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PETROGRAPHY, GEOCHEMISTRY AND AGE OF VOLCANIC ROCKS IN THE GURASADA AREA, SOUTHERN APUSENI MTS.

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Abstract: This paper proves for the first time the existence of a complex distribution of volcanic rock types occurring in the Gurasada region. At the base of these a bentonite deposit crops out in the Gurasada open pit, followed by pyroclastic deposits represented by pyroclastic breccia and rare tuff levels the youngest rocks are lava flows exposed in the Runcşor Hill. Thermometamorphic products represented by hornfels are described here for the first time within the outcrop area of the pyroclastic breccia. The site observations, petrographic, XRD, RAMAN spectroscopy and chemical analyses indicated the formation of the bentonite deposit by weathering of a vitroclastic tuff, probably of dacitic composition, belonging to a first (more felsic) eruptive stage consisting of Plinian-type explosive volcanism. The pyroclastic breccia, tuffs and lava flows are mainly of calc-alkaline andesitic composition and belong to a second stage of volcanism, which developed intermittently, over a longer period of time. Radiometric dating (K/Ar method) of the rocks indicates the formation of the volcanic-volcaniclastic deposits within a period of 69 to 80 million years ago. These ages confirm that these volcanics belong to the laramic cycle as inferred previously place them at the level of Upper Cretaceous (Senonian).

Keywords: Andesite, volcaniclastics, Laramian, bentonite

1. INTRODUCTION

The study area is part of the southern Apuseni Mountains, also known as the Metalliferous Mountains, and it is outlined by the following natural borders: Băişoara Valley to the East, Zam Valley to the West, Mureş Valley to the South. To the North it is bounded by the contact between the Paleocene volcaniclastic rocks with the Cretaceous sedimentary units and with the Mesozoic „ophiolites" in the area of Valea Lungă – Boiu de Sus – Glodghileşti localities (from east to west) (Fig. 1).

The volcanic rocks in this area belong to the Laramian (locally known as "banatitic") magmatism (Upper Cretaceous–Paleogene in age) and they resulted from continental arc-type volcanic activity, related to the subduction of the Moesian plate beneath the Transylvanian plate (Savu et al., 1992).

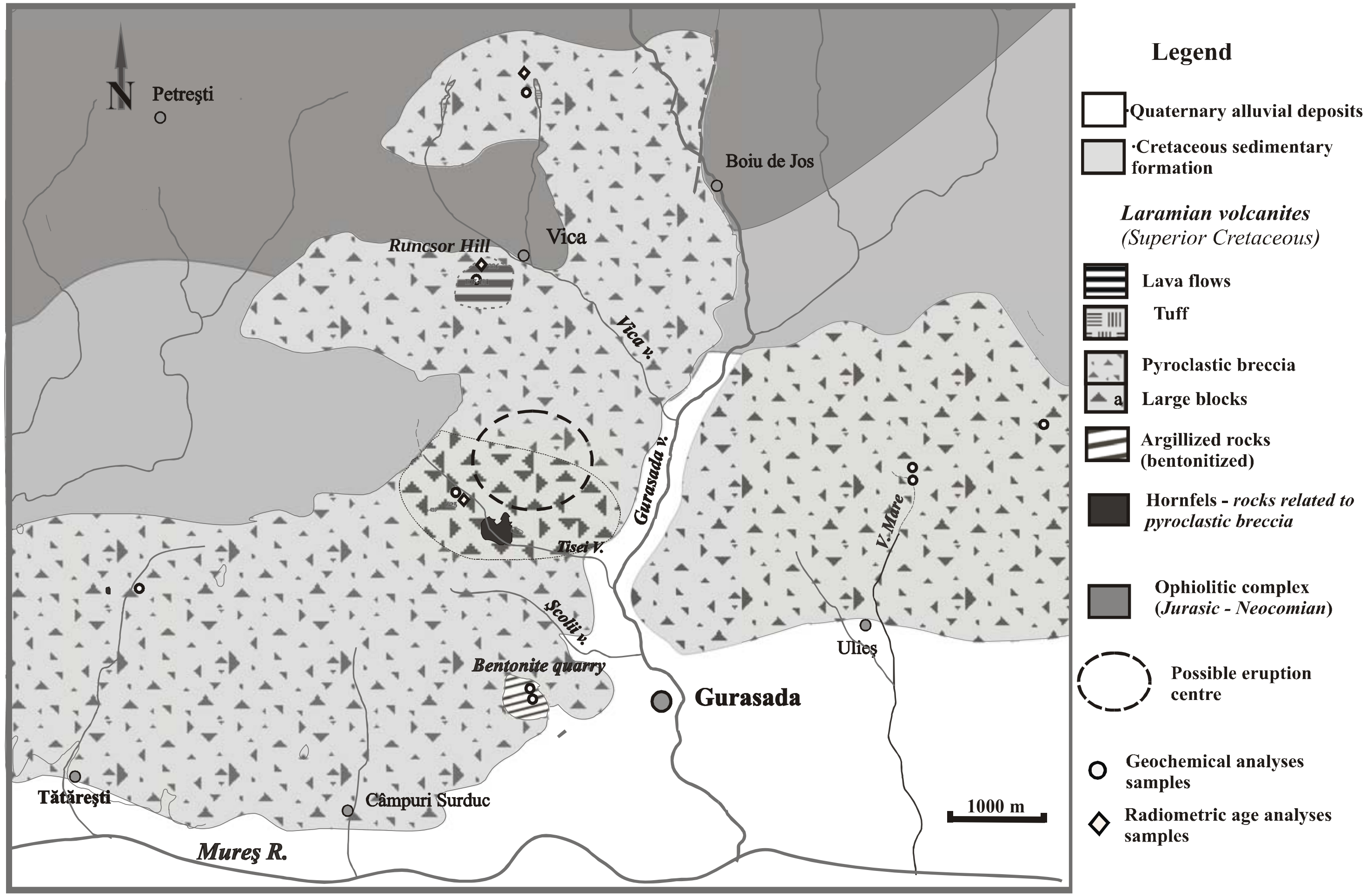

Figure 1. Geological map of the Gurasada region.

In early works, before 1983, the volcanics occurring along both sides of the Mures valley were considered Neogene in age. Later on, they were assigned to the Laramian stage (Paleocene) based on radiometric datings. In volcanological terms, they were globally referred to as „volcaniclastics" (e.g. Geological Map of Romania, scale1:50.000 sheets Gurasada, (Dobra, 1984, Savu et al., 1992).

According to Kadič (1906), the volcanic rocks along the Mureş valley were named biotite andesites and trachites. Other authors, such as Papiu (1954), Savu (1962), Peltz & Peltz (1965), Ghițulescu & Borcoş (1966), Rădulescu & Borcoş (1968), Ianovici et al. (1969), treated later these volcaniclastic rocks rather summarily.

Savu et al. (1992) described these rocks as Paleocene volcanics represented by andesite lava flows and, mainly, by pyroclastic rocks (agglomerates, tuffs). The coarse pyroclastics („volcanic agglomerates") are composed of blocks of various types of andesites and basalts. In places, they were subjected to intense alteration processes as in the case of the Gurasada bentonites.

2. PETROGRAPHICAL FEATURES

The research performed during this work led to the identification of several distinct types of deposits. By using the descriptive non-genetic classification of McPhie et al. (1993), we assign the volcanic deposits in the area to the following types:

- compact volcanic deposits represented by ***lava flows**,* cropping out in Runcşor Hill (Fig. 1); they represent the youngest primary volcanic products;

- volcaniclastic deposits mainly represented by ***pyroclastic breccia*** and rare ***tuff*** levels cropping out in the western, central and northern parts of the study area, (Fig 1).

In the occurrence area of the pyroclastic deposits occurrence a few isolated hornfels bodies have been identified and noticed by us for the first time, while near Gurasada an important bentonite deposit resulted by the argillization of volcanic tuffs. To the East, the pyroclastic breccias are bordered by polymictic volcanic conglomerates.

2.1. Compact volcanic deposits – lava flows

In the Runcşor Hill (between Vica and Runcşor localities), an artificial hill slope exposure of andesitic lava flows crops out. The rock presents an obvious separation in horizontal plaine (fine tabular jointing, and it is slightly altered. The rock is dark grey in colour, and small feldspar and pyroxene phenocrysts are visible by naked-eye, as well as an obvious fluidal structure (Plate I, Fig. 1).

The microscopic study has revealed the nature of the rock, i.e. ***fluidal pyroxenic andesite***. The texture is slightly porphyritic, especially due to the presence of the pyroxene (augite and hypersthene), and less to the feldspar phenocrysts (Plate I, Fig. 2).

2.2. Volcaniclastic deposits

2.2.1. Tuffs

Tuffs rarely crop out in the region, and they consist of levels up to 1 m thickness, with a limited horizontal extension. They crop out only in the lower sector of

Vica Valley (in the northern part of the study area) and in the middle one of the Ţiganului Valley (Tătărăşti locality, in the south-western part of the region). Macroscopically, the tuff levels are grey in colour and they are poorly sorted (Plate I, Fig. 3). The tuff is vitrocrystalloclastic, the feldspar crystals being visible also by naked-eye.

At Gurasada, the tuffs have been affected by bentonitization processes, with the formation of secondary clay minerals.

Under the microscope, the rock presents the characteristic features of *vitrocrystalloclastic tuffs*. The crystals, representing about 65 % of the rock mass, are usually fractured and rarely euhedral, with the exception of the plagioclase (Plate I, Fig. 4).

2.2.2. Pyroclastic breccia

As a general rule, the pyroclastic breccias are coarse-grained, massive and not stratified. Only locally, at certain levels and on extensions of a few meters, poor grain-sorting features have been noticed in the study area.

The breccia mainly consists of volcaniclasts from a few cm to one meter in diameter. The morphology of the volcaniclasts varies from angular to subangular (Plate I, Fig. 5). This breccia is also characterised by the presence of a matrix. In the same time, decimetre-sized volcanic blocks with prismatic-radial joints were also identified (similar with those described by Szakács & Jánosi, 1987 in the Harghita Mountains).

The outcrop in the upper part of Tisa Valley (Gurasada) is characterised by the abundance of large blocks (often exceeding 2 m) and a more significant presence of the matrix (Plate I, Fig. 6).

The microscopic study of the pyroclastic breccia consisted in the investigation of thin sections and of a few polished slides of various types of volcaniclastic rocks including both blocks and matrix (where it was possible). This study has revealeded the following petrographic types of blocks:

Pyroxene andesites composed of angular clasts of the pyroclastic breccia from Valea Mare (Ulieş), Tisa Valley (Gurasada), Câmpuri Valley (Câmpuri Surduc), and Vica Valley, where they represent the most frequent petrotype.

Microscopically, they show hyalopilitic, porphyritic structure, and massive texture. The main components are represented by polysynthetically twinned plagioclase and by fresh (both ortho- and clino-) pyroxenes. The main accessory minerals are represented by hematite and magnetite (Plate II, Fig. 1).

The block clast samples collected from Vica Valley are characterised by a large amount of pyroxenes, mainly in the groundmass of the rock. Based on the major element content of two samples (Tab. 1), this rock can be assigned to ***basaltic andesites.***

Andesites with amphibole and pyroxenes are also frequent rock types in the breccia blocks under study.

Microscopically, the rock has massive structure, porphyritic and pilotaxitic texture. The groundmass consists of feldspar microcrystals. The main minerals are represented by plagioclase, brown hornblende and pyroxenes. The plagioclase feldspars are polysynthetically twinned and show a zoned structure; some phenocrysts contain glass inclusions. Locally, the feldspar crystals are partly magmatically corroded. The brown hornblende is present as euhedral crystals, (Plate II, Fig. 2).

The microscopic study of the weakly crystallized matrix of the pyroclastic breccia revealed a fluidal to subfluidal structure.

The plagioclase is polysynthetically twinned according to the albite law. Its composition is 43–47 % An (*andesine)* as determined by using the Fedorov Universal stage and the graphical method based on the evaluation of the twin and cleavage planes.

The hornblende, pyroxenes and biotite andesites are not common in the samples we have examined. Macroscopically they are similar to the hornblende and pyroxene andesites.

In summary, the main petrotype of the pyroclastic breccias is represented by ***pyroxene and hornblende ± biotite andesites.***

Hornfels have been identified for the first time within the occurrence area of the pyroclastic breccias. They are exposed along an upper-track tributary of the Ţiganului valley (a small outcrop of 6/4 m) and along the Tisa valley (within an area of about 50/20 m).Given their origin as contact metamorphic rocks, one may suppose the close location of a rooted magmatic/volcanic structure such as a neck or a small shallow intrusion.

3. DEPOSITS OF ARGILLIZED (BENTONITIZED) ROCKS

At Gurasada, the exploration works in the bentonite quarry have evidenced rocks that were almost entirely altered (bentonitized) on a significant area (about 0.5/0.5 km). The maximum thickness of these deposits, from the base to the top of the quarry step is of about 15 m. In the eastern part of the quarry, the bentonite is covered by pyroclastic rocks, represented by pyroclastic breccia (Plate II, Fig. 4).

Some of the 1-3 cm fragments of weakly weathered rock collected from the bentonite at Gurasada have been investigated in thin section under the microscope. Their petrographic nature is diverse, including both volcanic and terrigenous (quartzites and sandstones) components, suggesting a sedimentary origin of the bentonite deposit. The chemical analysis of one volcanic fragment (DV-104) indicated its dacitic composition.

Besides the Gurasada quarry, intensely transformed areas in the pyroclastic rocks have been further identified in outcrops along the Tisa Valley (Gurasada) and Ţiganului Valley (Tătărăşti).

The study of bentonites concerned their grain size distribution, as well as the investigation of the crystals of the arenitic fraction under the binocular microscope. Subsequently, both the lutitic and the coarse fractions have been studied by X-ray diffraction, while the microspherules separated at the binocular microscope from the coarse fraction have been investigated by RAMAN spectroscopy.

The grain size distribution (5-7% crystals and 93-97% fine fraction represented by weathered glass) of the bentonite samples suggest that the pre-existing material was mainly represented by a vitroclastic tuff. The study under the binocular microsope of the coarse fraction of the bentonitized rock has revealed the presence of twinned plagioclase crystals (approximate 90%), rare crystals of magmatic quartz (approximate 8%), mica lamellae and translucent microspheres (approximate 2%) (Plate II, Fig. 5), as well as some almost transparent spherical micron-sized (up to 0.5 mm) grains (Plate II, Fig. 6).

A bentonite sample (DV-105) from Gurasada (from the clay fraction) has been also investigated chemically. The results are presented in table 1.

3.1. The X-ray investigation

The clay minerals of the lutitic fraction and the crystals of the coarse fraction from the bentonitized rock from Gurasada have been studied by using X-ray diffraction at the North University in Baia Mare.

The investigated samples mainly consist of montmorillonite as the dominant mineral phase. It is a Na-dominated, poorly-crystallized montmorillonite species, similar to the Wyoming and Sadvaráno types (Erno, 1973), (Fig. 2).

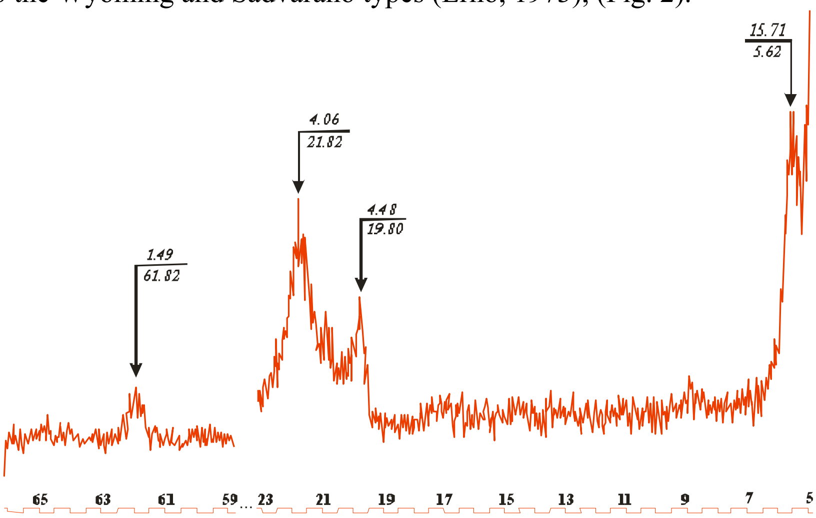

Figure 2. The X-ray diffraction pattern of sample 72 from the bentonite quarry from Gurasada.

For the identification of the original petrographic nature of the pre-alteration rock, we performed X-ray diffraction investigation on the crystals separated from the coarse fraction of the bentonitized rock (Fig. 3).

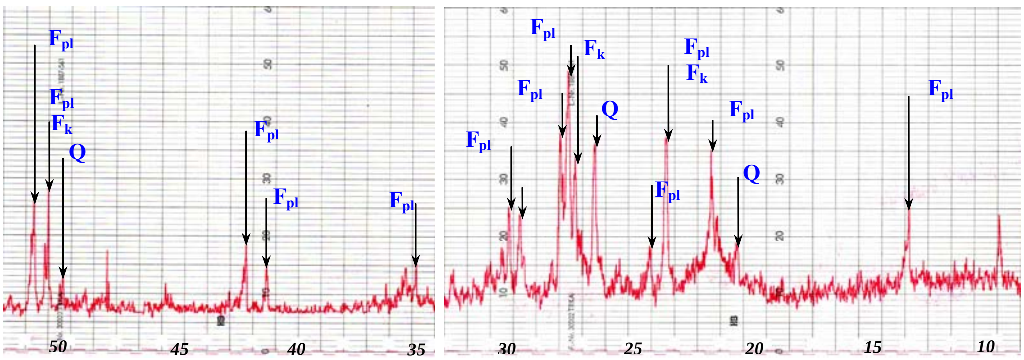

Figure 3. The X-ray diffraction pattern of the coarse fraction from the bentonitized rock of Gurasada (Q-quartz, F_{pl}-plagioclase feldspar, F_K-K-feldspar).

Plate I

Figure 1. Andesitic lava flowwith fine platty jointing in outcrop (Runcşor Hill).

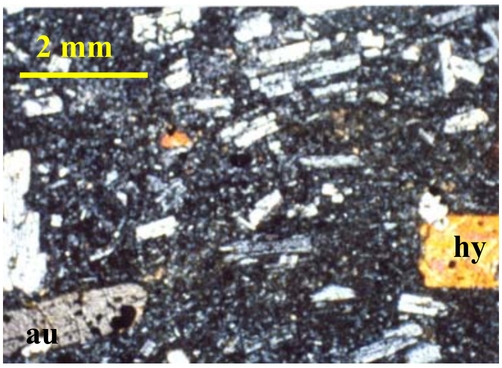

Figure 2. Andesitic lava flow. Hypersthene *(hy)* and Augite *(au)* crystals embedded in a pilotaxitic matrix (Runcşor Hill). Microphotograph, N+.

Figure 3. Local dm-thick levels of vitrocrystalloclasic tuffs in outcrop (Vica valley).

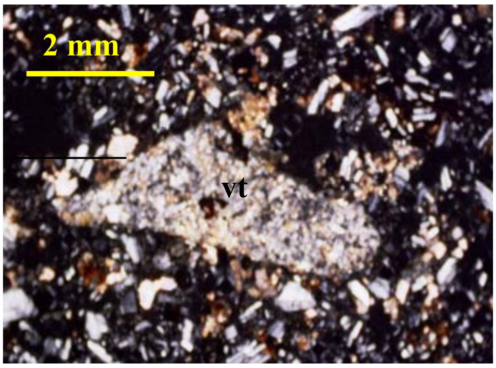

Figure 4. Vitrocrystalloclastic tuff. Inclusion of older generation vitroclastic tuff inclusion *(vt)* (Vica valley). Microphotograph, N+.

Figure 5. Pyroclastic breccia – detail. Angular to subrounded clasts (cm to dm in size), embedded in a poorly represented matrix are visible (Valea Mare, Ulieş).

Figure 6. Chaotic pyroclastic breccia. Large blocks (about 1 m) are present,besides dm-sized blocks (Tisa valley, Gurasada).

Plate II

Figure 1. Pyroxenic andesite. Clustered pyroxene *(py)* phenocrysts forming glomerulitic structures (Tisa valley) Microphotograph, N+, 30 X.

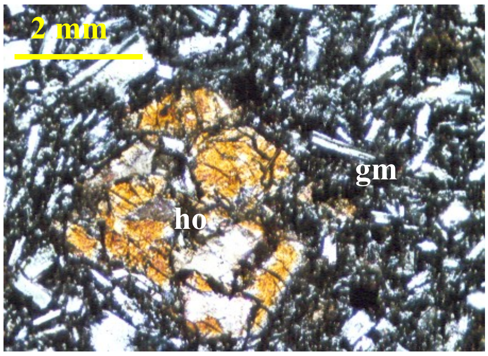

Figure 2. Hornblende andesite. Fractured hornblende phenocrystal *(ho)* in a groundmass *(gm)* of plagioclase microcrystal (Tătărăşti valley) Microphotograph, N+; 30X.

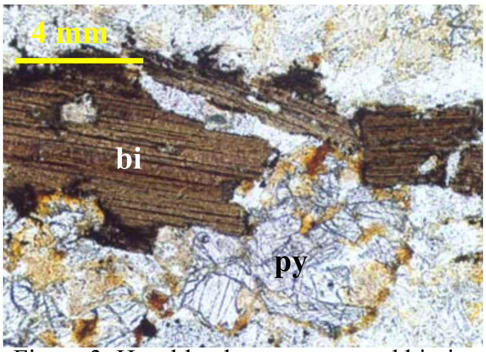

Figure 3. Hornblende, pyroxens and biotite andesite. Biotite lamella *(bi)* and a local concentration of pyroxenes *(px)* are visible. (Valea Mare-Ulieş) Microphotograph, N II.

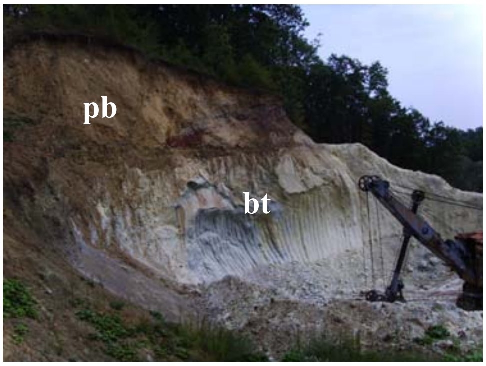

Figure 4. The bentonite quarry from Gurasada (general view). The pyroclastic breccia *(pb)* are noticeable over the bentonite deposit *(bt).*

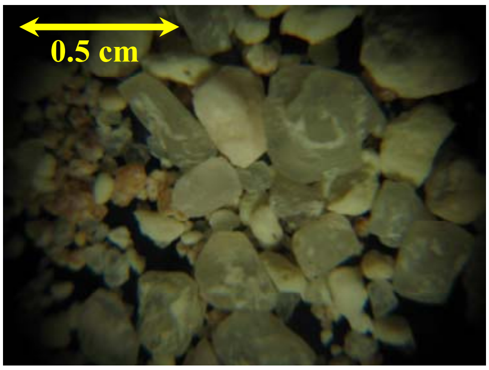

Figure 5. Feldspar and quartz crystals from the coarse fraction of the bentonitised rock from Gurasada (photograph under the binocular microscope).

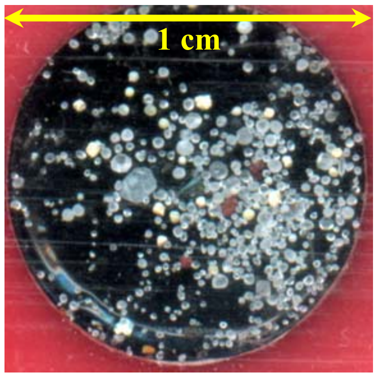

Figure 6. Translucent microspherules from the coarse fraction of the bentonitised rock (Gurasada quarry).

According to ICDD (International Centre for Diffraction Data), the crystals in the bentonite from Gurasada are represented basically by plagioclases feldspar and, to a lesser extend, by K-feldspar and quartz. The values and the peak shape of the plagioclases point to oligoclase and andesine varieties, while the K-feldspar could be represented by sanidine.

By taking these results into account and also based on the chemical analyses of both bentonite samples and of a slightly altered volcanic rock fragment separated from the same deposit, we consider that the volcanic products that have generated the bentonite deposit were probably of dacitic composition.

3.2. The RAMAN spectroscopy

The RAMAN investigations have been performed at the Faculty of Physics of the Babeş-Bolyai University Cluj-Napoca on the translucent microspheres separated from the bentonite. Figure 4 displays the Raman spectra of the 4 investigated samples corresponding to the standard spectrum of calcite, the shape of the band suggesting a poor crystallinity of this mineral. We consider that these calcite microspheres have formed via sedimentary processes in an aquatic environment during the formation of the bentonite deposit.

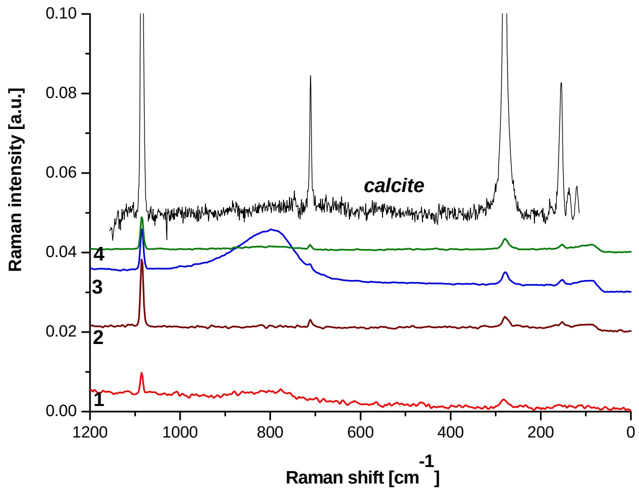

Figure 4. RAMAN spectra of the translucent microspheres separated from the bentonite at Gurasada.

Taking into account the possible continuation of the bentonite deposit to the South of Mures valley (at Debra there is a similar deposit with the bentonite from Gurasada) we consider that the bentonitized volcanics from Gurasada resulted by an intense (plinian) eruption that has mainly produced aboundant fine grained material (volcanic ash) deposited on large surface. A vitroclastic tuff of probably dacitic composition resulted from the eruption, as suggested by the high concentration of plagioclase feldspars of oligoclase-andesine type in the coarse fraction of the bentonite samples.

The significant thickness (more than 15 m) of the present day bentonite deposit suggests that the fine pyroclastic material has been reworked and redeposited in a sedimentary basin, where it underwent the postdepositional argillization processes (Meunier, 2005).

4. CHEMISTRY OF VOLCANIC ROCKS AND ORIGIN OF MAGMAS

Of the results of more recent previous works it is worthy to mention those of Savu et al. (1992), who distinguished three petrographic groups (olivine basalts and balasltic andesites, andesites and trachiandesites, and leucocratic acidic/alkaline rocks) and suggest that the volcanics in the broader area belong to a calc-alkaline series with an obvious alkaline trend.

The chemical analyses (10 samples) have been performed at the ALS Chemex Laboratory in Vancouver, Canada (Tab. 1).

4.1. Major elements

Except for the rock fragment from Gurasada quarry (sample DV-104), with higher silica content (67%, i.e dacite), SiO_2 ranges between 53.5–62%, which classifies the studied rocks as intermediate (andesitic) in composition. In the TAS diagram, the samples plot mainly in the andesite field, at the limit with the trachyandesite one. This is due to the high content of alkalis (Na_2O + K_2O ranges from 4.47 to 6.7 %). According to their alkali contents, these rocks belong to the medium to high-K series. The rocks in the andesite and trachyandesite fields have been mineralogically described as pyroxenic andesites, and pyroxenes and hornblende ± biotite andesites. Two samples (DV-101 and DV-110) plot in the field of basaltic andesites. From mineralogical point of view, these samples were described as pyroxene andesite. Sample DV-104 represents the exception, due to its high SiO_2 content; it was classified as an acidic (dacitic) rock, according to the TAS diagram (Fig. 5).

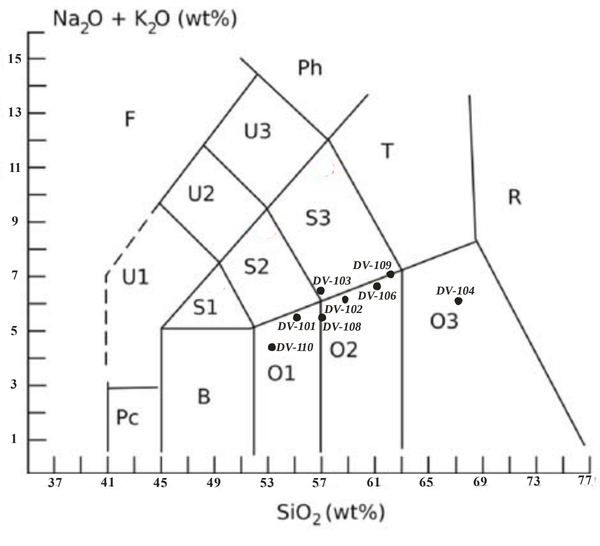

Figure 5. TAS diagram (Le Maitre et al., 2002) and the projection of the samples under study. B - Basalt, O1 - Basaltic andesite, O2 - Andesite, O3 - Dacite, R - Rhyolite, T Trachyte or Trachydacite, Ph Phonolite, S1 Trachybasalt, S2 - Basaltic trachyandesite, S3 – Trachyandesite, Pc – Picrobasalt, U1 - Basanite or Tephrite, U2- Phonotephrite, U3 – Tephriphonolite, F - Foidite.

Table 1. Major and trace elements composition of the studied volcanic rocks.

Method		ME-ICP06	ME-ICP06	ME-ICP06	ME-ICP06	ME-ICP06	ME-ICP06	ME-ICP06	ME-ICP06	ME-ICPO6	ME-ICP06	ME-ICP06	ME-ICP06	ME-ICP06	OA-GRA05	TOT-ICP06
Analysis	**Weight**	**SiO_2**	**TiO_2**	**AI_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**Cr_2O_3**	**SrO**	**BaO**	**LOI**	**Total**
Unit	kg	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Minimum error	*0.02*	*0.01*	0.01	*0.01*	*0.01*	0.01	0.01	*0.01*	0.01	0.01	0.01	0.01	0.01	0.01	*0.01*	*0.01*
DV-101	0.14	55.5	0.84	17.35	7.12	0.10	3.09	5.84	2.94	2.42	0.21	<0.01	0.05	0.06	2.55	98.1
DV-102	0.12	58.4	0.67	16.25	5.55	0.12	3.05	5.53	2.85	3.29	0.25	0.01	0.06	0.08	2.02	98.1
DV-103	0.20	57.0	0.79	16.91	5.21	0.08	2.35	6.88	3.21	3.26	0.32	0.01	0.07	0.07	2.06	98.2
DV-104	0.12	67.7	0.57	14.68	2.38	0.01	1.59	2.39	2.86	3.20	0.10	0.01	0	0.2	2.73	98.4
DV-105	0.10	63.7	0.23	13.35	1.95	0.02	2.38	1.18	0.36	2.48	0.01	<0.01	0.02	0.01	13.95	99.6
DV-106	0.12	60.4	0.70	16.40	6.16	0.04	1.64	5.26	2.88	3.85	0.29	0.01	0.07	0.08	2.25	100.0
DV-107	0.14	61.5	0.34	3.93	2.32	0.08	1.62	15.55	0.85	0.40	0.04	0.01	0.04	0.01	13.40	100.0
DV-108	0.12	57.2	0.67	16.94	6.23	0.12	3.86	6.17	2.70	2.72	0.23	0.01	0.06	0.06	1.64	98.6
DV-109	0.12	62.0	0.67	17.10	4.84	0.03	0.85	4.90	3.44	3.59	0.25	0.01	0.06	0.09	2.12	100.0
DV-110	0.14	53.5	1.10	16.70	8.80	0.15	3.64	9.23	2.64	1.83	0.23	0.01	0.05	0.04	1.90	99.8

Method	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS42	ME-MS81	ME-MS81	ME-MS81	ME-MS42	ME-MS42	ME-MS42	ME-MS42
Analysis	**Cr**	**Ni**	**Co**	**V**	**Cu**	**Pb**	**Zn**	**Bi**	**Sn**	**W**	**MO**	**As**	**Se**	**Sb**	**Te**
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Minimum error	*10*	*5*	*0.5*	*5*	*5*	*5*	*5*	*0.01*	*1*	*1*	*2*	*0.1*	*0.2*	*0.05*	*0.01*
DV-101	10	<5	17.2	188	21	22	97	0.07	3	3	<2	3.1	0.5	0.13	<0.01
DV-102	50	13	15.1	120	32	29	86	0.02	4	1	<2	9.6	0.4	<0.05	<0.01
DV-103	50	14	13.8	163	38	24	84	0.04	2	5	<2	4.6	0.5	0.08	0.01
DV-104	40	24	33.9	39	15	53	50	0.08	5	7	4	13.9	1.3	0.59	0.01
DV-105	10	9	1.6	18	23	32	69	0.06	8	3	<2	1.2	0.6	0.38	0.01
DV-106	50	18	12.5	138	19	33	95	0.07	2	3	<2	2.1	0.4	0.31	0.01
DV-107	40	23	6.1	18	18	17	37	0.12	2	2	<2	2.2	0.5	0.17	0.02
DV-106	40	19	19.0	143	23	27	73	0.45	3	3	<2	0.7	0.3	<0.05	0.03
DV-109	40	15	11.1	129	19	36	65	0.04	2	3	<2	6.3	0.5	0.11	<0.01
DV-110	70	19	26.2	271	15	29	103	0.06	1	3	<2	3.8	0.5	0.05	<0.01

Table 1. (continuation)

Method	ME-MS81	ME-MS42	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81
Analysis	**Ag**	**Hg**	**Rb**	**Cs**	**Ba**	**Sr**	**Tl**	**Ga**	**Ta**	**Nb**	**Hf**	**Zr**	**Y**	**Th**	**U**
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Minimum error	*1*	*0.005*	*0.2*	*0.01*	*0.5*	*0.1*	*0.5*	*0.1*	*0.1*	*0.2*	*0.2*	*2*	*0.5*	*0.05*	*0..05*
DV-101	<1	0.005	80.2	1.63	544	408	<9.5	20.6	0.5	7.2	4.2	147	22.0	8.29	2.00
DV-102	<1	<0.005	122.5	4.04	704	509	<0.5	19.8	0.7	10.0	4.9	184	21.6	13.40	3.46
DV-103	<1	<0.005	100.0	2.97	625	607	<0.5	19.2	0.7	9.7	4.4	161	19.3	10.50	3.20
DV-104	<1	0.012	64.2	2.09	960	260.5	1.3	10.6	0.8	12.3	4.9	197	36.9	12.25	14.12
DV-105	<1	0.009	80.7	3.47	106.5	125.5	<0.5	18.7	0.8	10.2	3.9	93	15.0	12.40	1.91
DV-106	<1	<0.005	131.0	3.86	659	562	<0.5	18.8	0.7	9.7	4.9	181	17.4	11.30	4.79
DV-107	<1	<0.005	14.0	0.24	77.2	286	<0.5	4.5	0.7	10.2	7.2	285	10.9	5.84	1.47
DV-108	<1	<0.005	187.0	4.99	549	518	1.8	18.5	0.6	8.2	3.9	144	18.5	7.81	3.40
DV-109	<1	<0.005	111.5	4.02	719	515	<0.5	19.7	0.6	9.4	4.8	181	21.8	11.30	3.21
DV-110	<1	<0.005	43.2	1.11	303	455	<0.5	19.7	0.5	7.6	3.1	111	27.0	4.64	1.80

Method	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81	ME-MS81
Analysis	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Minimum error	*0.5*	*0.5*	*0.03*	*0.1*	*0.03*	*0.03*	*0.05*	*0.01*	*0.05*	*0.01*	*0.03*	*0.01*	*0.03*	*0.01*
DV-101	25.2	49.4	6.42	25.3	5.21	1.42	5.25	0.75	4.35	0.91	2.49	0.37	2.21	0.33
DV-102	38.5	77.5	8.79	32.5	6.26	1.57	5.72	0.77	4.08	0.82	2.34	0.32	2.11	0.32
DV-103	33.7	69.3	8.10	32.5	6.47	1.70	5.84	0.75	3.84	0.76	2.08	0.23	1.75	0.26
DV-104	43.3	83.0	9.90	41.0	7.35	2.06	7.17	1.42	6.13	1.70	3.72	0.60	2.89	0.60
DV-105	28.4	57.6	6.42	23.9	4.74	0.55	4.40	0.64	3.41	0.58	1.66	0.21	1.55	0.22
DV-106	36.3	70.7	7.91	29.6	5.51	1.48	5.10	0.65	3.66	0.65	1.97	0.25	1.89	0.25
DV-107	17.4	33.8	3.83	14.1	2.65	0.70	2.60	0.39	2.06	0.39	1.18	0.17	1.16	0.17
DV-108	31.9	57.8	6.57	25.8	5.10	1.36	5.02	0.71	3.92	0.67	2.08	0.26	1.87	0.27
DV-109	40.4	76.6	9.13	35.5	6.80	1.72	6.52	0.85	4.69	0.84	2.51	0.32	2.23	0.32
DV-110	18.3	37.6	4.91	21.6	5.05	1.49	5.46	0.86	5.26	0.98	3.01	0.40	2.77	0.40

The samples in the table are from: DV-101 – lava flow - αpx (Runcşor Hill); DV-102 – pyroclastic breccia - α px+ho (Țiganului V.); DV-103 – pyroclastic breccia αpx (Tisei V.); DV-104 – fragment of andesite in bentonite (Gurasada quarry); DV-105 – bentonite (Gurasada quarry); DV-106 – andesitic pebble in the polymictic conglomerates (Băcioara V.); DV-107 – pyroclastic breccia αpx (Vica V.); DV-108 – pyroclastic breccia α px+ho (Mare V.); DV-109 – pyroclastic breccia α px+ho (Mare V.); DV-110 – pyroclastic breccia α px (V. Vica).

4.2. Trace elements

The distribution of trace elements normalised to chondrites (Thompson, 1982) (Fig. 6) shows enrichment in large lithophile ions (LILE = K, Rb, Ba) as well as in light rare earth elements (LREE = La, Ce, Nd, Sm), which determine a decrease of the HFSE/LILE ratio. These data suggest that 1) the processes that controlled the differentiation of the parental magmas generated in a subduction setting were represented by crustal assimilation associated with fractional crystallization and/or 2) the trace element pattern resulted from local enrichment in LREE of the upper mantle and its partial melting.

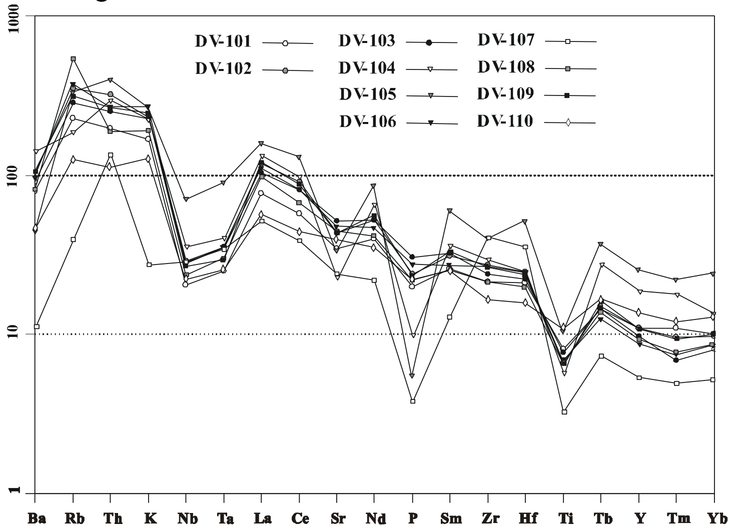

Figure 6. Trace element distribution normalised to chondrites (accord to Thompson, 1982).

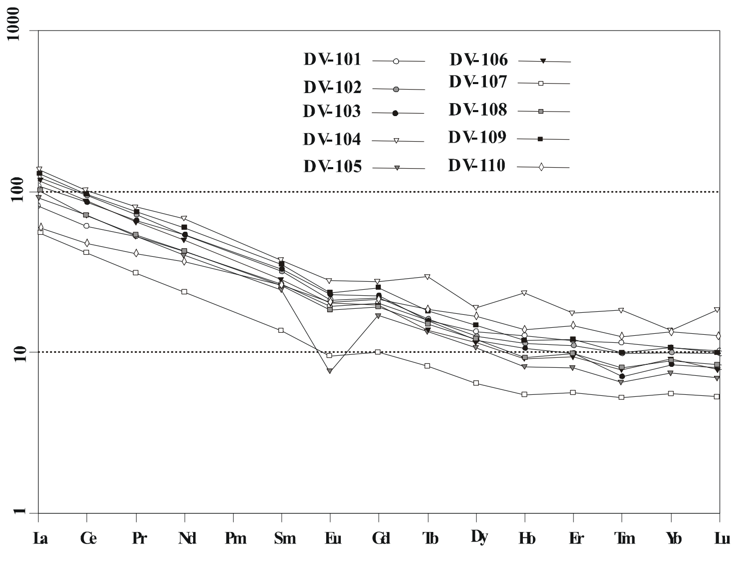

Figure 7. REE distribution of volcanic rocks normalised to chondrites (Boynton, 1984).

The chondrite-normalised REE spectrum shows a descending allure with higher slopes in the LREE domain and low slope in the HREE domain, (Fig. 7) and an overall enrichment of 10 to 100 times with respect to chondritic values and present positive values. A slight Europium anomaly is obvious for all samples and is remarkably high for sample DV-105, suggesting plagioclase fractionation during magma differentiation. The low-slope to flat pattern of HREE suggest a weak to no fractionation of these elements, thus no or minimal role of garnet involvement in magma genesis and diversification.

The rocks in the study area were generated in a subduction environment and they were subjected to differentiation processes resulted in a wide range of rocks - from dacites to basaltic andesites - with a significant participation of andesites. All these rock types plot in the field of the K-rich calc-alkaline series. The variation of the main oxides and of the trace elements (especially in the rocks of andesitic composition) suggests that the parental magma which generated these products had a basaltic, relatively alkali-rich composition, which underwent magmatic differentiation and crustal contamination.

5. AGE OF THE VOLCANICS

Until 1983, the volcanic rocks in the study area have been considered by various authors (Kadič, 1906; Papiu, 1954; Savu, 1962; Ghițulescu & Borcoş, 1966; Rădulescu & Borcoş, 1968; Ianovici et al., 1969) as products associated to the Neogene volcanism. After this period, considering microfaunal investigations, Popescu (in Borcoş et al., 1986) thinks that the volcanic rocks outcropping along the Mureş valley are products of Laramic volcanism (Upper Cretaceous-Paleocene).

Our results on the age of pyroclastites were obtained by K-Ar radiometric dating, performed on three rock samples (Tab. 2). The analyses have been carried out at the Institute for Nuclear Research of the Hungarian Academy of Sciences (ATOMKI) from Debrecen (Hungary). The results of these analyses are presented in table 2.

Table 2. Results of the radiometric dating (K/Ar method).

No. sample	Type of investigated rock /location	Reference Table 1	K (%)	40Ar rad (%)	40Ar rad (ccSTP/g)	Age K- Ar (My)	Period/epoch (acc. ICS*)
221	Block in pyroclastic breccia (pyroxene andesites)/Tisa Valley (Gurasada)	DV-103	3.14	84.1	9.483×10^{-6}	76.1 +/- 2.3	Upper Cretaceous/ Campanian
222	Lava flow (fluidal pyroxenic andesite) /Runcşor Hill (Runcşor)	DV-101	2.42	78.6	6.594×10^{-6}	68.8 +/- 2.1	Upper Cretaceous / Maastrichtian
223	Block in pyroclastic breccia (pyroxene andesites)/Vica Valley (Vica)	DV-110	1.93	57.8	6.139×10^{-6}	80.0 +/- 2.7	Upper Cretaceous/ Campanian

* *International Commission on Stratigraphy*

The radiometric dating resulted in Upper Cretaceous ages for all three samples (Tab. 2) in contrast to the earlier inferred Paleocene ages in the area. However, the differences between the ages obtained for the measured samples are quite large covering an interval of 10-11 Ma. One possible interpretation is that the andesitic volcanic products in the study area have been emplaced during polyphasic volcanic activity. Field relationships show that the lava flows in the Runcşor hill are emplaced on top of pyroclastic breccias, thus their youngest age (about 69 Ma) among the rocks analysed is fully supported. It is, however, unclear whether the different ages obtained for the blocks from pyroclastic breccias (samples 221 and 223) represent two different stages of volcanic activity separated in time by a few million years or, alternatively, they can be viewed as resulting during the same volcanic stage and the age difference can be reconciled taking into account the analytical errors.

The age of volcanic activity generating the tuffs subjected to bentonitization at Gurasada is still unknown. We only know that the bentonite deposit is overlain by pyroclastic breccias having age in the interval defined by their respective K-Ar ages, i.e. 76,1 +/- 2.3 Ma and 80 +/- 2.7 Ma, respectively (Campanian). Field observation show that the emplacement of pyroclastic flow deposits postdated the complete consolidation of the bentonite deposit, therefore one may infer that the explosive volcanic activity which generated the pre-bentonitization tuffs occurred much earlier than, about 80 Ma (Campanian). To our best knowledge no such acidic volcanism has been pointed out so far in the broader Apuseni Mts. area. Further studies are needed to solve this problem.

Since no previous radiometric age data have been published for the study area and the biostratigraphic data only show that the studied volcanic rocks overlie the „Bejan Beds” of Barremian - Lower Aptian age and the Jurasic-Neocomian „ophiolitic” basalts, now we are in the position to confirm definitely that the volcanics belong to the Laramic magmatism of the Apusenu Mts. and their age is Upper Cretaceous.

6. CONCLUSIONS

Our investigation has provided several new results concerning the spatial distribution, mineralogical-petrographical composition, chemistry and the age of the volcanic rocks in the Tătărăşti-Gurasada-Bacea area.

For the first time we have determined the spatial distribution pattern of the rock types as indicated on the new geological map of the area (Fig. 1), by identifying and mapping the following lithologic entities:

- compact volcanic deposits represented by **lava flows**, occurring in the Runcşor Hill; they represent the youngest primary volcanic products;

- volcaniclastic deposits mainly represented by **pyroclastic breccia** and rare levels of **tuff.**

In the occurrence area of the pyroclastic breccia, several outcrops of **hornfels** have been newly identified, while in the neighbourhood of Gurasada locality a **bentonite** deposit resulted by argillization (bentonitization) of volcanic tuffs has been studied.

The volcanic products are the results of two stages of volcanic activity:

- a first stage, of **felsic (probably dacitic)** composition represented by the presence of the argillized volcanic tuffs, corresponding to the bentonites from Gurasada quarry;
- a second stage, of **intermediary calc-alkaline (andesitic)** composition: pyroclastic breccia, lava flows and sparce vitro-crystalloclastic tuffs**.** Geochemically they plot in the andesite field, at the border with the trachyandesites, two of the samples plotting in the basaltic andesite field. Also, the rocks belong to the K-rich calc-alkaline series. The variation of the main oxides and trace elements suggests that the parental magma had a relatively alkali-rich basaltic composition, which underwent magmatic differentiation and crustal contamination processes. These rock types were emplaced in a continental arc setting in the Southern Carpathians, determined by the presumed subduction of the Moesian plate beneath the Transylvanian one (Savu et al., 1992).

The formation of the deposits of the first volcanic cycle was due to a plinian-type explosive eruption from a so far unidentified source that has generated a large amount of ash that was subsequently transformed into bentonite via sedimentary processes.

The deposits of the second stage have formed as a result of several volcanic episodes in a long time interval, mainly consisting of lava flows and blocks-and-ash-flow mechanisms. The eruptions had mainly a subaerial effusive character, and the emplacement mechanism of the block-and-ash-flow deposits could be explained by the collapse of volcanic domes that has generated nuée ardent-type pyroclastic flows.

The existence of enrooted structure (s) may be a pertinent hypothesis, as suggested by the well-represented distribution of hornfels that might have resulted due to thermal-metamorphic contact processes, as well as by the autochthon character of these products. The outcrop of lava flows in Runcşor Hill and the presence of large blocks in the vicinity of the hornfels on Tisei Valley (Gurasada) suggest proximity to the source. All these observations have allowed us to infer a possible eruption centre north-west from Gurasada locality. Pyroclastic breccias of the same composition also occur south of the Mureş valley, with the only noticeable difference consisiting in the lack of large blocks. No tuffs or lava flows have been found here. These observations are in compliance with the general pattern of spatial distribution of andesitic volcanic rocks with respect their inferred source area.

The K/Ar radiometric age measurements represent the first radiometric dating results on rocks from this region. These data point to the formation of the volcanic, volcaniclastic deposits 69-80 million years ago. These data confirm the Laramian affiliation of these volcanics and for the first time confer them an **Upper Cretaceous** (Campanian-Maastrichtian) age.

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