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GEOMORPHOSITES INVENTORY IN THE MĂCIN MOUNTAINS (SOUTH-EASTERN ROMANIA)

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Abstract: Our study aims to achieve the working stages to be followed in the geomorphosites inventory process. The proposed inventory methodology requires the performing of three main stages: documentation regarding the morphological specificity of the studied area; identification of landforms with potential of geomorphosite and the inventory of the geomorphosites features (scientific, educational, aesthetic, cultural, historical, religious, touristic). The methodological working stages were applied in the Măcin Mountains area, the result consisting in the detailed inventory of 47 geomorphosites. The data obtained through geomorphosites inventory in Măcin Mountains were further used in the assessment process, geomorphosites ranking and geotouristic capitalization.

Key words: inventory, method, geomorphosites, spatial distribution, geomorphosites typology, Măcin Mountains.

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INTRODUCTION

Since the beginning of the '90s several scientific papers have been carried out at international level regarding the inventory of geological and geomorphological heritage (Panizza & Cannillo, 1994; Grandgirard, 1995; Bertacchini et al., 1999; Marchetti, 1999). Although it has been a highly debated topic, in the scientific literature are often occur confusions between the inventory and the assessment processes, the terms being frequently considered similar. Such aspects are common in studies of Costamagna (2005), Fuertez-Gutiérrez & Fernández-Martínes (2010) etc.

From our viewpoint, the inventory process involve the detailed analysis of all sites of geomorphological heritage within a study area; while the assessment process implies the quantitative examination of geomorphosite features (numerical analysis). Therefore, the inventory constitutes a distinct study that precede the geomorphosites assessment. Actually, the result of the inventory process consists in a census of geomorphosites within a study area (Reynard, 2009); while the outcome of assessment process consists in obtaining the aproximative value of each geomorphosite.

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The purpose of our study is the conceptual and applied delineation of the two methods used in the geomorphosites study (inventory and assessment) and achieving a methodology (working stages) to be followed in the inventory process. Data obtained through the inventory constitutes the starting base in the assessment process, respectively in determining the geomorphosites value and their ranking, in order to establish the priorities in their touristic capitalization (geotourism).

The proposed methodology has been applied in Măcin Mountains, respectively in the area of the oldest mountains in Romania. Our study area is situated in the North-Weastern part of Dobrogea Plateau and is delinead by Măcin Branch (Old Danube) in the west; Danube and its associated ponds and channels in north; Lodzova, Taița and Luncavița valleys in east and Iaila valley in south (Figure 1).

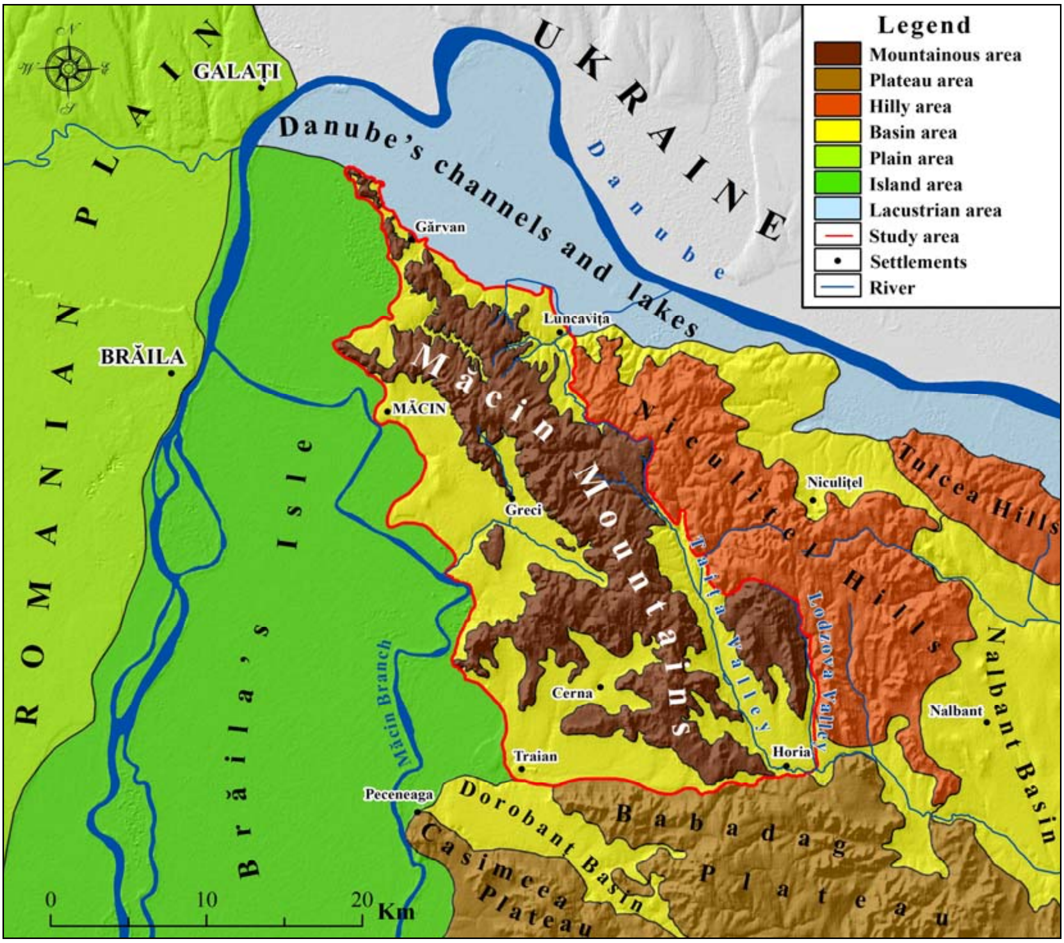

Figure 1. The geographical position of Măcin Mountains in the Northern Dobrogea Plateau

Being completely exondated and exposed to the aerial regime since the Upper Carboniferous, Măcin Mountains morphology is mainly represented by rounded and flattened ridges, bornhardts and basins (buried pediments) and, in a lesser extend, by residual ridges. It can be also noticed the predominance of surfaces with low altitudes, under 200 meters (80,2% of the total surface of the study area) and low fragmentation depth, under 200 m/km² (92,5 % of the total surface) (Gavrilă, 2012). Therefore, especially because of the low values of morphometric parameters and their predominantly flattened morphology, the touristic potential of Măcin Mountains morphology is often considered reduced. The unique morphology (given by the high number of inselbergs and the wide surfaces occupied by pediments) and its diversity (ridges, peaks, gorges, lakes, suffosion valleys, weathering micromorphology etc.); the scientific and educational features of the landforms; the increased accesibility of the area and the traditional lifestyle constitutes, from our viewpoint, atributes that makes from Măcin Mountains one of the most representative mountainous area from our country for practicing geotourism.

INVENTORY METHODOLOGY OF GEOMORPHOSITES

Based on international and national scientific literature we attempted the achieving of a phased structured methodology to be used in the inventory of geomorphosites. Therefore, the inventory process was divided in three main stages: documentation, identification and inventory.

Documentation stage is carried out in the laboratory, as well as in the field and aims the detailed research of the study area, by following the working steps below:

- The study of geological and geomorphological literature and the interpretation of cartographic materials (thematic maps, ortophotoplans, aerial photos, satellite images) that refers to the study area (Coratza & Giusti, 2005). The aim of this working step consists in acquinted with the morphological specificity of the study area and achieving a complex database of local morphology.

- Carrying out successive field campaigns on the entire surface of the studied area, in order to observe and mapping the local morphology.

-Knowledge of all the existing landforms within the study area and carrying out the detailed geomorphological map. In our case, the geomorphological map of Măcin Mountains was based on geological and geomorphological informations from the existing scientific literature; photo interpretation; observations and field mapping (geomorphological profiles and sketches), being further achieved by using classical mapping methods, as well as GIS tehniques.

Identification stage is carried out exclusively in the laboratory and consists in the effective nomination of geomorphosites. Therefore, by knowledge the local morphological context (documentation stage) are selected only those landforms that, through their morphological features, are representative for a cathegory of morphogenetic process. As well are considered geomorphosites those landforms that represents a model for understanding the local, regional or even national paleo-evolution (Strasser et al., 1995; Grandgirard, 1995, 1997).

Inventory stage consists in a analysis of geomorphosites features, in order to achieve a database comprising detailed information for each geosite within the study area. An important aspect is the fact that the analysis from this stage is not quantitative (numerical). The research is carried out only in the field and consists in collecting information regarding the existing morphology and other elements of ecologic, cultural or touristic interest (touristic sights, touristic infrastructure etc.). The data obtained through field research are stored using as working tool, the inventory sheet.

RESULTS

The inventory of geomorphosites in the Măcin Mountains begun with the documentation stage regarding local geomorphological context: genesis, evolution and morphology. In this phase were consulted over 80 geological (Mirăuță & Mirăuță, 1975; Ionesi, 1994; Mutihac et al., 2007; Seghedi, 2007) and geomorphological (Posea, 1980a; Popescu & Ielenicz, 2003; Vespremeanu, 2004; Burcea, 2008) studies (scientific papers, PhD thesis, synthesis, monographies etc.); as well topographical maps (diferent editions), thematic maps (geological maps scales 1:50.000 and 1:200.000; pedological maps, geomorphological maps etc.), ortophotoplans (scale 1:5.000, 2003-2005 edition), satellite images (scale 1:2.000, 2010 edition), digital databases available online (Google Earth, www.geospatial.org) etc.

After this methodological phase it can be noticed that Măcin Mountains are widely investigated through geologic viewpoint and lesser in terms of geomorphology, studies from this category being focused especially on the evolution of landscape (Coteţ, 1966; Basarabeanu & Marin, 1978; Vespremeanu, 2003). The bibliographic analysis reveals a complex teritory from tectonic and structural viewpoint and diverse in terms of petrography, being characterized by the existing of all main types of rocks: metamorphic rocks (Proterozoic and Upper Cambrian mezo and epi-metamorphic crystalline schists); Paleozoic sedimentary rocks (Carboniferous sandstones and conglomerates; Devonian limestones; Silurian limestones, sandstones, marls and clays) and igneous rocks (especially Paleozoic granites and granodiorites) resulted during the hercynic, caledonian and assyntic orogenesis and completed in neochimmeric orogenesis (Ionesi, 1994).

The geomorphological studies reveals an unique morphology (including Niculiţel Plateau) at national level, due to the presence in the contemporary configuration of Măcin Mountains, of relict landforms shaped in post-Hercynian stages (Martonne, 1924; Nordon, 1930; Ielenicz & Burcea, 2000). The wide number of inselbergs, their dimensional and morphological variety (bornhardts, nubbins and castle koppies) are features that makes the Măcin Mountains a representative area at national and even international level. The typical pediments surfaces (Posea, 1980b) and morphology developed in granites through weathering processes are another attributes that gives specificity of our study area.

The bibliographic research was followed by field campaings in order to map the geomorphology of study area. The wide spatial extension of the studied area (568,8 km²) has required the performing of 12 field campaign (during the three years of PhD studies). Concretely, during the field works were carried out: research routes on the entire surface of study area in order to observe and map the local morphology; sketches and profiles in order to synthesize the detailed aspects of landforms; was mapped the entire spectrum of landforms; were measured macro - and micro-morphology (suffosion valleys, weathering micromorphology like tors or rounded boulders etc.); were made analysis for determining the main type of surface deposits etc.

Data obtained through bibliographic analysis and the interpretation of some thematic maps (Nedelcu & Dragomirescu, 1965; Posea, 1980b; Popescu, 1988), along with our own observations and field maps were used for achieving the detailed geomorphological map of Măcin Mountains (mapping scale 1:5.000) that synthesize the hole types of landforms and geomorphological processes of study area (Gavrilă, 2012).

Knowledge of morphological specificity of Măcin Mountains allowed to identify geomorphosites representative for the diverse spectrum of forms of Northern Dobrogea Plateau (peaks, ridges, gorges, inselbergs, pediments, torrential-suffosion valleys, natural and anthropogenic lakes). In the same time, the aquire of the local morphological context allowed us the objective analysis of geomorphosites, in the identified context, not in isolation (Fuertez-Gutiérrez & Fernández-Martínes, 2010; Wimbledon et al., 2000). Therefore, based exclusively on the scientific and educational features of forms and not on criteria of other type (aesthetic, cultural, touristic) were identified ***47 geomorphosites*** in the Măcin Mountains area**.** The criteria previously submitted are often called in the scientific literature, “*additional values*”, being intended to enhance and diversify the touristic offer of geomorphosites (Panizza & Piacente, 1993; Panizza, 2001; Reynard, 2006; Ilieş & Josan, 2009).

A wide number of geomorphosites were identified upon peaks (29 geomorphosites), most of them being developed on Paleozoic granites (17 geomorphosites). The scientific importance of peaks mainly derives from their genesis, being resulted through the slopes withdrawal caused by weathering processes (Posea, 1980b). The residual peaks developed on granites (Caramalău Peak, Fântâna de Leac Peak, Cheiţa Peak, Vraju Peak etc.) comprises the entire spectrum of weathering micromorphology: tors (nubbins, castle koppies), boulders (upright, overturned, grouped or dispersed), exfoliated rocks, figurative rocks (Sfinx – Vraju Peak), rock fields, granitic arenas etc.; that constitutes an undeniable educational value. The variety and abundance of weathering micromorphology (especially in Pricopan Ridge), as well the nationwide rarity of this type of morphology, constitutes atributes that includes peaks developed on granites on the geomorphosites list within the Măcin Mountains (Figure 2).

Figure 2. Weathering micromorphology developed on Paleozoic granites: tor (A); grouped boulders (B); exfoliated rocks (C)

From ridge morphology, only 3 sectors can be considered geomorphosites: Chervant – Banului, Boclugea and Priopcea ridges due to their high didactical value, conferred by the model function for explaining the genesis of ridge morphology tectonically generated. In these sense, the Chervant-Banului ridge is the most representative exemple for tectonically generated ridge in the Măcin Mountains area. It can be easily seen the lithologic contact, created by tectonics, between Cambrian epimetamorphic crystalline schists (quartzite) and Silurian sedimentary rocks (limestones, sandstones, clays). From morphologic viewpoint the lithologic contact consists, in the field, in the association between a discontinuous ridge sector (with rough profile and steep slopes) and a slope with low declivity covered by grasslands, glades and even forest vegetation (Figure 3).

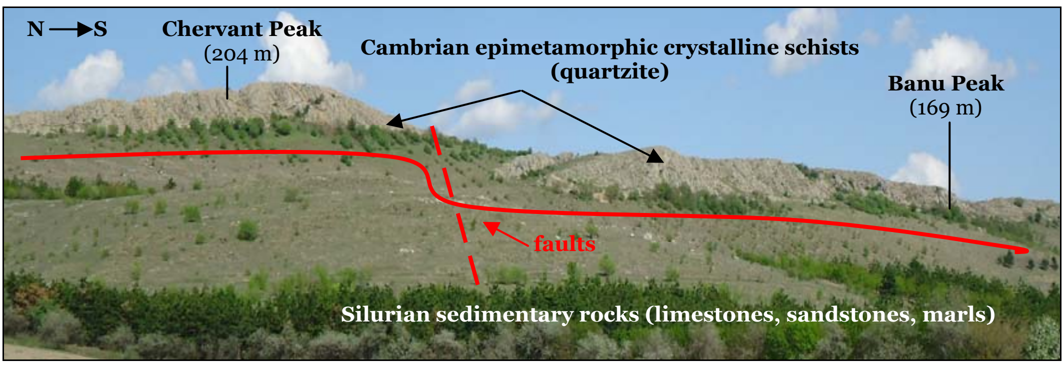

Figure 3. Chervant – Banu Ridge (view towards the western slope): a model for explaining the ridge morphology tectonically generated

The Chediu Gorges created by homonymous river (in Carbonifer conglomerates and sandstones) is another representative form for the morphological diversity of Măcin Mountains. The geomorphosite attribute is conferred by the educational model of Chediu Gorges for explaining the genesis of gorges sectors through antecedence. The educational value of Chediu Gorges is heightened by the fact that in the study area is no longer encountered such a morphology. The scientific value is also increased by the morphologic (steep slopes of Moroianu II and Ioaneş peaks; ruiniphorm peak – Ioaneş; micromorphology resulted through differential erosion) and hidrologic diversity (waterfalls şi reprezişuri) within the gorge sector (Figure 4) etc.

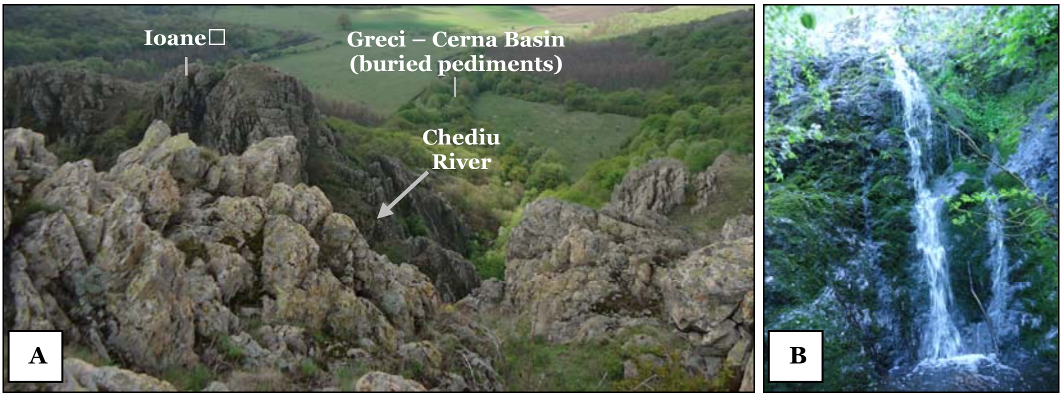

Figure 4. Chediu Gorges (view from the southern slope of Moroianu II Peak) (A); Chediu Waterfall (B)

Inselbergs, forms that through their high frequency of appearance defines the morphological specificity of Măcin Mountains, constitutes another type of geomorphosites. The rich morphological fund, the genesis and the different evolutive stages of inselbergs allowed us to identify 9 typical geomorphosites in the Măcin Mountains area. Therefore were selected residual inselbergs (Pietrele Mariei, Piatra Roşie, Colina Dălchii etc.) and rounded inselbergs (dom, bornhardt) smoothened in the upper part by steep flattening determined by weathering processes (Bujoare Hills, Carcaliu etc.) (Figure 5).

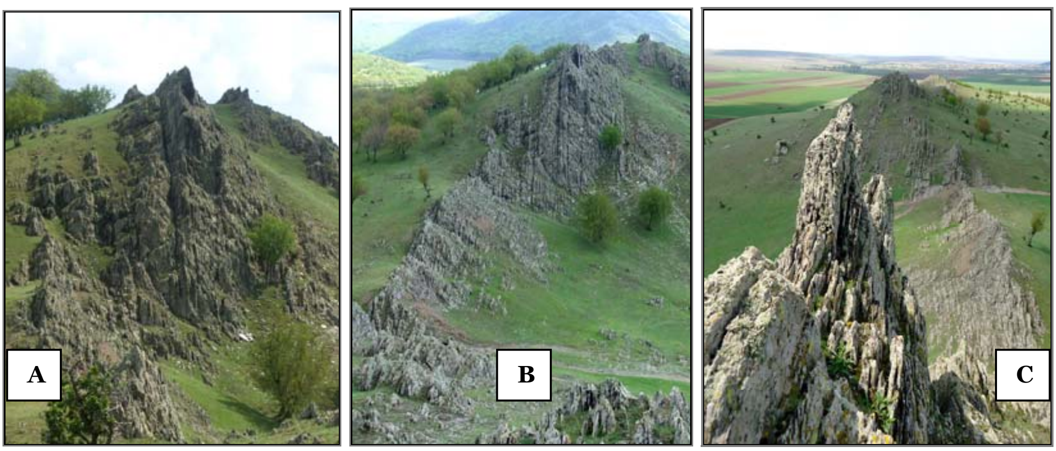

Figure 5. Pietrele Mariei Inselberg (Măcin – Greci basin) seen form the north (A, B) and south (C)

Beside inselbergs (of which are closely linked in terms of morphological evolution), pediments constitutes another morphologic objectives that gaves identity and unicity of the Northern Dobrogea Plateau area. The existence of typical pediments surfaces (in the Cerna-Mircea Vodă basin), the wide spatial extension of pediments in Northern Dobrogea Plateau (Măcin – Greci, Jijila, Luncavița basins) and the rarity of morphology at national level confers, to this type of morphology, the function of scientific and educational model with high degree of expressivity. The attributes aforementioned qualifying pediments in Măcin Mountains as geomorphosites (Figure 6).

Figure 6. Pediments covered by loess deposits in Măcin – Greci basin (A)
Inselbergs and pediments in Măcin – Greci basin (B)

The morphology resulted through suffosion processes has a wide spread in the study area, especially in the basins from the western and northern side of Măcin Mountains (Jijila, Luncavița, Măcin – Greci and Cerna – Mircea Vodă basins) due to the large spatial extension and thickness of loess deposits (that often reach 30 meters). From the suffosion landforms were identified two representative valleys with complexe genesis: Măgăreți and Gărvan. The morphometric features (lengths of 1 - 2 km, widths of 7 - 8 m, hights of 15 - 25 m) and micromorphological variety are attibutes that includes the abovementioned valleys into geomorphosites category. The Măgăreți and Gărvan valleys have important educational value, being considered as presentation models of the micromorphology that usually compose a suffosion complexe: subsidence steps; vertical walls of 25 – 30 m heights; boreholes and flues, caves, tunnels etc.

In terms of genesis of the lacustrian cuvette, two of the natural and anthropogenic lakes within the study area can be considered geomorphosites: Traian and Iacobdeal lakes. Therefore, in the case of Traian lake we are dealing with a typical cuvette of fluvial shore resulted through the alluvial damming of the Cerna river mouth; while in the Iacobdeal case is about a anthropogenic cuvette generated by mining exploitation in the homonymous inselberg.

The features of the 47 geomorphosites identified in the Măcin Mountains area were inventoried in the field, using as working tool the individual inventory sheet. Concretely, in this stage:

- were colected informations regarding the geographical position of each site (GPS coordinate), the minimum and maximum altitudes within site (GPS data) etc.;
- were identified the elements of geomorphological interest within the site;
- was mapped the entire surface of the site by using the reak function of GPS, in order to achieve a clear delineation of each geomorphosite;
- was detailed mapped the of geomorphosite morphology;
- cromorphology;

- were localized, by using GPS, all forms and microforms mapped within the site, in order to achieve their further cartographic representation (geomorphological map of each geomorphosite);
- were measured the dimensional features of forms and microforms: diameter, lenght, width, hight etc. (morphometrical measurements of Măgăreți and Gărvan suffosion valleys; of weathering microforms: tors, spherical boulders etc.)
- were made observations regarding the state conservation of geomorphosites and were identified the possible natural or anthropogenic threats on their morphology;
- were colected informations regarding the existence within the geomorphosite surface of anthropogenic touristic sights of cultural, historical, religious interest etc. (were taken GPS points for every touristic objective mentioned above);
- were colected informations concerning the accesibility and touristic infrastructure (marked trails, camping places, halting places, interpretative panels, viewpoints etc.) by taken GPS points for each of them;
- was photographed, from different angles, the overall morphology and micromorphology of the geomorphosite, as well the elements of touristic interest (touristic objetives, access infrastructure, touristic infrastructure etc.)

From the inventory process was achieved a complex database for each geomorphosite in Măcin Mountains (Table 1).

Table 1. A model of inventory sheet completed in the field

Geomorphosite designation	**Fântâna de Leac Peak**	
Morphological unit	Pricopan Ridge	
Geographical coordinates of geomorphosite	45°15′31″.80 lat. N	28°11′01″.43 long. E
Altitudes	maximum: 277 m	minimum: 58 m
Elements of geomorphological interest	Residual peak (castel koppie), petrographical steep slope (western slope) and weathering micromorphology	
Morphological features	High frequency of weathering micromorphology (on northern, western and southern slopes) Residual weathering micromorphology: tors (nubbins and castle koppies), boulders (upright, overturned, grouped or dispersed) and exfoliated rocks Acummulation weathering micromorphology: rock fields and granitic arenas (on the western slope)	
Dimensional features of micromorphology	Tors: the height vary from 0,80 - 1 m up to 4-5 m	
	Boulders: the diameters vary between <1 m and 10-14 m; the height vary from 30-40 cm up to 7-9 m	
State of coonservation	Very good	
Threats on geomorphosite morphology	Natural threats: does not exist	
	Anthropogenic threats: does not exist	
Cultural objectives and/or cultural events (archaeological sites, historical sites; religious sites etc.)	“Izvorul Tămăduirii” Monastery (built in 2000) positioned at the foot of the western slope of geomorphosite	
Informations regarding accesibility, the existing touristic infrastructure; the state of touristic territorial planning	- car acces, through a quarry road (gravel road), up to the foot of the western slope of geomorphosite, - existing touristic infrastructure: marked trail, 1 halting place and 1 camping place at the foot of the western slope of geomorphosite, interpretative panels with general informations regarding the morphology of the Pricopan Ridge - possibility to intercept the surrounding morphology – viewpoint with a circumference of 360°	

Based on field data regarding the delineation of geomorphosites was further achieved, in the laboratory, the cartographic representation of surface occupied of each geomorphosites as well as their spatial distribution in the Măcin Mountains (Figure 7).

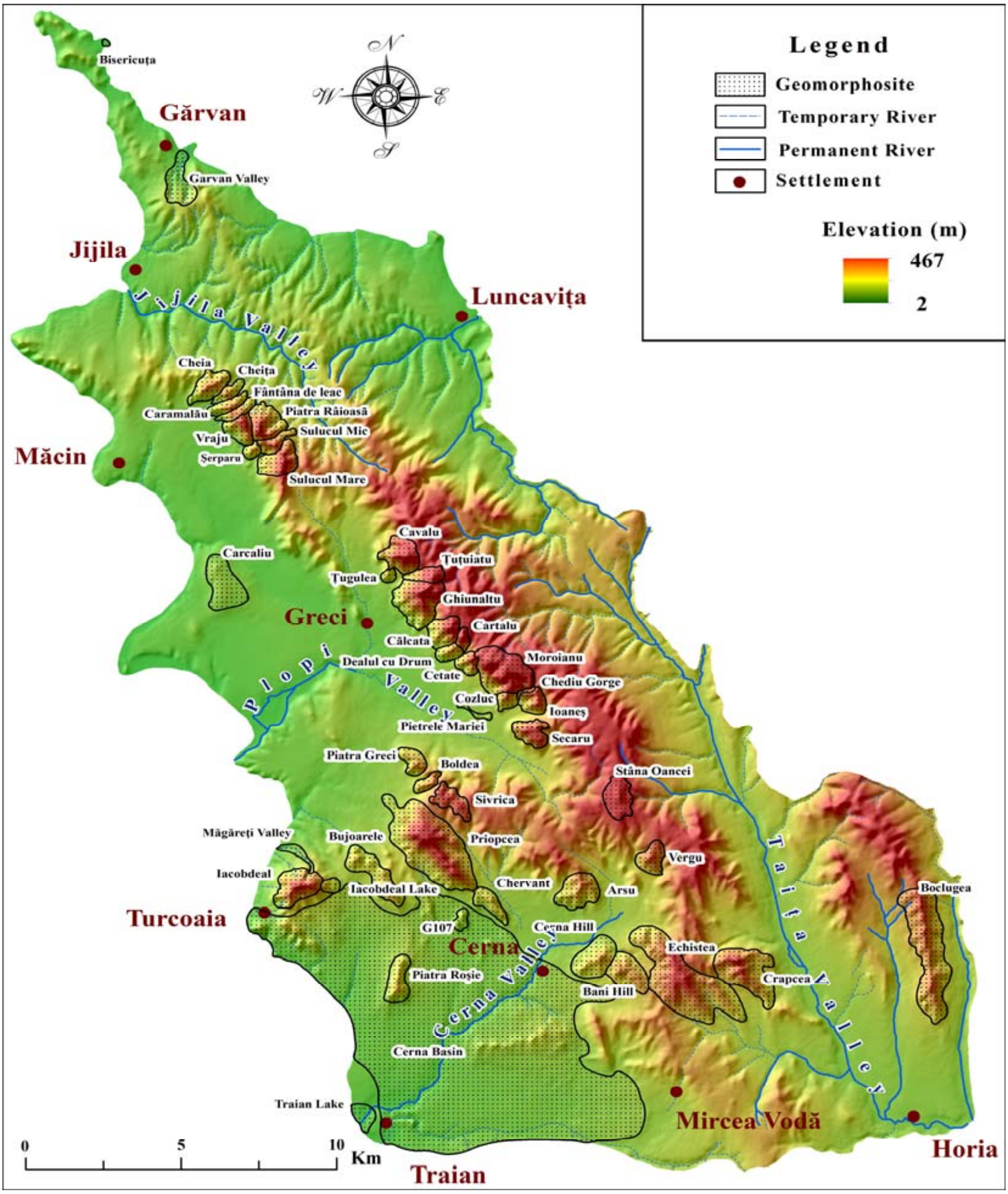

Figure 7. Spatial distribution of geomorphosites within Măcin Mountains

DISCUSSIONS

Considering the genesis, dynamics and geomorphological complexity was performed an analysis of geomorphosites within the Măcin Mountains, based on the informations resulted in the inventory process. In terms of **genesis** dominates *natural* *geomorphosites* (Ghiunaltu Peak, Sivrica Peak, Cetate Peak, Pietrele Mariei inselberg, Cerna – Mircea Vodă Basin etc.), that represents 97,87% of the total number of geomorphosites identified in Măcin Mountains area (Figure 8). *Anthropogenic geomorphosites* have a low weight of the total number (2,13 %), being represented by Iacobdeal Lake, of whose lacustrian cuvette was anthropogenic generated (through the exploitation of granites in the homonymous inselberg).

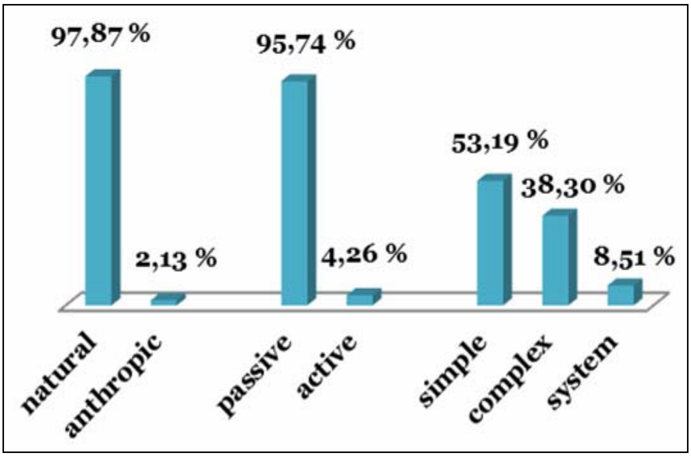

Figure 8. The weight of the main types of geomorphosites within Măcin Mountains

Regarding the dynamics of the main morphogenetic process, it can be notice the predominance of *passive geomorphosites* in the Măcin Mountains (95,74%). This are represented by the sites of which morphology was generated by geomorphological processes with slow dynamic in the contemporary climate (Hooke, 1994). A case in point are the geomorphosites mainly generated by weathering processes, their physiognomy being possible to change in geologic time (Vraju Peak, Sulucu Mic Peak, Arsu Peak etc). The category of *active geomorphosites* (4,26%) includes the Măgăreți and Gărvan valleys, due to the accentuated dynamics of suffusion processes in the contemporary climate conditions of the Măcin Mountains. The result of accelerated dynamics is reflected through the annual changes into micromorphology configuration, aspect that constitutes an element of attractiveness from educational and scientific viewpoint. On the other hand, active geomorphosites have a high degree of vulnerability to self-destruction due to the accelerated rhythm of torential and suffosion processes.

The morphologic complexity has enabled the classification of geomorphosites within Măcin Mountains in *simple*, *complexe* and *system* (Grandgirard, 1997). A wide number of geomorphosites are included in the category of those s*imple* (53,19%), that have a singular morphology generated mainly by a single dominant morphogenetic process (Traian Lake, Carcaliu inselberg, Cozluk Peak, Piatra Râioasă Peak, Bujoarele Inselberg). A significant percentage also have the *complexe geomorphosites* (38,30%), being represented by different microforms generated by a single dominant morphogenetic process (diferent types of forms – tors, boulders, exfoliated rocks etc – resulted through weathering process in Caramalău, Cavalu, Vraju, Cheia geomorphosites; a complex of form - boreholes and flues, caves, tunnels etc. - resulted through suffusion process in Gărvan valley). Although they have the lowest weight in the study area (8,51%), *system geomorphosites* have the higher degree of attractiveness from educational viewpoint because includes a varied morphology generated by the action of different morphogenetic factors (tectonics, differential erosion, weathering). An exemple in this sense is represented by Moroianu geomorphosite (Greci Ridge), in which the differential erosion has led to a Sphinx morphology, while the tectonics and liniar erosion of Chediu River generated a gorge morphology – Chediu Gorges.

CONCLUSIONS

Applying of phased inventory methodology allowed the knowledge of the morphological specificity of Măcin Mountains, the identification of 47 landforms with geomorphosite attribute and the detailed analysis of the entire spectrum of geomorphosites features. In terms of dimensions and particularities of shapes (linear, areal), geomorphosites within the study area does not fall into a predefinite standard. They cover small surfaces, less than 1 km² (Bisericuţa inselberg – 0,9 km²) as well as very extended surface, over 80 km² (Cerna – Mircea Vodă Basin – 85 km²). Regarding the spatial distribution, geomorphosites within the study area are concentrated in two zones: one in mountainous area (predominantly in the western side of Măcin Mountains, respectively in the Pricopan Ridge, the Greci Ridge, the Priopcea - Chervant ridges) and the other in the Cerna – Mircea Vodă basin area. The highest number of geomorphosites is found in the mountainous area (34 geomorphosites), due to the morphological diversity encountered here (residual ridges, ruiniphorm peaks, gorges, steep slopes, weathering micromorphology). The predominance of natural geomorphosites and the high weight of complexe geomorphosites in the Măcin Mountains, reveals a complexe area from morphological viewpoint and with a high educational value, being possible to observe the entire spectrum of forms resulted by a dominantly morphogenetic process – weathering.

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