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CARACTERÍSTICAS GEOMORFOLÓGICAS DE ESTRUTURAS INTRUSIVAS ÍGNEAS DAS MONTANHAS BÂRGĂU (CARPATOS ORIENTAIS, ROMÊNIA)

THE GEOMORPHOLOGIC FEATURES OF INTRUSIVE MAGMATIC STRUCTURES FROM BÂRGĂU MOUNTAINS (EASTERN CARPATHIANS, ROMANIA)

LAS CARACTERÍSTICAS GEOMORFOLOGICAS ESTRUCTURAS MAGMATICAS INSTRUSIVAS DE MONTANAS BÂRGĂU (CARPATOS ORIENTALES, RUMANIA)

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RESUMO:
Estruturas intrusivas ígneas das Montanhas Bârgău pertencem ao grupo central da cadeia vulcânica do Neógeno nos Cárpatos Orientais da Romênia. A evolução do relevo desenvolvido nestas estruturas são devido a três etapas principais: estágio de injeção de estruturas (panonianas), estágio de corpos intrusivos ígneas abaixo da sedimentar Oligo-Mioceno (Plioceno) e estágio de modelagem de corpos magmáticos subaerial (Plioceno-correntes). Nestas circunstâncias, a geodiversidade das estruturas ígneas intrusivas da Montanhas Bârgău é representado por vários tipos de relevo, como relevo policíclicos (erosão superficial), relevo estrutural (configuração de estruturas ígnea intrusiva), relevo petrográfico (andesite, contato lithological), relevo fluvial (vales, encostas, alturas), o relevo periglacial (relevo criogênico, relevo crionival), relevo biogênicas e relevo antropogênica. Este estudo destaca certas características da paisagem modelada em corpos intrusivos ígneas com o objectivo de desenvolver estratégia de recuperação de turismo pelas autoridades locais e municipais.
Palavra chave: vulcanismo neógeno; Cárpatos Orientais; estruturas magmáticas intrusivas; Geodiversidade; Montanhas Bârgău.

ABSTRACT:
Igneous intrusive structures from Bârgău Mountains belong to the group of central Neogene volcanic chain of the Eastern Carpathians of Romania. The evolution of the relief developed on these structures are three main stages: the stage of injection of structures (Pannonian), the stage of uncovering of igneous intrusive bodies from Oligo-Miocene sedimentary cover (Pliocene), and the stage of subaerial modeling of magmatic bodies (Pliocene-current).In those circumstances, the geodiversity of intrusive magmatic structures from Bârgău Mountains is represented by several types of landforms such as: polycyclic landforms (erosional levels), structural landforms (the configuration of igneous intrusive structures), petrographic landforms (andesites, lithological contact), fluvial landforms (valleys, slopes, ridges), periglacial landforms (cryogenic and crionival landforms), biogenic and anthropogenic landforms. This study highlights certain features of the landforms modeled on igneous intrusive bodies with the aim of developing some strategy for tourism recovery by local and county authorities.

Keywords: neogene volcanism; Eastern Carpathians; intrusive magmatic structures; geodiversity; Bârgău Mountains.

RESUMEN:

Estructuras intrusivas ígneas de Bârgău montañas pertenecen al grupo de la cadena volcánica central Neógeno en los Cárpatos Orientales de Rumanía. La evolución del relieve desarrolló estas estructuras son tres etapas principales: etapa de inyección estructuras (Pannonian), etapa escala cuerpos intrusivos ígneos de Oligo-Mioceno cubierta sedimentaria (Plioceno), y etapa de modelado subaérea el cuerpos magmáticos (Plioceno-corrientes). En estas circunstancias, la geodiversidad de las estructuras magmáticas intrusivas de Bârgău Montañas está representado por varios tipos de alivio como: el alivio policíclicos (áreas de erosión), el alivio estructural (configuración estructuras intrusivos), alivio petrográfico (andesitas, contactos litológica), alivio fluvial (valles, laderas, alturas), el alivio periglacial (relieve crionival, alivio criogénico) alivio biogénico y alivio antropogénico. Este estudio pone de relieve ciertas características del paisaje inspirado en cuerpos ígneos intrusivos con el objetivo de desarrollar la estrategia de recuperación del turismo por las autoridades locales y del condado.

Palabras clave: volcanismo neógeno; Cárpatos Orientales; estructuras magmáticas intrusivas; geodiversidad; Montañas Bârgău.

1.INTRODUCTION

Carpathian Neogene volcanism generated the longest volcanic chain in Europe, wich in Romania totaling 350-400 km and is divided, after characteristics and geographical location of structures, in three groups:
-north volcanic group, which includes Oaş, Ignis-Gutâi and Lăpuş Mountains, with products and structures predominantly extrusive associated with intrusions;
-central volcanic group or intermediate volcanic group, wich comprising mountainous area from central part of Ţibleş Mountains, south-eastern part of Maramureş Mountains, southern part of Rodnei Mountains and Bârgă Mountains, with products and structures exclusively in intrusive facies;
-south volcanic group, composed of Calimani, Gurghiu, Harghita and Perşani Mountains, with predominantly extrusive products and structures, which joins some intrusive structures.

Magmatic activity on the internal side of the Carpathians is the result of subduction processes located in the outer East European plate (RĂDULESCU, SĂNDULESCU, 1973; BLEAHU, 1973; BOCALETTI, 1973; RĂDULESCU, 1973). Following the volcanic eruption an volcanic arch formed,of active continental margins type, which in terms of its spatial deployment can be divided into two segments:
-western segment (Western Carpathians), located in the northern part of the Pannonian Basin, which includes Central Slovakia-Dunazung-Börzsöny-Burda-Cserhát-Matra-Bukk-Gemerides-Tokay-Zemplen-Slanski-Vrchy;
-eastern segmen (Eastern Carpathians), located on the internal side of the Carpathians, which includes Vihorlat, Oaş-Gutâi, Ţibleş-Bârgău, Călimani-Gurghiu-Harghita-Northern Perşani sector (BALINTONI, 1997) (Figure 1).

The outbreak of Neogene volcanism in the Eastern Carpathians and its materialization in the shape of a magmatic arc is the last step in structural finalization of the orogen area in this region, to be seen in a wider geotectonic context , linked to the evolution of the geographical area that includes today Romania.
In this regard have been developed numerous assumptions and models, which assume that on each edge of the Eurasian Plate existed, since Triassic, a conglomerate of microplates or rigid blocks, whose dynamics has led to the structural individualization of units of this region (RĂDULESCU, 1973; BLEAHU, BOCALETTI, 1973, 1978; AIRINEI, 1977).

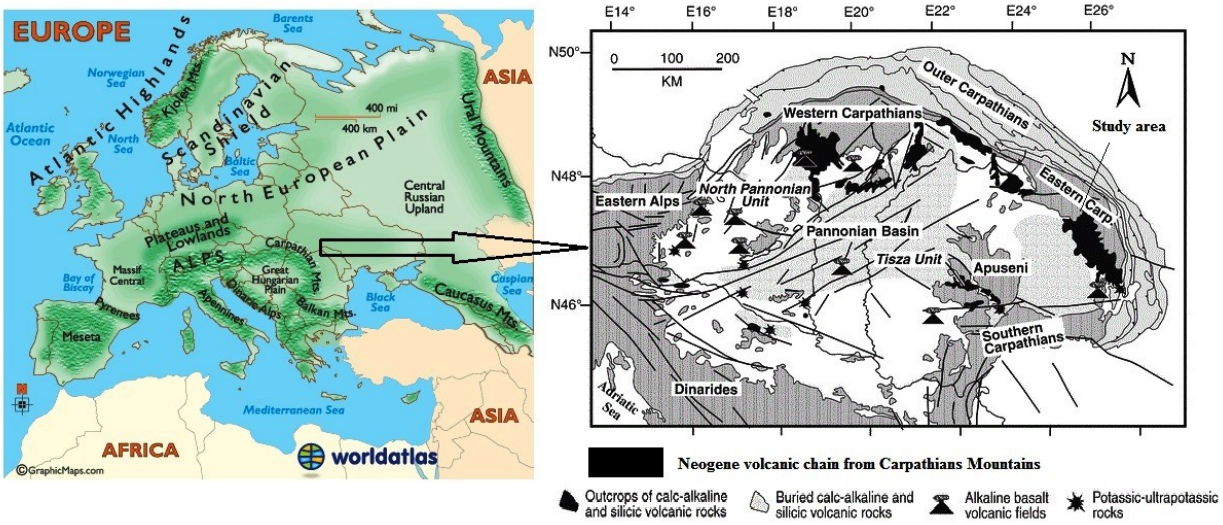

Figure 1-Neogene volcanic chain from Carpathians Mountains
(source: Harangi, Lenkey, 2007-with changes)

According to more recent models (CSONTOS, 1995; SEGHEDI et al., 1997; BALINTONI et al., 1997; TISCHLER et al., 2007), the tectonic plates interpenetrated in the area of Romania were following:

-East European plate, to the East and Northeast;

-ALCAPA (Alpine-Carpatho-Pannonian) microplate to west, and Tisza-Dacia (Getia) microplate on southwest, separated by Mid-Hungarian fault zone (Figure 2).

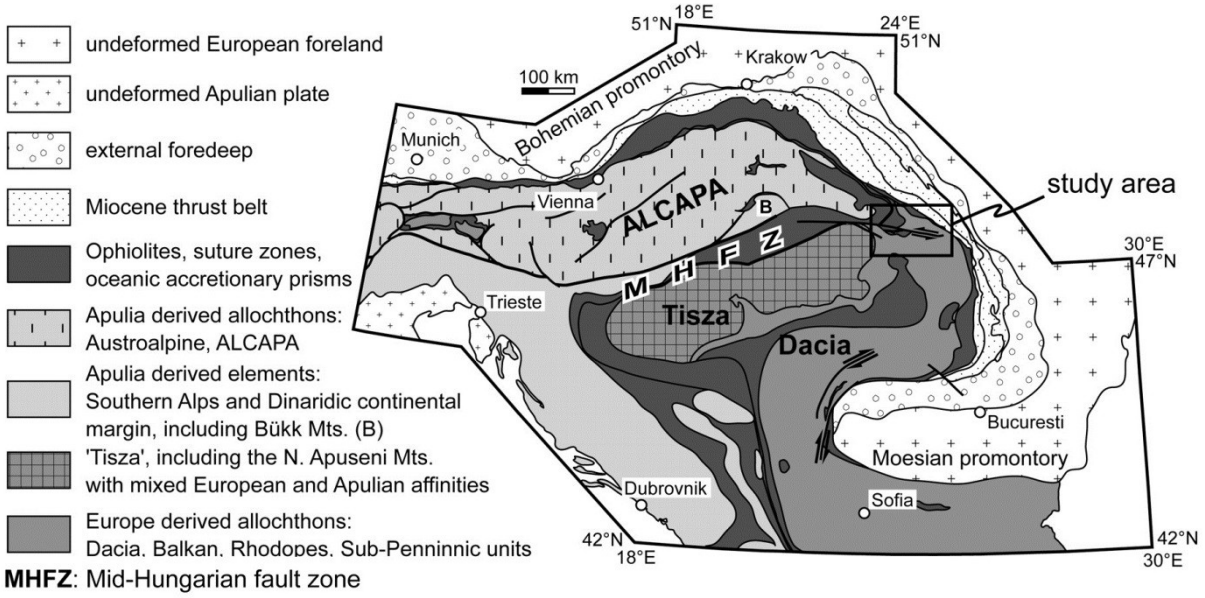

Figure 2-The geotectonic context of neogene volcanism from Eastern Carpathian of Romania
(source: Tischler et al., 2007-with minor changing)

Intrusive activity, held in the central group Ţibleş-Toroiaga-Rodna-Bârgău, put in place numerous hipoabisal structures, varied sizes, shapes of ore, and petrography, in various stages of exhumation. Igneous bodies with larger and more representative forms (lacolites, microlacolites, stoks, dyks) is reflected in morphology through massifs like conical knolls (magura in traditional language), and local influences in the ridges, slopes and valleys.

The tectonic position of intrusive magmatic massives is linked to the especially tectonic regime in this sector, characterized by partitioning of the strong prevolcanic foundation in blocks, placed vertically at different levels, and separated by numerous fractures, who controlled the location of eruptive activities and the tectonic-magmatic pattern of territory. In this context, major fractures, G11-G13, were the main structural elements that have guided injection processes of silicate melts and implementing intrusive igneous structures instead.

2.MATERIALS AND METHODS

In preparing this study were following steps:

-consulting works of Neogene volcanism the Eastern Carpathians of Romania (RĂDULESCU, SĂNDULESCU, 1973; BLEAHU, BOCALETTI, 1973; BOCALETTI et al., 1973; RĂDULESCU, 1973; BALINTONI et al., 1997; RĂDULESCU, 1973; BLEAHU, 1973, 1978; AIRINEI, 1977; CSONTOS, 1995; SEGHEDI et al., 1997; HARANGI, LENKEY, 2007; TISCHLER et al., 2007; KOVACS et al., 2013);

-consulting materials about Bârgău Mountains evolution (KRAUTNER, 1930; SÂRCU, 1957; NAUM, 1986; NAUM, MOLDOVAN, 1987; RUSU, 1998);

-consulting geological literature about the structures of intrusive igneous complex Ţibleş-Toroiaga-Rodna-Bârgău from Eastern Carpathians (ATANASIU, 1954, 1955, 1956a, 1956b; PAVELESCU, 1953; SZOKE, 1962a, 1962b, 1965; BLEAHU et al., 1968; PELTZ et al. 1971; EDELSTEIN et al., 1981; POP et al., 1984; KOVACS et al., 1985-1987; BROTEA et al., 1991; PECSKAY et al., 1995, 1996; MASSON et al., 1996; URECHE, 1998, 2000; BÂCA, 2002, 2003, 2010) and elaborating the geologic inventory sheet (table 1);

Table 1. Geologic inventory sheet of intrusive magmatic structures

Crt no.	Magmatic structure	Deposit form	Petrography

-geomorphometry analysis of magmatic structures based on topographic maps (1:25 000 scale) and elaborating the geomorphometry inventory sheet (table 2);

-elaborating geologic profiles based on topographic maps 1:25 000 scale and Geologic Map of Romania 1:200 000 scale (1967, 1968);

Table 2. The geomorphometry inventory sheet of intrusive magmatic

Crt. no.	Magmatic structure	Altitude m	Energy m/km^2	Fragmentation m/km	Slope^0

-field trip research for inventory landforms resulting from modeling magmatic intrusive structures and elaborating the geomorphology sheet (table 3);

Table 3. The geomorphology inventory sheet of landforms

Magmatic structure	Landforms type						
	Structural	Petrographic	Plicyclic	Fluvial	Periglacial	Biogene	Antropogene

3.STUDY AREA

Bârgău Mountains are located in the northern Romania, on the counties territory Bistrița-Năsăud and Suceava, at 18 km east from Bistrița city, and 15 km west from Vatra Dornei city, in the central group of the Eastern Carpathians, between Someşul Mare Valley to northwest, Maria Valley, and Maria Mare Valley to the north, Coşna Valley to northeast, Dorna Valley, Dornișoara Valley, and Magura-Buba-Terha summit at east, Terha Col, Dălbidan Col, and Colbu Valley to southeast, Colibița Depression and Bistrița Valley to southwest, Pârâul Muntelui (a tributary of Bistrița river), Strâmba Pass and Strâmba Valley (affluent of Ilva) to west. Bârgău Mountains extending over an area of 1500 square km, between 47^0 30` 30`` N-$47^0$ 08` 23`` S, 24^0 40` 12`` W-$25^0$ 11` 24`` E, and bordering Rodnei Mountains to the north, Suhard Mountains to the north-east, Dorna Depression to the east, Călimani Montains to the south, and Bistrița Hills to the west (Figure 3).

The structural and oro-hidrografic pattern of this mountain area is represented by a surface developed on sedimentary formations of transcarpathian flysch (sandstone, marl, conglomerates, clays), with falls from east to west, pierced by neogene igneous intrusive bodies, in shape of knolls (Figure 4). These igneous bodies are composed of andesites, diorites and dacites belonging to sub-volcanic area of Eastern Carpathians, which includes Toroiaga, Ţibleş, South Rodna and Bârgău groups (Figure 5).

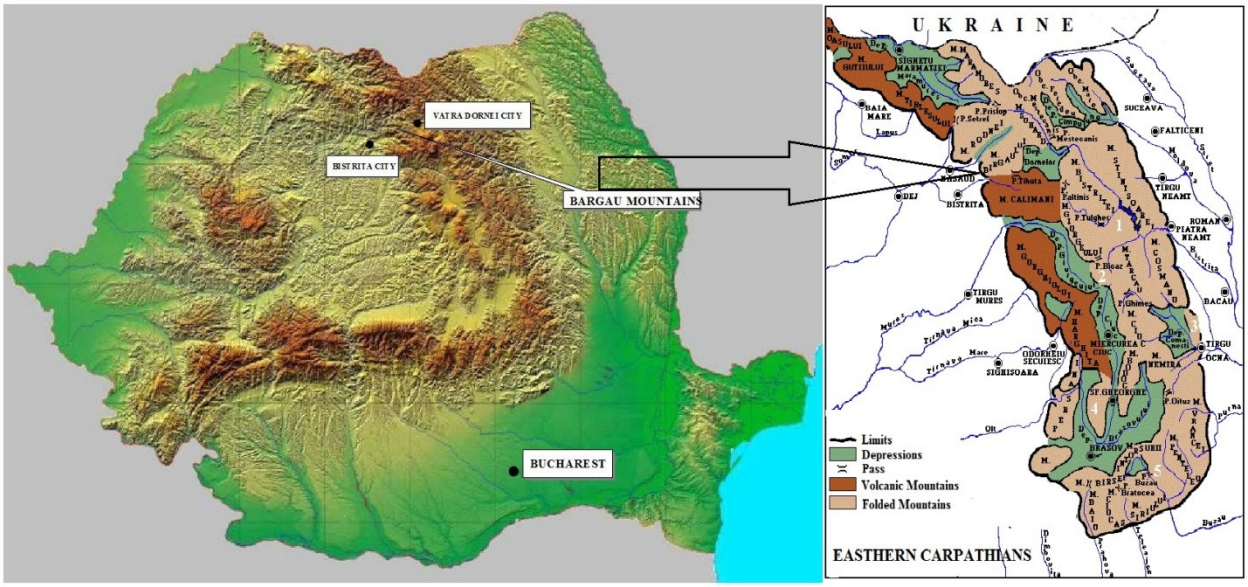

Figure 3-Geographic position of Bârgău Mountains in Easthern Carpathians (Romania)
(source:http://www.welcometoromania.ro/Romania/Romania_Harta_Geografica_r.htm-with changes)

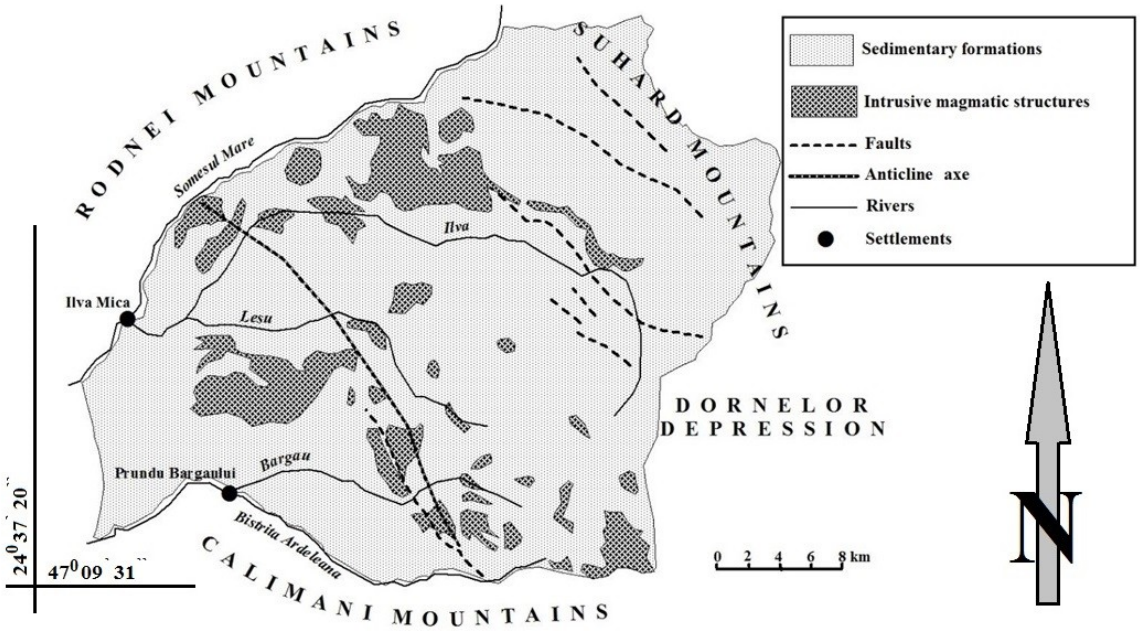

Figure4-Bârgău Mountains Area
(after Geologic Map of Romania-1:200 000, 1967, 1968)

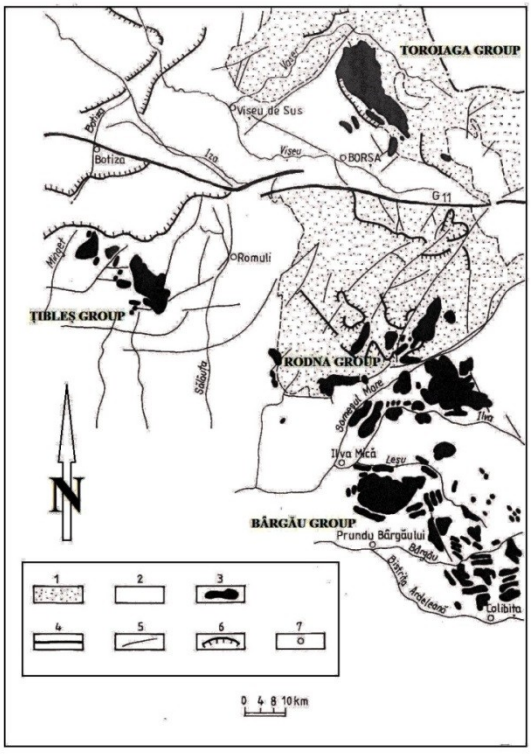

Figure 5-Intrusive area from Eastern Carpathians (after Ureche, 2000)
1-Metamorphic formations; 2-Sedimentary formations; 3-Intrusive magmatic structures; 4-Major Faults; 6-Local Faults; 6-Nappes; 7-Settlements

4.RESULTS AND DISCUSSION

4.1.The geology of intrusive magmatic massifs

In terms of petrography, the intrusive igneous bodies from Bârgău Mountains consist of:
-dacites/porphyritic microdiorites: Bucnitori, Măgura Sturzilor;
-diorites/ porphyritic microgranodiorites: Dealul Pietrei;
-andesites and diorites/ porphyritic microgranodiorites: Măgura Mare, Măgura Corni, Măgura Şanţ, Heniu, Miroslava;
-andesites: Măgura lui Arsente, Măgura Borcutului, Măgura neagră, Păltineasa, Dealul Ciosa, Erboasa, Bârgău, Zimbroaia, Lăzăroaia, Tăşuleasa, Frumuşeaua Magura Calului, Căsaru, Măguriţa, Dealul Ariilor, Cornu;

As the shape, the intrusive igneous bodies from Bârgău Mountains are:
-lacolites: Bucnitori Măgura Sturzilor, Măgura lui Arsente, Măgura Borcutului, Măgura Corni, Măgura Neagră, Heniu, Erboasa, Bârgău, Dealul Pietrei, Miroslava, Lăzăroaia, Păltineasa;
-stoks: Căsaru, Măguriţa, Dealul Ariilor;
-dykes: Zimbroaia, Tăsuleasa;
-pillar: Măgura Mare, Frumuşeaua, Dealul Ciosa, Măgura Calului, Cornu (Figure 6).

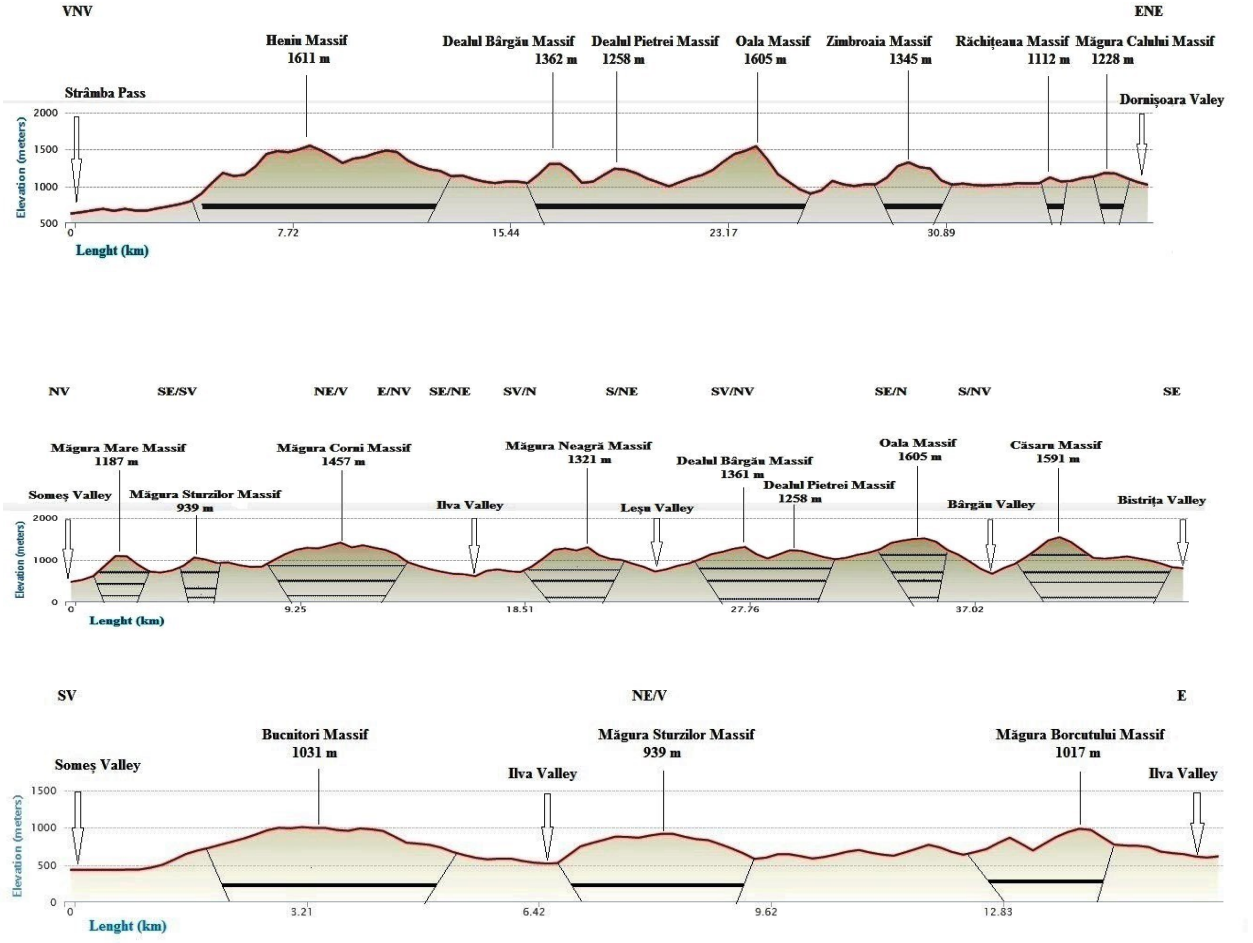

Figure 6-Geologic profiles along Bârgău Mountains area wich reveals the pannonian intrusive magmatic structures (Source: Topographic Map 1:25 000 and Geologic Map of Romania-1:200 000, 1967, 1968

4.2.The geomorphology of intrusive magmatic bodies

In the evolution of lanforms on intrusive magmatic structures from Bârgău Mountains can be separated two distinct stages:

a)the stage of injection of intrusive bodies, with two phases:

-phase 1 lower Pannonian (11.7-10.6 Ma)-the massifs Bucnitori, Măgura Sturzilor, Heniu, Erboasa, Bârgău, Dealul Pietrei;

-phase 2 middle Pannonian (10.6-8.5 Ma)- the massifs Măgura Mare, Măgura lui Arsente, Măgura Șanț, Măgura Corni, Măgura Neagră, Miroslava, Zimbroaia, Măgura Piatra Fântanele Căsaru, Măguriţa, Dealul Ariilor, Cornu;

b)the stage of enveiling the intrusive igneous bodies and their subaerial modeling (Pliocene-current) (polycyclic modeling, fluvial modeling, periglacial modeling, biogenic and anthropogenic modeling).

In this context, the intrusive igneous bodies from Bârgău Mountains presents the following genetic types of landform: polycyclic landforms, fluvial landforms, periglacial landforms, biogenic and anthropogenic landforms.

The polycyclic relief is represented by erosional levels shaped in lower Pliocene (Zimbroaia Surface) and in upper Pliocene-lower Quaternary (replata levels). Zimbroaia Surface leveling the sedimentary formations of Bârgău Mountains, ranging between 1000-1400 m.

During the modeling of this surface, the top of the magmatic structures were exhumated, while deepening the river network and detachment of valley erosional levels contributed to scraping their lower parts (Figure 7). These modeling processes affected too the intrusive magmatic structures, on igneous rocks being present many erosional levels tiered according to the size of these structures.

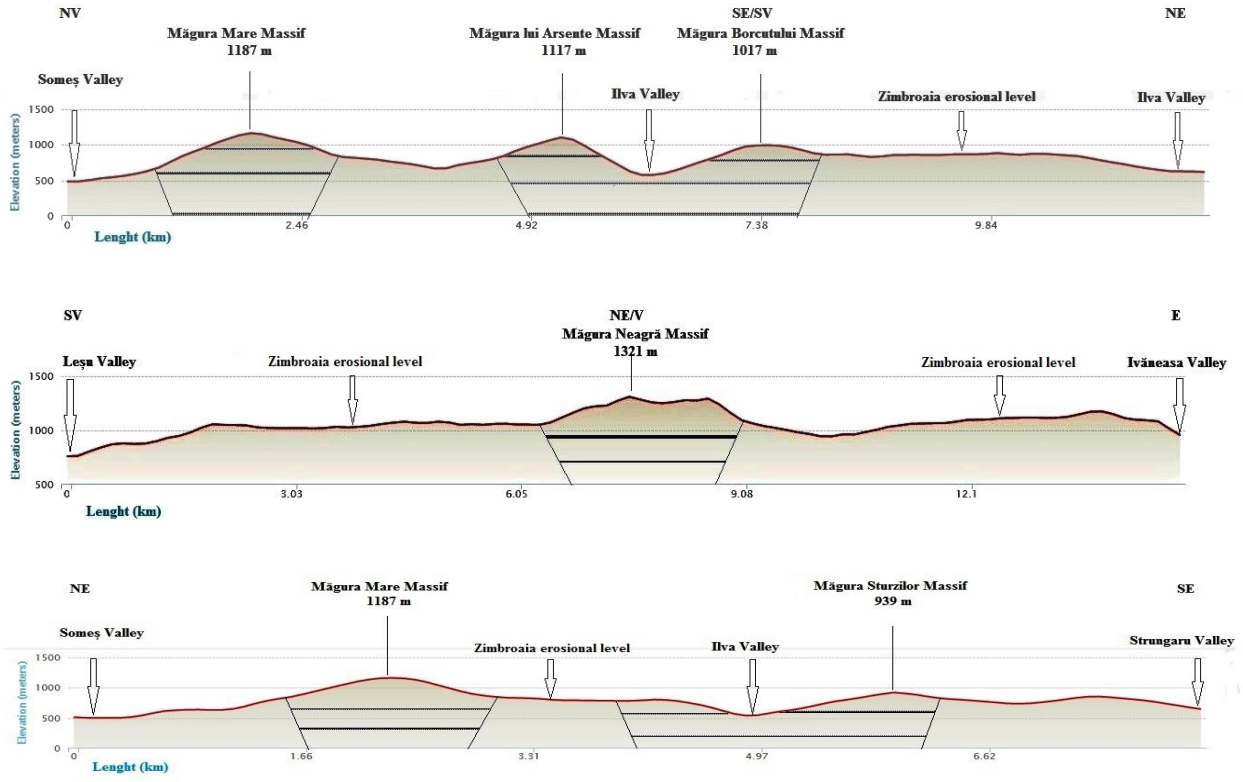

Figure 7-The relations between intrusive magmatic bodies and erosional level Zimbroaia (low pliocene)
(Source: Topographic Map 1:25 000 and Geologic Map of Romania-1:200 000, 1967, 1968)

Fluvial modeling, of Upper Miocene-Pliocene, carried out the fragmentation of sedimentary edifice of Bârgău Mountains and drafting of their orohidrographic pattern, depending on the structural features and basic level represented by the Transylvanian Basin. Deepening of the river system on the Zimbroaia Surface conducted in most, to highlighting of some magmatic structures (Cornu, Zimbroaia, Căsaru, Miroslava, Heniu Măgura neagră, Măgura Corni, Măgura Borcutului Măgura lui Arsente, Măgura Sturzilor, Bucnitori), but also the dissection of some igneous bodies (Măgura lui Arrsente, Măgura Stursilor etc.), which favored the formation of canyons (Ilva).

In this context, the main valleys (Someşul Mare, Ilva, Leşu, Bârgău) are antecedents at Zimbroaia Surface level, and their direction is the result of the game between linear erosion, lithology (sedimentary, metamorphic, magmatic, lithologic contacts), and tectonic lines (fault). In some places they have maintained their antecedent route, slipping between igneous bodies (Bârgău, leşu, Ilva), other they places have adjusted their route according to the presence of magmatic bodies, wich they have avoided (Someşul Mare), and other places they have maintained the antecedent character and cut off the igneous bodies, acquired epigenetic features (Ilva, Leşu). In the late Pliocene, the main valleys route was finalized and the unveiled igneous bodies delimited their river basins.

With the diversification of river system, on the uncovered igneous bodies installing a secondary waterway network, which is routed to the main valleys. There were thus, radial-divergent, recyangular or dendritic valleys eich sectioned the intrusive magmatic structures, causing carving of specific detailed landforms, represented by flared catchment areas, deep valleys, ridges, riverbed with stepped profile etc. Lithologic contacts between sedimentary and igneous bodies (sills) are often marked by steps in riverbed or on the slopes faces and on the summit profiles (Figure 8).

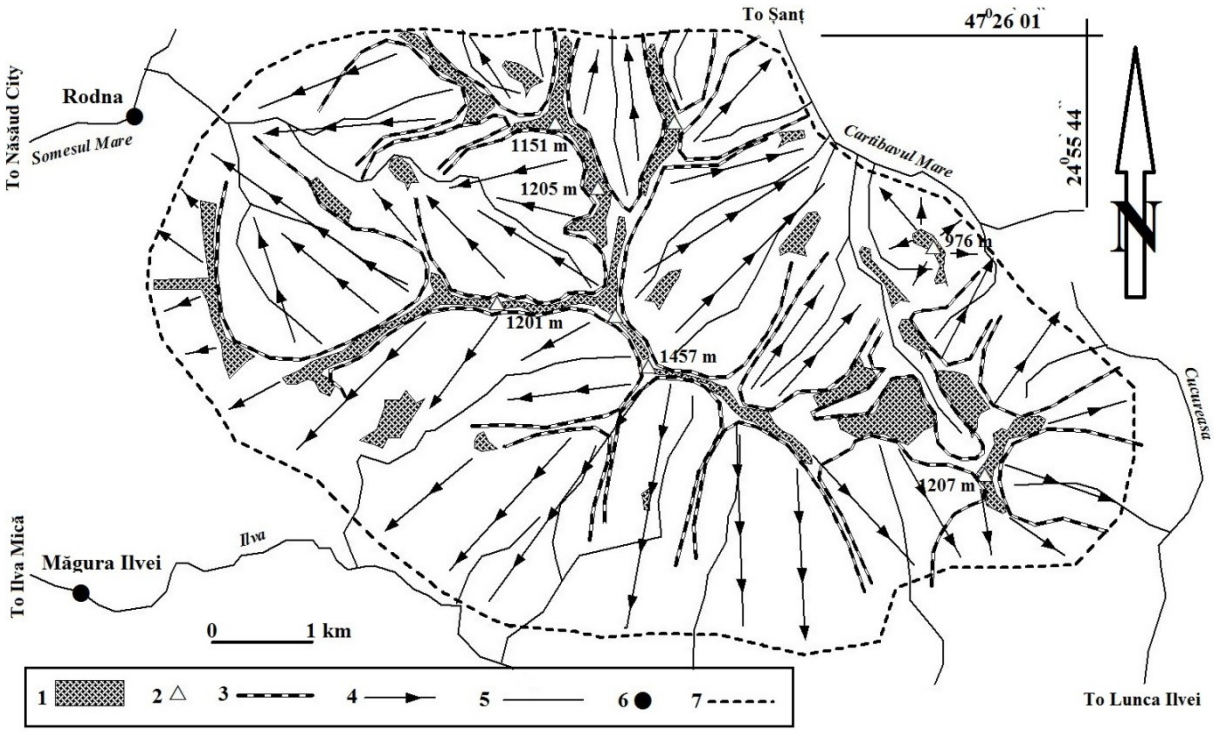

Figure 8-The geomorphology of Măgura Corni (1457 m) intrusive magmatic massif
1-Erosional levels on magmatic rocks; 2-Peaks; 3-Catchment area; 4-Slopes; 5-Rivers; 6-Settlements; 7-The limit of magmatic bodie

Periglacial modeling periglacial held in the Upper Pleistocene, acted on magmatic bodies, generating cryogenic and crionival landforms represented by: cliffs, ravines, peaks, ridges, cols, steps and waterfalls, boulder fields, crionival funnels and culoirs.

Current modeling of the relief take places under the action of mountain temperate climate and human activities that trigger or accelerate certain processes. Thus, forestry work and digging roads sustain gully erosion and lanslides, the exploitation of andesites has led to quarry (Poiana Ilvei, Sângeorz Băi, Leşu, Colibița), overgrazing causes herbaceous and shrubs cover removing, soil compaction and the development of cattle paths, morphological formations wich represents the first step in triggering erosion, gully processes carried along most important river basins, as well as their tributaries, determine crumbling banks, destruction of forest roads and driving away a large masses of silt and trunks trees during floods, which causes changes in riverbed configuration and affects tourists' access to different attractive targets (Figure 9).

Figure 9-The intrusive magmatic massif Măgura Mare (1187 m) dominating the Maieru village from Bistrița-Năsăud County

Geomorphometry features of the landformes shaped on intrusive magmatic structures of Bârgău Mountains illustrates the morfphogenetic complexity of this area. Thus, the energy relief is between 50-600 m/km^2, relief fragmentation reaches 1-4 km/km^2, slopes frequently recorded values of 25-45^0, reaching 50-90^0 on the cliffs, and in terms of altimetry the following classes are distinguished:

a)massifs between 900-1100 m (Măgura Sturzilor, Măgura Borcutului, Bucnitori, Măgura de la Șanț, Lăzăroaia, Măgura lui Arsente, Piatra Fântânele, Măgura Mare, Dealul Ciosa);

b)massifs between 1200-1400 m (Tășuleasa, Frumușeaua, Măgura Calului, Păltineasa, Bondari, Erboasa, Măgura Neagră, Zimbroaia, Bârgău, Măgura Corni).

c)massifs between 1500-1600 (Cornu, Dealul Ariilor, Măgurița, Căsaru, Miroslava, Heniu).

Regarding their positioning in the territory, intrusive igneous structures of Bârgău Mountains can be grouped as follows:

a)transverse, on four alignments, conditioned by valleys deepning in sedimentary formations:

-northern alignment, between Someşul Mare Valley and Ilva Valley: Bucnitori, Măgura Mare, Măgura Corni, Măgura de la Șanț;

-central-northern alignment, between Ilva Valley and Iliuța Bozghi Valley: Măgura Borcutului, Măgura Neagră, Păltineasa, Ciosa;

-central-southern alignment, between Ilva-Iliuța Bozghi and Bistrița-Bârgău Valleys: Heniu, Bârgău, Miroslava, Lăzăroaia, Zimbroaia, Tășuleasa, Frumușaua;

-south-eastern alignment, between Bârgă Valley and Bistrița Valley: Căsaru, Măgurița, Dealul Ariilor, Cornu, Măgura Calului;

b)longitudinally, in two alignments, according to the time of magmas injection in the sedimentary formations and their chemistry (acid, intermediate):

-south-western alignment, build in lower pannonian period (11,7-10,6 Ma): the massifs Bucnitori, Măgura Sturzilor, Heniu;

-north-eastern alignment, build in upper pannonian period (10,6-8,5 Ma): the massifs Măgura Mare, Măgura lui Arsente, Măgura Borcutului, Măgura Corni, Măgura Neagră, Miroslava, Zimbroaia, Căsaru-Măgurița-Dealul Ariilor-Cornu.

5.CONCLUSIONS

Igneous intrusive structures are well defined geographical entities in mountainous landscape of Bârgău Mountains, distinguished by special geomorphological features resulted from the interconnectedness of geological (configuration and petrography of magmatic bodies, structure and petrography of sedimentary cover) and the morphogenetic factors (agents and processes, basic levels).

The stages of landscape development are confirmed by geodiversity of this area, represented by several types of landforms, such as polycyclic landforms (erosional levels), structural landforms (configuration of magmatic bodies), petrographyc landforms (hardness of igneous rocks, lithological contacts), fluvial landforms (valleys, slopes and summits) periglacial landforms (residual and crionival landforms), biogenic and anthropogenic landforms.

These geomorphological features allow highlighting in this area an intrusive igneous testimony landscape, unique in the Neogene volcanic chain in the Eastern Carpathians, which could be framed in a Natural Park of Intrusive Magmatic Massifs.

For this, it is necessary to develop some strategies for tourism recovery of intrusive igneous structures, and the stakeholders involved in this process are: Bistrița-Năsăud County Council, municipalities, schools and tourism organizations.

The local strategies for sustainable development of communities wich includes the intrusive igneous structures (Rodna, Ilva Mică, Poiana Ilvei Măgura Ilvei, Ilva Mare, Lunca Ilvei, Leşu, Tiha Bârgaului, Bistrița Bârgăului) provide at this time many actions for the planning and exploitation of the relief and other elements of the natural environment (mineral springs, biodiversity), such as: setting up tourist routes, placement of rest and picnic sites, construction of scenic towers etc.

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