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GEOMORPHOLOGICAL HERITAGE ASSESSMENT USING GIS ANALYSIS FOR GEOTOURISM DEVELOPMENT IN MĂCIN MOUNTAINS, DOBROGEA, ROMANIA

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Abstract: Our study follow the assessment of geomorphological heritage of the Măcin Mountains for geotourism development in the area. In order to analyze geomorphological features of this area and to achieve a digital map, we created a GIS databases comprising topographic map sheets, digital ortophotos and satellite images. Using these datasets the main geomorphologic features were extracted. As a result of this study we combined the most representative elements of the topography and we realized a digital map of landforms with geotouristic potential.

Key words: geomorphological heritage, GIS analysis, geotourism, Măcin Mountains

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INTRODUCTION

The term of geotourism was introduced in the scientific literature at the beginning of '90ties, but a universally accepted definition was not issued until today. In a broad sense, geotourism was defined by Reynard (2005) as being an esemble of activities, infrastructure and services that aimed the recovery of Earth sciences through tourism. A more precise definition was made by Hose (1996, 2000) which introduce in the concept of geotourism the terms of geological and geomorphological sites and the importance of preserving them for their use in educational and tourist purpose: "*...the provision of interpretative facilities and services to promote the value and social benefit of geologic and geomorphologic sites and their materials and to ensure their conservation, for the use of students, tourists and other casual recreationalists*". Even if currently there isn't a universally accepted definition, we can observe that the geotourism focuses on the recovery of geological and geomorphological heritage of an area.

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For the geomorphological heritage concept were also used different terms like: geomorphological assets (Panizza & Piacente, 1993), geomorphological goods (Carton et al., 1994), geomorphological sites (Hooke, 1994), geomorphological geotopes (Grandgirard, 1997) and sites of geomorphological interest (Rivas et al., 1997). In the present, for the geomorphological heritage concept is used the term of "*geomorphosite*" which was recently introduced in the scientific literature by M. Panizza, in 2001. The term was defined as being a landform that has acquired a special value due to human perception. Thus the geomorphosites, due to the human perception has two main values: scientific value and additional values (Reynard, 2005). So, geomorphosites are considered natural goods not only because of their intrinsic value (scientific, aesthetic), but also due to their extrinsic values (ecologic, historical, cultural, economic) thus forming the main resources underlying the development of geotourism.

Măcin Mountains unfolds in the form of parallel ridges, in the south-east of Romania, respectively in the north-western part of Dobrogea Plateau, in Tulcea County. Although it covers a relatively restricted area, with altitudes lower than 500 meters, Măcin Mountains are individualized in relation with adjacent units through a variety induced by structure, lithology, tectonics.

The rising of Măcin Mountains in hercynic-chimeric orogenesis determined the existence of one of the oldest and diverse geological formations from our country. The lithological diversity have led to the development of an geomorphological variety characterized by the alternance of jagged ridges with pyramidal peaks, steep slopes and ruiniphorm relief with lower depression areas, in which frequently imposing inselbergs occurs. The geodiversity and geomorphological variety is also increased by the existence in our study area (respectivelly on 1 % of our country territory) of approximately 50 % of Romania's flora. From the floristic viewpoint the region is remarkable due the presence of over 72 rare or vulnerable flora species and 27 endemic flora species (Doniţă et al., 2007). Likewise, the ecological character of our study area is both represented by the presence of six from eight groups of Europe ecosystems and a unique priority habitat in the world (the dobrogean beech forest). Thus, the ecological and botanical richness enhance the scientific value of our study area.

Our study approach a topical issue and follow the assessment of the Măcin Mountains heritage for the geotourism development in the area. In order to achieve the proposed objectives were made field observation and were used the methods of geological and geomorphological mapping, photo-interpretation and digital mapping. As a result we identify the most representative elements of the topography and we realized a digital map of landforms with geotouristic potential.

METHODOLOGY

The analysis of geomorphological heritage for geotourism development in Măcin Mountains was realized in two stages: the first stage consisted of field campaigns in which morphological information were accumulated and the second stage consisted in achieving the map of landforms with geotouristic potential from our study area.

During field campaigns were used both the lithological map of Măcin Mountains at a scale of 1:50.000 and the topographical maps at a scale of 1:25.000. In the field were identified the landforms with geotouristic potential and were mapped these landforms both through representation on the map sketches and by taking GPS points.

In the following stage (laboratory stage), by GIS analysis, we realized the digital elevation model of the Măcin Mountains using contour lines of topographical map sheets (at a scale of 1:25 000). On digital elevation model were added the morphological information obtained during the field campaigns like ridges, peaks, steep slopes, gorges and quarries.

Thus, by layers overlapping resulted a map that contains both the topography and morphology of Măcin Mountains. On the resulted map of our study area were represented

only those landforms that can be easily identified in the field and which can be valorized from the scientific, educational and touristic viewpoint. On the map were also represented settlemets, main access roads, adjacent morphological units etc.

The resulted map which highlights the areas with geotouristic potential represents the first step in achieving the geotouristic map of the Măcin Mountains.

GEOLOGICAL FEATURES

The geological structure of the Măcin Mountains is characterized by great diversity (both in terms of age and genesis) being resulted during the hercynic and chimeric orogenesis.

The main types of rocks that form the Măcin Mountains are crystalline schists, magmatic and sedimentary rocks. Mezometamorphic crystalline schists are indigenous to the Orliga Hill and the Megina Ridge being represented through amphibolites, gneiss, micaschists, quartz, carbonatic gneiss of Upper Proterozoic age, as well as feldspathic gneisses and micaceous tuffs. Epimetamorphic crystalline schists are represented by quartz, quartz and muscovite schists and they are indigenous to the Priopcea, Coşlugea, Boclugea, Piatra Râioasa peaks and Buceag Hill etc.

Crystalline schists and sedimentary rocks that form our study area are pierced by magmatic rocks like granite and granodiorite of Paleozoic age (Mutihac, 1990). Granites are characteristic to the Negoiu, Piatra Mare, David, Carapcea hills etc. but they also appear in the Pricopanului ridge, Moroianu and Greci peaks being represented by quartz diorite, grandiorite, porphyre etc. We can also find alkali granite that compose Iacobdeal and Piatra Roşie hills.

Among the sedimentary rocks we can distinguish tree main lithologic formations respectively Cerna, Bujoarele and Carapelit formations. The Cerna formation is of Silurian age and it is composed of quartz sandstones and clays on which limestones and marls overlap. The Cerna landform is characteristic between Priopcea and Bujoarele saddle. The Upper Devonian is represented through the Bujoarele formation being composed of clays, sandstones and limestones intercalations being indigenous to the Bujoarele and Igliţa hill. The Carapelit formation registers widths of over 1500 meters and is composed of arenites, gravels, volcanic rocks, sandstones and conglomerates from the Lower Carbonifer age (Ionesi, 1992)

A large spatial extension in the study area is represented by loess and quaternary loess deposits which can be found along the Danube banks, in depressions and valleys.

The geological diversity along with the age of the lithologic deposits individualized the Măcin Mountains within the territory of our country. The different resistance of rocks determined a spectacular morphology characterized by pyramidal peaks, structural steeps, ruiniform relief thus representing an area with real possibilities of practicing geotourism.

GEOMORPHOLOGICAL HERITAGE

The overall morphology of the study area is characterized by the alternance of prominent forms, oriented north-west – south-east with lower depression areas. The relief of the Măcin Mountains is composed of an esemble of long ridges, related with erosion witnesses, with altitudes lower than 500 meters. They are associated with lower areas generated by tectonics, weathering processes and erosion. Generally, slopes have stepped profiles and are fragmented by an underdevelopped torrential network.

The morphological characteristics of our study area are determined by the configuration of the complex geological structure. Within the Măcin Mountains we can identify two anticlines (Megina and Taiţa) as well as two synclines structures (Blasova - Sacar Dere and Greci - Carapelit). Highly inclined formations appear as peaks or ridges, well individualized in territory. Valleys and depressions are developed both on the axis and the flank of the syncline, morphological materialization consisting of longitudinal

valleys in both cases (Luncaviţa, Taiţa valleys). Along the anticlines and its flanks (White Valley etc) appear transverse valleys such as Greci and Cerna Valleys.

During the field campaigns we have found that interesting landforms from geotouristic viewpoint are determined by the petrographical composition. So, the geomorphological heritage assessment will be made through the petrographical relief viewpoint. The lithological variety of Măcin Mountains is reflected in the morphological diversity and spectacularity of landforms.

The relief formed on the crystalline schists has a spread extension in Măcin Mountains, being covered with continuous debris deposits and fine eluviale deposits. Crystalline schists are reflected in the study area through dominant landforms, imposing ridges, pyramidal peaks and steep slopes.

On the metamorphic rocks often appears steep slopes, heavily affected by weathering processes, which accumulates on their lower part debris deposits. From field observations we found that the petrographical relief developed on metamorphic rocks presents ruiniphorm aspects. Representative from this viewpoint are Priopcea and Dălchii ridges, Chervant peak, Piatra Cerna peak, etc. Also, the existence of older crystalline schists in the area is reflected by the rounded peaks with lower heights and peaks with the appearance of a dome being characteristic to the Orliga, Sărărie, Megina, Buceag hills.

Măcin Mountains geomorphological heritage is also represented by petrographical relief developed on magmato-volcanic rocks. Within the area of study this type of relief occupies almost half of the surface.

The morphology developped of granitic rocks is characterized by rounded peaks and erosion surfaces in which inselbergs like Piatra Roşie and Coşlugea often occurs. The different types of igneous rocks, especially of Paleozoic age have imposed in our study area spectacular and jagged ridges (Pricopan ridge), sharps peaks (Greci Massive), steep slopes (Buceag hills) etc. Also, they make themselves noticed in the landscape through high ridges being bounded by steep slopes, with level differences sometimes higher than 100 meters like Negoiu, Piatra Mare, David hills etc.

Spatial extention of granite rocks in the area also favored the expression of weathering processes. The resulted typical forms are granitic arenas, isolated spherical blocks and overcrowding spherical blocks, exfoliated rocks, towers, columns, walls, etc.

Debris deposits and rocks flow (Colina Dălchii) are also frequent in our study area, being resulted by the weathering processes. Likewise, the weathering of quartzitic rocks from Priopcea Ridge and granitic rocks of Pricopan Ridge have led to the formation of tafons with small dimensions.

Typical landscapes of weathered granitic rocks are common in Pricopan Ridge (between Cheia and Căprăriei peaks), Îmbulzita Hill, on the main ridge of Măcin Mountains (between Căpuşa and Cartalu peaks), Mangina and Curia valleys (in the north-east of Cerna locality), Cailău and Coşlugea peaks, Piatra Roşie massive, etc.

As a result of selective erosion resulted both isolated and grouped peaks, likewise flat plateaus with limited extension. This type of morphology is very spectacular and can be an important resource for development of hiking touristic trails.

Through field observations we found that the morphology developed on sedimentary rocks has a low visual impact due to both limited extensions of deposits and absence of prominent forms. In the following, we will only present those aspects that are important for geomorphological heritage. Paleozoic sedimentary formations like Bujoarele are represented by inselbergs in the form of domes. Representative of this type of morphology are Bujoarele Hills (Bujorul Românesc and Bujorul Bulgăresc) whose geotouristic interest is enhanced by the existence of Devonian age fossils. Limestones of the Muchea Lungă are represented through a fragmented ridge and gorges sector. The Carapelit formations are reflected in the area by gentle slopes and rounded peaks specific to the southern part of Măcin Mountains main ridge. Landscapes developped on loess

deposits has a narrower spread in Măcin Mountains, being represented by subsidence landforms. This landscapes doesn't represent a part of geomorphological heritage of the study area, therefore will not be detailed.

Besides the morphology developed on lithological formations, the morphology generated by anthropogenic activities is also a significant recovery with geotouristic potential. From Măcin canva are extracted magmatic rocks (granite, granodiorite and porphyre), metamorphic rocks (quartzite) and also sedimentary rocks (kaolinic clays).

Anthropogenic exploitation activities of construction rocks have led to the creation of an excavation morphology, the most prominent landforms being quarries. By field mapping we identified more than 100 quarries, most of them abandoned (Izvoarele, Sulucu, Piatra Râioasa, Priopcea, Cheia).

RESULTS AND DISCUSSIONS

The result of our research consists in achieving the digital map of landforms with geotouristic potential of Măcin Mountains using GIS analysis. On the map we have represented only spectacular landforms, respectively those areas where geomorphological heritage can be a resource for practicing geotourism. To get information on altitudes and accessibility to the interest points were represented on the resulted map, the land elevation by using color tints. On the digital map of landforms with geotouristic potential of the Măcin Mountins were represented the following elements with geotouristic potential: ridges, steep slopes, peaks, gorges, fossiliferous points and quarries. Depending on the landforms identified as being part of geomorphologic heritage, in the future will be proposed thematic touristic trails.

In following, we will present each morphological element identified and represented on the map and its geotouristic importance.

Ridges are one of those landforms that are part of geological and geomorhopological heritage. One of the most representative ridge with geotouristic potential from our study area is Pricopan Ridge (figure 1). This is due to granitic lithology, alpine morphology and due the resulting forms generated by weathering processes. Thus, Pricopan Ridge presents geotouristic interes due their morphology characterized by **pyramidal peaks** (Caramalău, Sulucu Mare, Sulucu Mic, Piatra Râioasa, Şerparu peaks) and **steep slopes** that strongly contrast with the lower limitrophe units. The geomorphological landscape is completed by unique ruiniphorm landforms represented by spherical blocks, towers, columns, etc. Ruiniphorm relief is distinguished by size, by its chaotically distribution and also by its occurrence frequency. Remarcable are spherical blocks that occurs both isolated and associated increasing the spectacularity of the landscape.

The **main ridge of the Măcin Mountains** represents another morphological element with geotouristic interest (figure 1). From landscape point of view the main ridge of Măcin Mountains is distinguished within territory by massiveness, amplitude differences imposed by the rock hardness level, etc. Thus, almost horizontal surfaces alternates with **steep slopes, structural sharps** and **peaks** well over 400 meters (Ţuţuiatu, Moroianu, Negoiu peaks). The occurrence frequency of morphology generated by weathering processes is lower than that of Pricopan Ridge, but the spectacularity of forms is similar. On the resulted map were also represented the jagged and intensely fragmentated ridge of Priopcea, Crapcea and the calcareous ridge of the Muchea Lungă. We have also noticed that the landscapes of these ridges presents real opportunities for practicing geotourism.

Likewise, representative for the development of geotourism in the Măcin Mountains are the **pyramidal** and **rocky peaks** that offer the possibility of observing the types of rocks that form the structure of the studied area: Sulucu Mare, Şerparu, Vraju, Piatra Râioasa, Ţuţuiatu, Chietrosul Mare, Călcata, Cheia, Priopcea, Carapelit, Chervant, Crapcea peaks etc (figure 1).

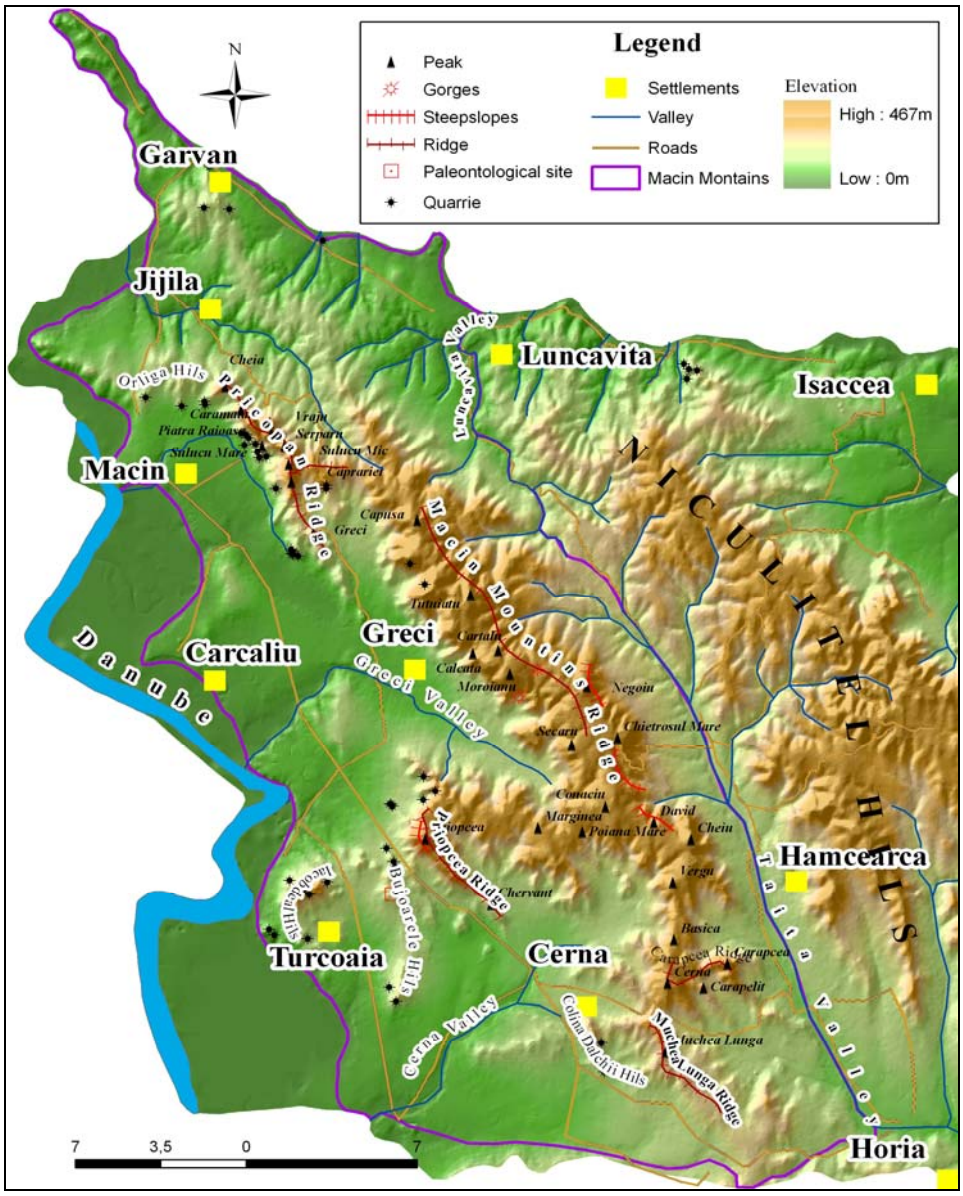

Figure.1 The digital map of landforms with geotouristic potential

Important from geotourist viewpoint are also the imposing **steep slopes**, with level differences of over 100 meters and vegetation devoid of the Negoiu, Piatra Mare, David hills, the western steep slope of Priopcea Peak, the western and south-western steep slope of Buceag Peak, the northern steep slope of Coşlugea Peak etc.

Another element of scientific interest represented on the digital map consists of **paleontological protected area** that is present within the Bujoarele Hill, where traces of fauna were discovered which testify the Devonian age of the lithological deposits. Likewise were represented the areas where the artificial oppenings occurred like quarries. The abandoned mining and quarries Greci, Pricopan, Turcoaia, Priopcea, Iglicioara, Cheia, Viţelaru, Orliga etc. present a particular importance for comprehension of Măcin Mountains evolution.

On the resulted map were also represented infrastructure elements (access roads, localities), the main hydrographic elements and limitrophe morphological units.

CONCLUSIONS

The paper aimed to analyze the geoheritage of Măcin Mountains for geotourism development in the area. In these sense were analyzed the geological and geomorphological features of our study area, were identified landforms which consists in geotouristic attractions and were represented their spatial distribution on the resulted digital map.

After field campaigns we have noticed that the petrographical relief is the main morphological element with geotouristic potential of Măcin Mountains. This is due its morphology developped on metamorphic and magmato – volcanic rocks represented by spectacular landforms (ridges, steep slopes, peaks, spherical blocks, towers, columns etc) which covers most of the mountainous area surface.

Anthropogenic landscape represented by abandoned quarries generated by exploatations of construction rocks consists, in our study area, in an important part of geomorphological heritage. Thus, quarries represents a particular interest for the geotourism development due their scientifical and educational role.

The existing fossiliferous point within the study area represents another advantage for geotourism development due its importance both for comprehension of Măcin Mountains evolution and understanding the Earth history.

Thus, the geological diversity along with the age of the lithologic deposits and the morphological variety individualized the Măcin Mountains within the territory of our country like an mountainous area with real possibilities of practicing geotourism.

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REFERENCES

Burcea Nela, (2008), *Dobrogea de Nord-Vest. Studiu geomorfologic,* Ed. Universitară, Bucureşti;

Carton A., Coratza P., Marchetti M., (2005), *Guidelines for geomorphological sites mapping: examples from Italy,* Géomorphologie, 3, 209 – 218;

Carton A., Cavallin A., Francavilla F., Mantovani F., Panizza M., Pellegrini G.G. and C. Tellini, (1994), *Ricerche ambientali per l'individuazione e la valutazione dei beni geomorfologici – metodi ed esempi*, in Il Quaternario 7, 365-372;

Doniţă N., Popescu A., Băjenaru B., (2007), *Cercetări asupra vegetaţiei Parcului Naţional "Munţii Măcinului"*, Bucureşti;

Grandgirard V., (1997), *Géomorphologie, protection de la nature et gestion du paysage*, Thèse de doctorat, Faculté des Sciences, Université de Fribourg ;

Hooke J. M, (1994), *Strategies for conserving and sustaining dynamic geomorphological sites*, in O'Halloran, D. et al., (eds) - Geological and landscape conservation – London, Geological Society, pp. 191-195;

Hose T., (2000), *European Geotourism – An overview of the promotion of geoconservation through interpretative provision, Symposium "Zukunftsfähiger Geotourismus – Ein Baustein zur lokalen Agenda 21"*, Bad Urach;

Hose T., (1996), *Geotourism, or can tourists become casual rock hounds?,* Geology on your doorstep : the role of urban geology in earth heritage conservation (eds.), London, Geological Society, pp. 207-228;
Ionesi, L., (1992), *Geologia unităţilor de platformă şi a orogenului nord - dobrogean,* Ed. Tehnică, Bucureşti;
Mutihac V., (1990), *Structura geologică a teritoriului României,* Ed. Tehnica, Bucureşti;
Newsome D., Dowling, R., (2006), *Geotourism – sustainability, impacts and management,* Elsevier, Oxford, Great Britan;
Panizza M., (2001), *Geomorphosites: concepts, methods and example of geomorphological survey*, in Chinese Science Bulletin 46, Suppl. vol. 4-6;
Panizza M, Piacente S., (1993), *Geomorphological assets evaluation*, in Zeitschrift für Geomorphologie, N.F., Suppl. Bd. 87, 13-18;
Panizza M., Piacente S., (2003), *Geomorfologia culturale*, Bologna, Ed. Pitagora;
Pralog, J. P., (2006), *Geotourisme et utilisation de sites naturels d'interet pour les sciences de la Terre: Les Regions de Crans-Montana-Sierre (Valais, Alpes suisses) et Chamonix-Mont Blanc (Haute-Savoie, Alpes francaise),* these de doctorat, Faculte des Geoscience et de l'Environnement, Universite de Lausanne;
Reynard E., (2009), *Geomorphosites,* eds. Reynard, E., Coratza Paola, Regolini - Bissig Geraldine, Verlag Dr. Friedrich, Munchen;
Reynard E., (2008), *Scientific research and tourist promotion of geomorphological heritage,* Geogr. Fis. Dinam. Quat., 31, 225 – 230 ;
Reynard E., (2005a), *Géomorphosites et paysages*, in Géomorphologie, Relief, processus, environnement, 3: 181-188;
Reynard E., (2005b), *Geomorphological sites, public policies and property rights. Conceptualization and examples from Switzerland*, in Il Quaternario 18, 1: 321-330;
Rivas, V., Rix, K., Frances, E., Cendrero, A., Brunsden, D., (1997), *Geomorphological indicators for environmental impact assessment: consumable and non-consumable geomorphological resources*, in Geomorphology 18: 169 182;
Robinson E. (1998), *Tourism in Geological landscapes,* Geology today, 14, pp. 151 – 153;
Stueve A. M., Cook S. D., Drew D., (2002), *The Geotourism study: Phase I excecutive study,* Travel Industry Association of America;

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