vârghiş). Some samples display glassy groundmasses, others are fine-grained. The shoshonitic rocks contain coexisting phenocrysts of magnesian olivine, clinopyroxene, plagioclase, quartz, amphibol, biotite and sphene. Xenoliths of crustal material, typically schists and gnaisses, are common within lava flows. Cognate xenoliths with igneous texture, composed of amphibol ± clinopyroxene ± plagioclase ± magnetite, are also widespread.

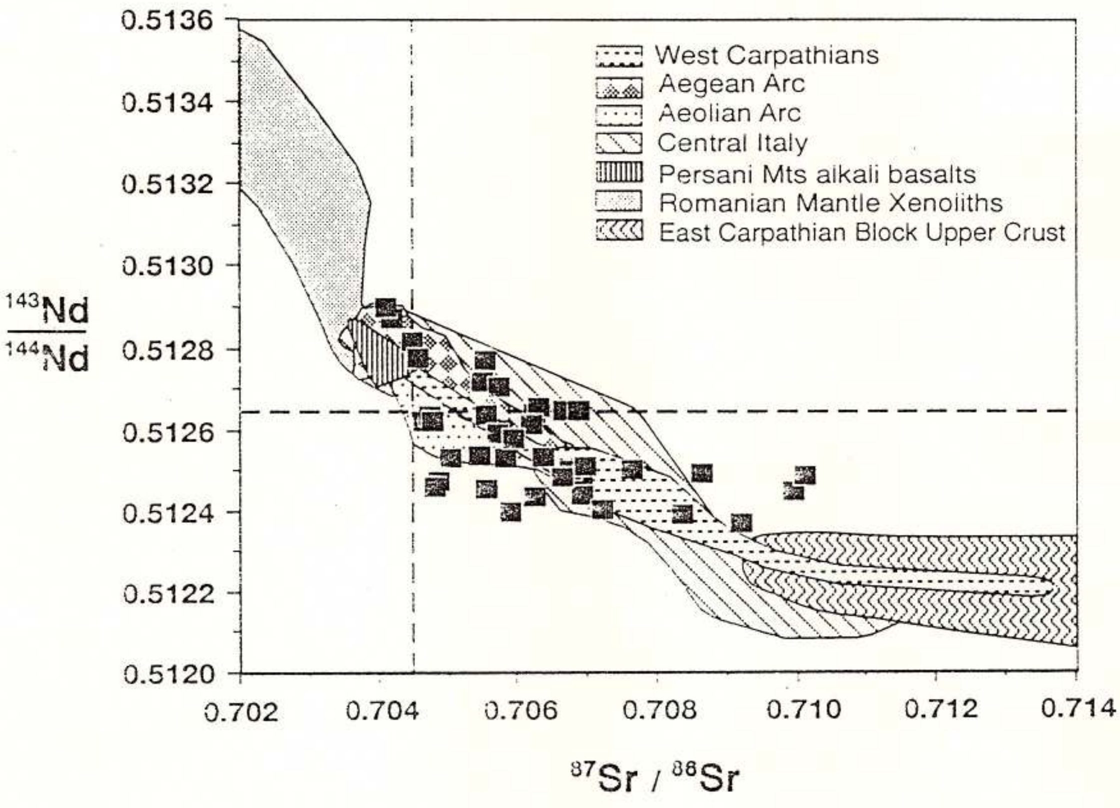


Fig.4 – $^{87}Sr/^{86}Sr$ vs. $^{143}Nd/^{144}Nd$ isotope diagram for CGH rocks. A comparison with other arc and magma reservoirs in the Carpatho-Balkano-Mediterranean areas (Mason et al., in press)

Petrogenetic summary

The petrographic and geochemical investigations suggest complex processes of generation and evolution of CGH magmas (Peltz et al.,1984, Seghedi et al., 1987, Mason et al., in press, Seghedi et al., in press). The petrogenetic processes can be summarized as follows:

Institutul Geologic al României

– The main magmas source is of mantle type (depleted MORB source asthenosphere; fig.4), affected by a "subduction-related" geochemical signature (fig 5a). There are two mantle source types: one for the South Harghita volcanics (from Cucu volcano southwards) and another for the remainder of the CGH (fig.5b). The latter source is a complex one. It is most depleted and uncontaminated in Călimani area, and probably slightly metasomathised in Gurghiu and North Harghita. An additional crustal source is suggested for the eastern part of the Călimani area (Drăgoiasa dacites), where small volume acid magmas erupted at the inception of the volcanic activity. The South Harghita source is different by its lower Sr and Pb isotopic ratios producing Sr and Ba enriched magmas;

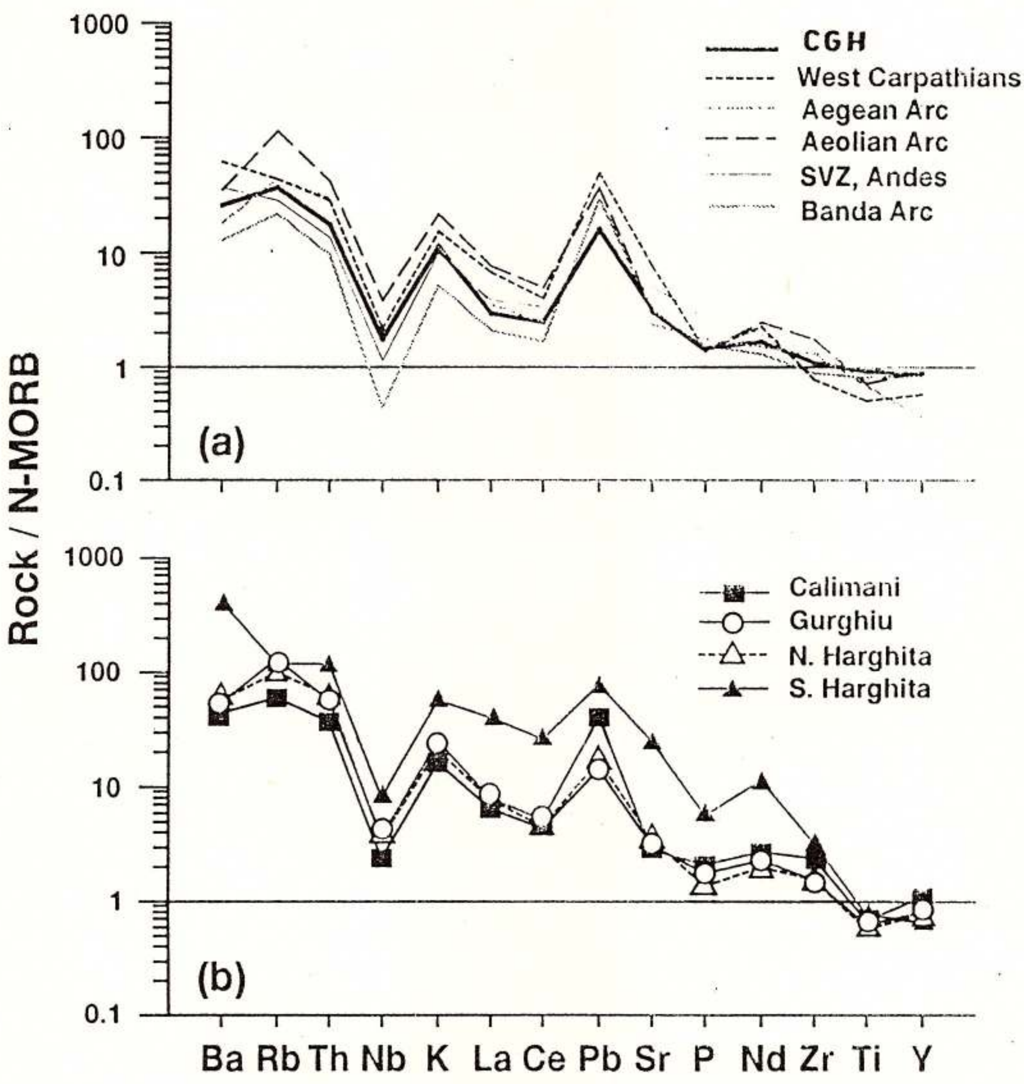


Fig.5 – N-MORB-normalised incompatible trace element diagrams using the normalising coefficient of Sun & McDonough (1989) . a) comparison with other arc and magma reservoirs in the Carpatho-Balkano-Mediterranean area; b) Representative samples at 57 % SiO_2 for the main groups of the CGH (Mason et al., in press)

Institutul Geologic al României

– For northern part of the CGH area almost constant degree of partial melting is infered, while South Harghita area magmas result from gradually lower degree of partial melting along the chain;

– In areas with large volume erupted magmas (Călimani, Gurghiu, North Harghita) petrogenetic processes are dominated by combined fractional crystallization and crustal assimilation. Upper crustal contamination has strongly masked source processes. The South Harghita volcanics suggest a complex combination of processes such as assimilation, fractional crystallisation and magma mixing, characteristic for each volcanic structure.

Description of the itinerary

Day 1: Vatra Dornei - Călimani Caldera interior - Dracula's Castle hotel (Tihuţa Pass) - Bistriţa

Stop 1.1. Neagra Şarului village, southern margin: General outlook on the Călimani Caldera edifice, its volcanic morphology and rough structure. The semicircular high-altitude border (c.a. 2 000 m with the Pietrosul peak as its highest point, 2104 m) consisting of the large volume precaldera lava flows outlines the large (c.a. 8 km wide) collapse caldera depression visible from this point. The lower part of the morphology is occupied by various pre- and postcaldera lavas and volcaniclastics. A short introduction to the problematics of the volcanic structure, evolution, and petrological aspects will be provided. Observation: The panoramic view of the caldera, especially its upper parts, is strongly dependent on weather conditions.

Stop 1.2. Gura Haitei village: Andesite lava flow belonging to the earlier stages of the precaldera edifice building. The outcrop displays the interior of a thick lava flow with massive irregular jointing in the middle and platy jointing in the upper part. The rock is medium porphyritic, rare amphibole- bearing pyroxene andesite, including numerous sedimentary xenoliths. Its K–Ar age is 7.94 ± 0.37 (Pécskay et al., in print).

The major and trace element composition points to a typical normal-K calc-alkaline suite rock (Table 1).

Table 1

Sample no. 717

%	%
SiO_2 - 57.40	K_2O - 1.50
Al_2O_3 - 21.62	Na_2O - 3.15
Fe_2O_3 - 1.98	TiO_2 - 0.47
FeO - 3.30	P_2O_5 - 0.20
MnO - 0.12	CO_2 - 0.29
MgO - 2.09	S - 0.09
CaO - 7.08	H_2O^+ - 0.87
	Total - 100.51

Institutul Geologic al României

Stop 1.3. Neagra valley, Bisericii brook (left-side tributary) confluence: Basaltic andesite lava flow sequence

The road-side part of the outcrop shows the breccious autoclastic part of the large pyroxene-bearing lava, probably its upper part. Further up in the valley side the transition between the massive interior (2-3 m thick) and the thick external autoclastic envelope (c.a. 15 m thick) of a different lava flow unit is cropping out. Angular centimetric to metric porous to vacuolar and massive blocks are conspicuous within the clinkery breccious autoclastic lava.

This lava sequence is part of the older pre-caldera complex stratovolcanic edifice of Călimani, probably belonging to the Tămău structure.

Stop 1.4. Neagra valley, Calului brook (right-side tributary) confluence: Minor intrusive bodies (domes and dykes) in volcaniclastic sequences

Intrusion contacts of small-scale intrusions are visible in road-side outcrops. They pierce a sequence of coarse, heterolithologic breccias with altered cineritic matrix, containing angular massive and porous centimetric to decimetric sized blocks, part of which looking like originally hot juvenile fragments, the others being detachable accidental material. Most of the blocks are basaltic andesitic in composition. Two domes, visible along the outcrops, several tens of meter wide, are of fine equigranular basaltic andesite, with irregular jointing. A several meters wide vertical dyke display a different composition: large porphyric amphibole-pyroxene andesite. The chilled margin of the dyke include typical fissuration normal to the contact surface.

The bodies are thought to belong to the older pre-caldera stratovolcanic structure. No K-Ar dating is available.

The chemical features of the intrusions are given in Table 2:

Table 2

Sample no. C 37 Basaltic andesite %	Sample no. 841 Pyroxene-amphibole bearing andesite %
SiO_2 - 56.96	SiO_2 - 57.35
Al_2O_3 - 18.30	Al_2O_3 - 17.71
Fe_2O_3 - 7.40	Fe_2O_3 - 3.85
FeO - 0.00	FeO - 3.00
MnO - 0.18	MnO - 0.13
MgO - 3.69	MgO - 3.41
CaO - 7.52	CaO - 7.03
Na_2O - 3.27	Na_2O - 3.24
K_2O - 1.74	K_2O - 2.05
TiO_2 - 0.80	TiO_2 - 0.78
P_2O_5 - 0.18	P_2O_5 - 0.07
	S - 0.04
	H_2O^+ - 0.90
Total 100.04	Total - 99.56

Lunch from pack

Institutul Geologic al României

Stop 1.5. Confluence between Haita and Răchitiş brooks: abandoned quarry in the post-caldera resurgent monzodioritic intrusive body; contact of the intrusion and related thermal and metasomatic effects

The quarry opens the near-contact marginal part of the large (ca. 7x5 km) late-stage intrusion that occupies the central and western parts of the Călimani Caldera, cropping out at an altitude range of more than 500 m, whereas bore-hole data indicates more than further 1100 m development in depth.

The intrusion consists of equigranular or porphyric holocrystalline rocks with the following mineral assemblage: plagioclase (45-62%), augite (9-20%), hyperstene (10-19%), K-feldspar (4-22%), quartz (1-12%), opaque + accesory minerals (2-4%), and in places, biotite (up to 4%) and amphibole (up to 4%). Their major element composition place them in the fields of monzodiorites and diorites (Seghedi, 1982).

Repeated attempts to date the intrusion event by the K-Ar method failed likely because excess argon problems related to the pervasive hydrothermal circulation throughout the entire accessible part of the body.

In the old quarry to be visited the marginal facies of the intrusion is displayed, including its contact with older massive andesite lavas. The contact surface in the outcrop is roughly vertical displaying a sinuous track. At smaller scale it is diffuse because the post-emplacement alteration processes. Contact phenomena induced both thermal (recrystallization) and metasomatic effects in both the surrounding volcanics and the body itself. High-temperature metasomatic associations include veinlets and impregnations of clinopyroxene (diopside), biotite, and amphibole. Later metasomatic assemblages (quartz, pyrite, epidote, calcite, andradite) are controlled by fissures and voids, and overprints the contact zone and earlier parageneses. Lower-temperature hydrometasomatism (albitization, actinolitization and argillization) are the final contact-related processes observable in the quarry.

Stop 1.6. Negoiul Românesc Big Sulphur Quarry: Section through the post-caldera stratovolcanic structure with pervasive hydrothermal alteration and sulphur deposits

A small sized post-caldera stratocone with its highest point in the Negoiul Românesc peak (1840 m) developed in the interior of the large Călimani Caldera. A very large quarry, dug for sulphur exploration and exploitation opens the interior of the cone. In the numerous levels of the quarry the stratovolcanic structure consisting of pyroxene andesite lava/pyroclastics alternations is exposed but the very intense hydrothermal alteration made that structure vaguely visible. Breccia bodies (pipes?) are largely visible. Fresh or slightly altered rocks, especially lavas are mostly encountered at the upper part and at the periphery of the structure. One fresh pyroxene andesite lava sample yielded a K-Ar age of 6.75 ± 0.45 Ma (Pécskay et al., in print).

Postvolcanic processes led to the intense, in places pervasive alteration of the volcanics. Both structural (volcanic conduits and fractures) and lithological (pyroclastic levels) control of the alteration process is obvious. Strong acid leaching in the vicinity of circulation paths, leaving behind a porous residual siliceous rock, predates the precipitation of medium to low temperature hydrothermal minerals. Two mineral assemblages with distinct redox conditions have been pointed out: one alunite-bearing association indicating an oxidic environment (quartz - alunite-natroalunite - kaolinite ± zunyite ± illite ± barite ± pyrite; cristobalite - tridymite - alunite - quartz - kaolinite) and another sulphurous one of anoxidic environment (quartz -

Institutul Geologic al României

kaolinite - montmorillonite - sulphur ± pyrite ± marcasite ± melnikovite) (Stanciu, Medeşan, 1971 a, b, Seghedi et al., 1992).

Dinner at the Dracula's Castle hotel (Tihuţa Pass); enjoying the nice landscape of Călimani Mts. and the Bârgău Subvolcanic zone

Day 2: Bistriţa - Reghin - Deda - Mureş valley section in volcaniclastics - Topliţa - Gheorgheni

Stop 2.1. Mureş valley near Deda village: Morphological expression of the boundary between the Upper Miocene sedimentary fill of the Transylvanian Basin and the overlying distal volcaniclastics of the western Călimani and Gurghiu Mts.

Introductory explanation to the problematics of the volcaniclastics to be examined during the day. A nice lava plateau can be seen (if weather permits) overtopping the volcaniclastics at the Scaunul (God's Chair) summit.

Stop 2.2. Răstoliţa, Jisa brook (northern tributary of Mureş valley): Debris avalanche deposit

Along a large roadside outcrop an extremely heterogenous thick, non-stratified, chaotic breccia-like deposit displaying features that suggest its debris-avalanche origin will be examined. Large (metric) to small (centimetric), compositionally and texturally heterolithic blocks showing a very non-uniform distribution are embedded in a well developed extremely heterogenous matrix. Pyroxene andesites and basaltic andesites are the prevailing petrotype. The source area of the deposit is actually unknown.

Stop 2.3. Androneasa: Debris avalanche vs. debris flow deposit

Thick (multimeter) non-stratified matrix-rich volcaniclastic breccias are well exposed along the road-side. Subangular to angular medium-sized heterolithic blocks are more or less evenly distributed within the matrix. Hydrothermally altered blocks typically occur in the deposit suggesting their origin from a central volcanic zone. This feature suggests a debris-avalanche origin of the otherwise debris flow-looking deposit.

Stop 2.4. Sălard (Sălard brook confluence with the Mureş Valley): basaltic andesite block-and-ash flow deposits

In a very high road-side cliff a succession of flow units of pyroclastic (block-and-ash) flow deposits and debris flow deposits are cropping out. They are monolithologic, of basaltic andesite composition. The thickness of the pyroclastics is typically of 1.5-2 m, generally showing a finer basal part followed by a reverse, then normal graded middle. Local aspects suggesting pyroclastic surge deposits can be found as well. Thinner interbeds of water-led secondary deposits are also present. The presence of prevailing massive, non-vesicular basaltic andesite blocks are suggestive for a Merapi-type mechanism of block-and-ash flow genesis (by gravitational collapse of high-level lava domes or flows over the steep sides of the volcanic cone). After a short walk (at Patulul brook) an interbedded basaltic andesite lava flow (8.13 ± 0.33

Institutul Geologic al României

Ma old, Pécskay et al., in press) can be examined and sampled.

Lunch: from pack or at the Sălard motel

Stop 2.5. Lunca Bradului: Debris flow deposits, tuffs and hyperconcentrated flood flow deposits. A nice road-side outcrop in the village displays a succession of different types of volcaniclastics.

In the lower ca. 3 m of the outcrop a thick coarse hyperconcentrated flood flow deposit is exposed consisting of grainsupported rounded and subrounded heterolithic, mostly basaltic andesite clasts. It is conformably overline by a c.a. 1.2 m thick yellowish debris flow deposit with suspended dense lithic clasts (amphibole andesite prevails) in a well developed finer matrix.

In turn, it supports a whitish well-sorted tuff horizon about 0.5 thick, probably of fallout origin.

Both the debris flow deposit and the overlying tuff are carved by the erosional base, including a channel, of a second debris flow deposit. It is rich in large rounded-subrounded dense clasts tending to concentrate within the channel. Finer matrix is more developed away from the channel. Other similar debris flow deposits occupy the upper part of the outcrop.

Stop 2.6. Neagra: Pyroclastic flow deposit (unwelded ignimbrite)

Pumice-rich amphibole andesite pyroclastic flow deposit is well exposed in a road-side outcrop. It is underlined by a debris flow deposit, with the boundary between the two inclined at c.a. 30 degrees. The presence of faults suggest that the volcaniclastics are tectonically disturbed.

The unwelded ignimbrite is ca. 4 m thick. Centimetric (2-6 cm) pumice clasts tend to cluster in lentiliform levels in the middle part of the flow unit. Small porous angular to subangular lithic clasts are present in small amounts. The pumice and lithic concentrations lend a weakly stratified appearance to the deposit. Both pumice and lithics are of acid amphibole-pyroxene andesite-dacite composition. The major chemical composition of pumice (SiO_2 = 62.9 %) (Table 3) plot at the andesite-dacite boundary.

Even though no K-Ar dating of the ignimbrite is available, a similar composition block in volcaniclastics in the neighboring area was dated 6.97 ± 0.42 Ma (Pécskay et al., in print). The source area of the ignimbrite is not well constrained. A possible origin could be in the Fâncel-Lapuşna caldera (northern Gurghiu Mts.).

Institutul Geologic al României

Table 3

Sample no. CL-84

%	%
SiO_2 - 62.88	CaO - 5.46
Al_2O_3- 16.53	K_2O - 1.95
Fe_2O_3- 2.27	Na_2O - 3.02
FeO - 2.21	TiO_2 - 0.40
MnO - 0.21	P_2O_5 - 0.15
MgO - 2.00	H_2O^+ - 2.87
	S - 0.15
	Total 100.01

Stop 2.7. Stânceni Quarry: Old (pre-volcanic) basaltic andesite shallow intrusive body

A large road-side quarry allows an insight in a small-sized intrusive body and its relationships with the host rocks. It pierce a sequence of Lower to Upper Miocene sedimentary deposits belonging to the eastern margin of the Transylvanian Basin. They include grey marls and limy marls, micaceous sandstones, microconglomerates and conglomerates (Ştefănescu in Peltz et al., 1981) and fine-grained rhyolitic tuffs. These rocks are visible in the upper and peripheral parts of the quarry. Contact phenomena are weak and poorly developed. The intrusive body consists of gray massive basaltic andesite displaying porphyritic texture with a microholocrystaline groundmass. Phenocryst assemblage is represented by plagioclase (37-43%, 42- 52% An), bastitized augite (6-10%), and hyperstene (1-3%). Its major element composition plot in the basaltic andesite field (SiO_2 = 54.23-56.72%; table 4). A K-Ar dating (9.59 ± 0.62 Ma, Pécskay et al., in print) places the body among the old, pre-volcanic intrusions largely developed in the northern Călimani Mts. but present in the southern Călimani Mts too.

In the left side of the quarry beautiful terrace morphology and related Pleistocene fluvial deposits can be seen.

Table 4

Sample no. 3426

%	%
SiO_2 - 54.23	K_2O - 0.67
Al_2O_3 - 17.93	Na_2O- 3.36
Fe_2O_3 - 5.66	TiO_2- 1.31
FeO - 2.59	P_2O_5- 0.18
MnO - 0.14	H_2O^+- 1.36
MgO - 3.46	S - 0.32
CaO - 7.33	Total 99.54

Stop 2.8. East of Stânceni: Basaltic andesite block-and ash flow vs hot debris avalanche deposit

Thick (5 m or more), massive, unstratified breccia-like rocks crop out along the road-side. They consist of rather uniformly sized, more or less porous monolithologic centimeter-sized basaltic andesite clasts and a triturated matrix of the same composition. Some of the clasts look like stuck with the matrix suggesting a point and edge contact welding. In places the

Institutul Geologic al României

rock is hard, almost lava-like. However jig-saw fit blocks can be seen in places, suggesting a debris avalanche mechanism. A large block of heterolithologic breccia with aragonite veins is embedded in the deposit supporting the debris avalanche origin. Most of the clasts are porous and variably oxidized. In places a columnar-like jointing indicating high emplacement temperatures is visible. These features are compatible with both hot block-and- ash flow (Peléean type) and hot, explosive eruption-related debris avalanche mechanisms.

Stop 2.9. West of Toplita: Debris flow sequences

Near the western entrance in Toplita town, successions of thin (0.5-1.2m) debris flow deposits are exposed along the road. They display variable aspects due to the block/matrix ratio variability and the variable degree of the matrix alteration. A number of at least 8 flow units can be distinguished with more or less obvious boundaries between them. Some of the debris flow units (lahars) have erosional bases with obvious channel development. Some of the thinner intercalations may represent fluvial deposits. The outcrop display post-depositional sideritization of the volcaniclastics.

This sequence is typical for a distal perivolcanic volcaniclastic facies developed on subdued topography at the foots of the stratovolcanoes where most of the debris flows discharge on plains beyond their more channelized upper reaches.

Dinner in Gheorgheni

Day 3: Gheorgheni - Bucin Pass - Praid (Sovata) - Corund - Odorheiu Secuiesc - Tolvaioş Pass - Miercurea Ciuc

Stop 3.1. Borzont village: panoramic view on the central part of the Gurghiu Mts.

Volcanic morphology of the Seaca-Tătarca, Borzont and Şumuleu volcanic edifices can be seen. The itinerary and problematics of the day will be introduced.

Stop 3.2. Bucin Pass quarry: Pyroxene andesite lava flow

The quarry exposes a section of a lava flow belonging to the Seaca-Tătarca volcano. This two pyroxene andesite is the most common rock-type in the whole CGH volcanic chain. The blocky-jointed middle part of the flow is visible in the lower part of the quarry, followed upwards by a platty-jointed zone and a weathered uppermost part. A chemical analysis of the lava is given in table 5. It was the subject of repeated K-Ar datings in three different laboratories yielding very consistent ages around 7.2 Ma (Michailova et al., 1984, Pécskay et al., in print, Seghedi et al., in print).

Institutul Geologic al României

Table 5

Sample no. GH-35

%	%
SiO_2 - 57.00	K_2O - 1.22
Al_2O_3 - 17.64	Na_2O - 3.54
Fe_2O_3 - 4.19	TiO_2 - 1.11
FeO - 3.18	P_2O_5 - 0.20
MnO - 0.15	H_2O^+ - 0.53
MgO - 3.52	S - 0.17
CaO - 7.35	Total 99.80

Stop 3.3. Bucin Pass: Volcanological explanations on the general structure of the CGH volcanic chain with an emphasis on the origin and development of the peripheral volcaniclastic formation.

Stop 3.4. West of Bucin Pass: Debris flow deposits

Debris flow deposits are cropping out in a roadcut exposure showing some interesting features. Unsorted heterolithic lithic blocks are embedded in a well developed matrix. Flow units can be distinguished. A block with radial cracks suggesting cooling of a hot rock-fragment is secondarily included in the deposit. These deposits have originated, probably, from the Seaca-Tătarca volcano.

Lunch in Sovata (or Praid)

Stop 3.5. Corund: Post-volcanic fossil and active carbonate deposition

The boundary between the peripheral volcaniclastic formation and its prevolcanic Neogene sedimentary basement, well marked in the topography, can be viewed from this place.

Three parallel elongated mounds are formed by fracture-controlled carbonatic spring deposits (calcareous tufa and travertine) and the filling of their feeding tensional fractures. One of these mounds will be visited.

Vertically layered aragonite pseudomorfosed by calcite forms the prominent walls of the fracture-filling carbonate body, suggesting sin-tectonic precipitation. The vein is overtopped by horizontally layered porous-vacuolar calcareous tufa deposited at and near fossil spring emergencies. Saline carbonate-oversaturated CO_2-bearing waters are still emerging at the bottom of the steep walls and on-going carbonate deposition can be observed.

The famous "Corund aragonite" has been used in the past for manufacturing of small decorative objects. Nice collection pieces of "aragonite", transformed in calcit can be collected.

A short touristic stop in the center of Corund village, famous for its popular potteries, will allow the participants to enjoy popular art and purchase souvenirs.

Stop 3.6. Vlăhiţa Plateau: Panoramic view on the large Vârghiş volcanic edifice; lava front coming from the youngest Vârghiş eruptions

Institutul Geologic al României

The Vlăhiţa Plateau along the road between Odorheiu Secuiesc and Miercurea Ciuc towns is a depositional surface of the peripheral volcaniclastic formation locally heightened by longer-reaching lava flows of the Vârghiş volcano, whose volcanic morphology is nicely outlined from this viewpoint. Fluid peripheral lava flows are of hyperstene-bearing andesitic composition (Tablé 6) displaying typical shear-induced platty jointing. Vârghiş volcano is the largest and most complex volcanic edifice of the Harghita Mts. built up between c.a. 5.5 - 4 Ma ago (Pécskay et al., in print). A southward opened amphitheater-shaped caldera formed at the end of the first-stage evolution. Voluminous debris avalanche and flow deposits widespread along SSW graben-and-horst structure far southward, are apparently related to the caldera formation event. Postcaldera lava centers were active giving rise to the youngest lava flows such as those on the Vlăhiţa Plateau.

The volcaniclastics hosted a small-volume iron ore (siderite) deposit at Vlăhiţa, exploited for more than a century, now exhausted.

Table 6

Sample no. LV 238

%	%
SiO_2 - 56.87	K_2O - 1.10
Al_2O_3 - 18.59	Na_2O - 3.13
Fe_2O_3 - 2.59	TiO_2 - 0.73
FeO - 4.00	P_2O_5 - 0.02
MnO - 0.13	H_2O^+ - 0.35
MgO - 3.85	S - 0.29
CaO - 8.12	Total 100.05

Stop 3.7. East of Tolvaioş Pass: Outlook on the Upper Pliocene/Quaternary Ciuc Basins

A string of three intramountain basins developed along the eastern boundary of the North and South Harghita volcanic segments separating morphologically the volcanic mountains from the East Carpathian orogenic range. The eastern borders of the depressions are tectonically bounded, while the western ones are formed by damming of the volcanic range. Peripheral volcaniclastics are present beneath the Late Pliocene - Pleistocene basin fill consisting of both western volcanic source material and eastern-source terrigenous material. Diatomites and low-quality coal are present in the fill.

Dinner in Miercurea Ciuc

Day 4: Miercurea Ciuc - Baile Tusnad - Sf. Ana crater lake - Turia mofetta - Brasov (Bucharest)

Stop 4.1. Cozmeni: outlook on the South Harghita volcanic range and the Lower Ciuc Basin. Introduction to the problematics of South Harghita

A nice panorama of the South Harghita volcanoes (Luci-Lazu, Cucu, Pilişca and Ciomadul, from north to south) can be seen from this point. Volcanic morphology can be examined. The

Institutul Geologic al României

youthful features of Ciomadul volcano, the youngest of the whole Carpathian volcanic arc, are especially striking. The peculiar position of the chain-terminus South Harghita segment with respect the other parts of the CGH Range will be explained.

Stop. 4.2. Quarry South of Băile Tuşnad: Ciomadul tephra sequence

A plinian pumice fall deposit (4.3 m thick) overline by two units of (several meters thick each) pumice-and-ash flow deposit (unwelded ignimbrite) and a debris flow deposit in the top, are exposed in an abandoned road-side quarry. All these deposits are part of the Ciomadul pyroclastic cone built up over a lava dome complex. They originated during its latest eruption through the Sf. Ana crater. Almost all of the Ciomadul edifice consist of high-K dacitic products.

A charcoal piece found in the upper pyroclastic flow unit yielded a ^{14}C age of 10,700 $\pm$ 180 years (Juvigné et al., 1994), while the paleosoil underlying the pumice fall deposit was dated about 40,000 years (Moriya, unpublished data) constraining the last eruption age to this interval. The pumice fall layer has been recognized in several outcrop some 35 km est of Ciomadul volcano having c.a. 0.2 m thickness.

Stop 4.3. East of Bicsad village: outlook on the morphology of Ciomadul volcano as viewed from south

The lower southern rim of the pyroclastic cone and the higher southwestern part of the volcano dominated by lava domes and flows are clearly visible. The Köves ponk summit on the pyroclastic rim is a sampling site for dacitic lava. It is apparently a lava dome remnant issuing from below the pyroclastics. The peripheral Dealul Mare dome (andesitic) and the Puturosul lava dome (dacitic) remnant, to be visited, can be seen as well.

Stop 4.4. Base surge deposit near the Mohoş crater rim

Mohoş is one of the twin craters topping the Ciomadul pyroclastic cone; it is now occupied by the Mohoş swamp. Near its border a small but significant outcrop exhibits cross-bedded base surge deposits containing accretionary lapilli. They resulted from a yet undated phreatomagmatic eruption through the Mohoş crater.

Stop 4.5. Köves Ponk summit and quarry: dacite lava

A small abandoned quarry near the Köves Ponk summit on the Southern Mohoş crater rim exposes fresh porphyric amphibole- biotite dacite lava of high-K calc-alkaline composition (table 7). Large plagioclase along with beautiful biotite tablets and amphibole needles form the phenocryst assemblage of the rock. Accesory apatite, zircon and sphene have also been reported from this rock.

A reference K-Ar age on biotite separated from this rock has been obtained recently (0.56 $\pm$ 0.11 Ma; Szakács et al., 1993), suggesting that the dome building phase much predates the late plinian eruption of the volcano.

155557
Institutul Geologic al României

Table 7

Sample no. AM 35

%	%
SiO_2 - 66.87	K_2O - 3.14
Al_2O_3- 14.94	Na_2O - 4.44
Fe_2O_3- 1.53	TiO_2 - 0.65
FeO - 0.73	P_2O_5 - 0.07
MnO - 0.09	H_2O^+ - 1.17
MgO - 2.70	S - 0.03
CaO - 3.64	Total 100.00

Stop 4.6. Sf. Ana crater lake

The lake is located on the bottom of a closed circular depression that is the youngest crater of the volcano and it is a unique volcanic feature in the whole eastern half of Europe. It is continuously colmating; its actual maximum depth is ca. 6 m, whereas one century ago it was ca. 13 m deep.

We will have three points of interest in this area. From the saddle between the two craters the Mohoş swamp and crater is nicely visible. From a viewpoint on the northern inner side of the crater a panoramic view of the Sf. Ana lake can be enjoyed and photographed. A walk on the shore of the lake, along which CO_2 emanations from a borehole occur, will be finally enjoyed.

Stop.4.7. Putuɾosul Hill: Mofetta cave

Artificially enlarged caves accumulate mofetta gases; one of them is primitively amenaged for gas-bath cures benefic for a number of diseases.

The level of the CO_2 accumulation in the caves is marked by the limit of the sulphur deposited from H_2S accompanying CO_2. The Puturosul hill is a remnant of an older lava dome of biotite amphibole dacite pervasively altered by fumarolic activity. Numerous free CO_2–bearing mineral springs and other mofettas are present in this area.

Lunch in the Carpați Hotel

Afternoon: travel to Brasov (or Bucharest)

References

Bleahu, M., Boccaletti, M., Manetti, P., Peltz, S. (1973) The Carpathian arc: A continental arc displaying the features of an "island arc". *Jour.Geophys Res.*, 78, 5025-5032

Boccaletti, M., Manetti, P., Peccerillo, A., Peltz, S. (1973) Young volcanism in the Călimani–Harghita Mountains (East Carpathians): evidence of paleoseismic zone. *Tectonophysics*, 19, 299-313.

Juvigné, E., Gewelt, M., Gilot, M., Hurtgen, Ch., Seghedi, I., Szakács, A., Hadnagy, A., Gabris, G., Horvath, E. (1994) Une eruption vieille d'environ 10.700 ans (^{14}C) dans le Carpathes Orientales (Roumanie). *C.R. Acad. Sci. Paris*, 318, 1233-1238

Karátson, D., Pécskay, Z., Szakács, S., Seghedi, I. (1992) An extict volcano in the Harghita Mts.: Mt. Cucu. *Tudomány* (Hungarian version of Scientific American), 1, 70-79, Budapest.

Institutul Geologic al României

Mason P., Downes H., Thirlwall M.F., Seghedi I., Szakács A (in press) Crustal assimilation as a major petrogenetic process in continental margin arcs: The East Carpathian Neogene and Quaternary volcanics. *Journal of Petrology.*

Michailova, N., Glevasskaia, A., Tsykora, V., Neştianu, T., Romanescu, D. (1983) New paleomagnetic data for the Călimani, Gurghiu and Harghita volcanic Mountains in the Romanian Carpathians, *An.Inst.Geol.Geofiz.*, LXIII, Bucureşti

Pécskay, Z., Edelstein, O., Seghedi, I., Szakács, A., Kovács, M., Crihan, M., Bernad, A. (in press) Recent K-Ar datings of Neogene-Quaternary calc-alkaline volcanic rocks in Romania. *Acta Volcanologica.*

Peltz, S., Ştefănescu, M., Balla, Z., Gheorghiu, A. (1981) Date noi privind structura geologica a regiunii Zebrac-Mermezeu (Stănceni, Munţii Călimani) *D.S. Inst Geol Geofiz.*, LXVI, 86- 93

— **, Grabari, G., Stoian, M., Tănăsescu, A., Vâjdea, E. (1984)** REE, Rb, Sr and K distribution in volcanic rocks from the East Carpathians (Călimani-Harghita and Perşani Mts.). Petrogenetic significance. In "Magmatism of the mollase- forming epoch and its relation with endogenous mineralization", Bratislava, 47-58

— **, Vâjdea, E., Balogh, K., Pécskay, Z.(1987)** Contributions to the chronological study of the volcanic processes in the Călimani and Harghita Mountains (East Carpathians, Romania). *D.S.Inst.Geol.Geofiz.*, 72-73 (1985-1986), 1, 323-338, Bucureşti

Rădulescu, D., Vasilescu, A., Peltz, S.(1964a) Contribuţii la cunoaşterea structurii geologice a munţilor Gurghiu. *An.Com.Geol.*, XXXIII, 87-151, Bucureşti

— **, Vasilescu, A., Peltz, S.(1964b)** Marea calderă Fincel-Lăpuşna din Munţii Gurghiu. *D. S. Inst. Geol.*, XLIX/1 (1961-1962), 383-396, Bucureşti.

— **, Peltz, S., Popescu, A.(1973)** Lower compartment of the structure of the Calimani, Gurghiu and Harghita Mountains: the volcano-sedimentary formation. *An.Inst.Geol.*, XLI, 15-26, Bucureşti

— **, Săndulescu, M., Borcoş, M. (1993)** Alpine magmatogenetic map of Romania: an approach to the systematization of the igneous activity. *Rev. Roumaine de Géologie*, Tome 37, 3-8, Bucureşti.

— **, Săndulescu, M. (1973)** The plate-tectonic concept and the geological structure of th Carpathians. *Tectonophysics*, 16, 155-161.

Săndulescu, M. (1984) Geotectonica Romaniei. Ed. Tehn., 334p, Bucureşti

Seghedi, I. (1982) Contribuţii la studiul petrologic al Calderei Călimani. *D.S.Inst.Geol.Geofiz.*, LXVII/1, 87-126, Bucureşti

— **(1987)** Studiul petrologic al Calderei Călimani. Teza de doctorat. Univ. Bucuresti, 161 p.

— **, Szakács, A., Udrescu, C., Stoian, M., Grabari, G. (1987)** Trace element geochemistry of the South Harghita volcanics (East Carpathians). Calc-alkaline and shoshonitic association *D.S.Inst.Geol.Geofiz.*, 72-73/1, 381-397, Bucureşti.

— **, Rădan, S., Vanghelie, I. (1992)** Comparative mineralogenetic study of alunite occurrences in Romania.*Rom. Journal of Mineralogy*, vol. 75, supplement no.1, 40-41 (abstract)

— **, Szakács, A., Snelling, N.J., Pécskay, Z. (in press)** New K-Ar datings on Neogene volcanics from the Gurghiu Mts. (East Carpathians, Romania): Implication for the volcanic evolution

— **, Szakács A., Mason P.R. (in press)** Magma genesis and evolution in the East Carpathian Neogene volcanic arc (Romania), as inferred from petrochemical data. *Acta Volcanologica.*

Stanciu, C., Medeşan A. (1971a) Argilizarea hidrotermală asociată depozitelor de sulf nativ din Caldera Călimani. *St. Cerc. Geol.*, 16, 107-121

— **, Medeşan A. (1971b)** Geochimia proceselor de transformare si mineralizare in zacamintul de sulf nativ din Caldera Călimani. *St Cerc. Geol.*, 16, 321-342

Institutul Geologic al României

— , **Udrescu, C., David, M. (1985)** The Mădăraşul Mare rhyodacite (Harghita Mountains). *D.S. Inst. Geol. Geofiz.*, LXIX, 199-215

Stănică, D., Stănică, M., Visarion, M. (1986) The structure of the crust and upper mantle in Romania as deduced from magnetotelluric data. *Rev. Géol. Géphys. Géogr., Géophysique*, 30, 25–35, Bucharest.

— , **Stănică, M, Pinna E. (1990)** Magnetotelluric sounding in the East Carpathians-Harghita area. *Rev. Roum. Geophysique*, 30, 25-35

Szakács, A., Seghedi, I. (1986) Chemical diagnosis of the volcanics from the most southernmost part of the Harghita Mountains- Proposal for a new nomenclature. *Rev. Roum. Geol. Geophys. Geogr., Geologie*, 30, 41-48

— , **Seghedi, I., Pécskay, Z. (1993)** Pecularities of South Harghita Mts. as the terminal segment of the Carpathian Neogene to Quaternary volcanic chain. *Rev. Roum. Geol.*,37, 21-36.

BIBLIOTECA 156557

Institutul Geologic al României

Editorial Staff:
Anca Andăr

Illustration:
Paraschiv Toader, Veronica Tuşinschi

Institutul Geologic al României

Institutul Geologic al României