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Geodiversity Aspects of Sohodolului Valley from Southern Carpathians

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ABSTRACT

The aim of this paper is to discuss the geodiversity of an area from the perspective of its geology and geomorphology. For this, a geological map was redrawn and correlated to tectonics. A karst map was realised for the sector of Runcului Gorges. It is introduced the term out of sequence thrust sheets, which is more appropriate instead of the "allotohtonus covers". Those covers were described as being broken horses of Cerna Unit. Threats of geodiversity are also discussed. Geodiversity of Sohodolului Valley is representative among other regards through its tectonic arrangement without which karst couldn't have been developed at the same scale.

1. INTRODUCTION

In the southern Vâlcan Mountains, the Sohodolului Valley belongs to the catchment area of the Sohodol River, whose course stretches over a distance of 18 km south of the tip of Şigleul Mare to Izbucul Jaleş, north of Runcu and Răchiţi villages. Although along its entire length the Sohodolului Valley has the morphology of gorges, by which hence the generic name of Sohodolului Gorges, the actual gorges are separated by areas of metamorphic rocks in several distinct sectors: Runcului, Vidra and Pătrunsa Gorges. The Sohodolului Gorges Nature Reserve is a protected area with a schematic boundary corresponding to Runcului Gorges. The Vidra Gorges have the same status of a protected area as the Sohodolului Gorges Nature Reserve, but without any boundaries set up officially. The two nature reserves are part of the site of community importance (SCI) North of the Western Gorj, whose primary purpose is the protection of biodiversity. In terms of territorial administration, Sohodolului Valley is located in Runcu rural commune, in the Gorj county. From geological point of view, the Sohodolului Valley is located in the Lower Danubian Units of the Central South Carpathians. The geodiversity elements belong almost entirely to the Mesozoic sedimentary cover, which is mainly carbonatic and presents numerous karstic shapes and phenomena. Geodiversity is related with biodiversity, as an impact on the abiotic environment is felt equally by the biotic environment.

The Sohodolului Valley (Fig. 1) runs from north to south between the Şigleul Mare tip and Tismana – Stăneşti Depression, where the confluence of Runcu and Sohodol rivers results in the Jaleş River. Considering that the groundwater in karstic areas is powered from allogene areas, consisting of non-karstic rocks, and the limits of the two nature reserves in the area did not include the rest of the important elements for geodiversity, it is necessary to suggest a new delimitation, which would include a larger geosite. The relief of the Sohodolului Valley is dominated by the Gornoviţa erosion platform, which has two levels. The first level, between 400 and 700 m, has a slight gradient, while the second level, between 750 and 1100 m, has a sharp slope.

This geosite has a landscape value and also a geo-educational one, and represent the support for geotourism development. The existence of an area of biodiversity overlapped (Fig. 1) only over the current area of the site, doesn't provide adequate and necessary integration of geodiversity which is characteristic for Vâlcan Mountains area, and it will not lead to a proper recovery of the benefits that would result from the application of geotourism in the area. Geodiversity provides the necessary foundation of life, in general, of ecosystems and life forms that make up these ecosystems. Their existence and survival depends on bedrock, soil types and surface geological processes. Studies have shown that biodiversity is directly related to geodiversity, being dependent on it, and more than that, a larger number of elements of geodiversity ensure the existence of a more diversified biodiversity. If the given importance of biodiversity is higher than the interest for geodiversity conservation, this could become a threat to the protection of geodiversity elements because the purpose and role of geoconservation will be diminished.

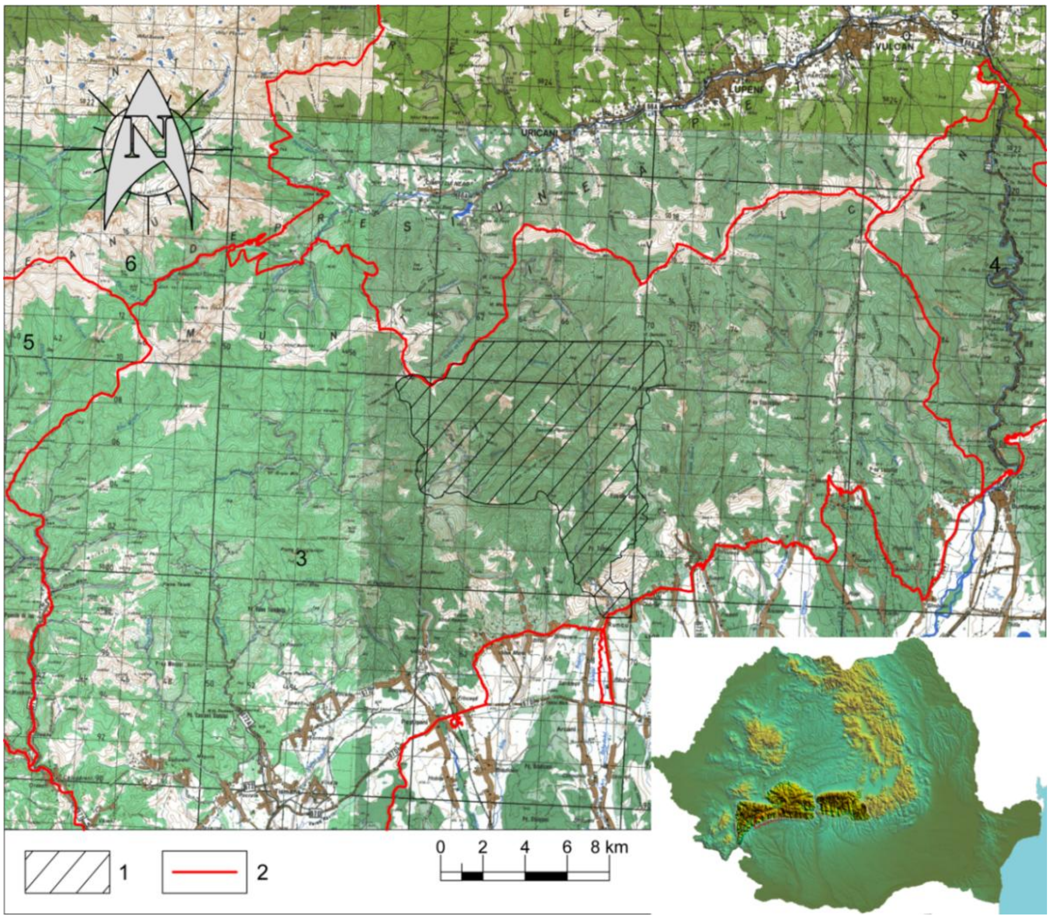

Figure 1. Topographic map of the Vâlcan Mountains, using topographic maps scale 1:100.000 of DTM 1996, sheets Deva, Petrosani, Orsova, Tg. Jiu. 1 – Study area; 2 – limits of natural protected areas; 3 – SCI North of the Western Gorj; 4 – Defielul Jiului National Park; 5 – Domogled-Valea Cernei National Park; 6 – SCI Țarcu Mountains.

Geodiversity should be understood under three main aspects. This classification comprises the geodiversity values identified by Gray (2004). The first one regards the rocks, minerals and fossils, as well as their tectonic features. The second aspect discusses the geomorphological component of geodiversity. The third one shows the links between geological diversity and natural protected areas, biodiversity and local communities (Roman, 2014a). Other aspects related to geodiversity are those of cultural heritage, with an emphasis to the evolution of researches during the last century, geoeducational methods and tools (Andrăşanu, 2009; Roman & Vasiliu, 2014 & 2015) and sustainable development of an area through geotourism (Roman, 2014b).

2. Methods

The geological map shown in Figure 2 was realised under GIS software by combining several methods with data obtained from GPS measurements and direct observations. The already published geological maps were rasterised, georeferenced and vectorised in Stereo '70 coordinates System. The geological map realised for the limits of Sohodolului Valley was interpolated with the geological cross sections prepared by Ştefãnescu (1988). The data obtained from measurements and those from direct observations were overlapped and juxtaposed to the existing materials. Improvements were made after some comparisons, which proved or invalidated the latest studies. GPS measurements were achieved for the geomorphological features, which were integrated in the karst map of Runcului Gorges (Fig. 3). The GPS measurements covered the all area of Runcului Gorges from east (Dealul Tufoaia) to west (Dealul Faţa Coastei) and from south (Răchiţi village) to north (Vidra Gorges) and were made in five sessions during the summer of 2015 by using a Leica GPS set up in ROMPOST (Romanian Position Determination System).

3. Geological and tectonic background of Sohodolului Valley

The Sohodolului Valley cuts through the sedimentary cover and crystalline basement of Lower Danubian Nappes on the southern slope of Vâlcan Mts (Fig. 2). The sedimentary cover includes mainly the stratified rocks of Jurassic and Cretaceous and belongs to Cerna Unit and Coşuştea Nappe. The metamorphic basement comprises the Lainici-Păiuş series, which is intruded by the Şuşiţa granite and belong to Vâlcan Unit (Ştefãnescu, 1988). Vâlcan Unit and Parâng Unit form the Lainici Nappe, which is in upper position to Schela Unit within the Alpine Units of Lower Danubian. Cerna Unit, Coşuştea Nappe, Lower Danubian Units and Upper Danubian Units form Danubian Complex, also known as the Marginal Dacides (Săndulescu, 1984). Danubian Complex and Moesian Platform represent a part of the European–Asian margin, which was separated from the Getic micro-continent by the Severin-

Ceahlău ocean basin. In the Getic depression, below the molasse of Moesian Platform, Coșuștea Nappe is lying tectonically over the formations of Cerna Unit and Severin Nappe lies over Coșuștea Nappe (Ștefãnescu, 1988). The crystalline schists of Getic Nappe are lying partially on Severin Nappe and on Coșuștea Nappe. On the southern slope of Vâlcan Mts, several „allochthonous covers" were separated between Obârșia Cloșani and Schela (Stan *et al*., 1978). These klippe are interpreted either as the result of a decollement before the emplacement of Getic Nappe (Săndulescu, 1984), or these covers were displaced due to the overthrust of Getic Nappe or/and Severin Nappe. In fact, these are out-of-sequence thrust sheets, which had a displacement over Coșuștea Nappe and after this overthrusted the Cerna Unit. According to Morley (1988), the out-of-sequence thrust sheets do not obey the foreland propagating or in-sequence pattern (deformation style). The same author claims that out-of-sequence thrust sheets should be considered common and part of the normal deformation sequence. The out-of-sequence thrust sheets of Sohodolului Valley are remnant of Cerna Unit broken up as horses. Even till recently these overthrust sheets were considered as nappes (Seghedi & Oaie, 2014). A nappe or a thrust sheet is defined as a rock unit, which had a displacement of tens of kilometres on a surface close to horizontal (Merle, 1998). In addition to this definition, as a difference between nappe and thrust sheet, there should be known that a nappe is detached from its roots, which are difficult to be identified, and that it overlays large areas.

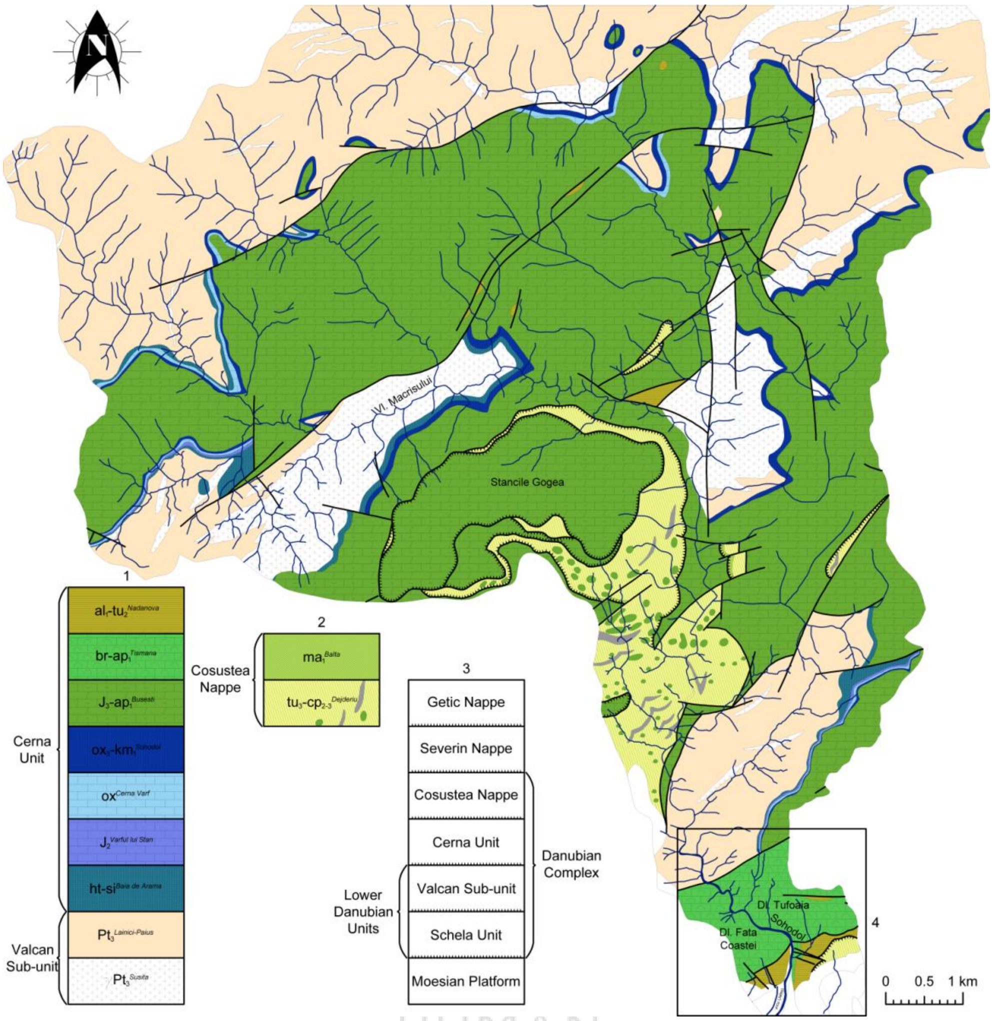

Figure 2. Geological map of Sohodolului Valley modified after Pop (1973, 1975), Stan *et al.* (1979) and according to Stănoiu (1996, 1997, 2000, 2008) and Pop et Bucur (2001) and Ștefănescu (1988). 1 – Schematic stratigraphic column of Cerna Unit and Vâlcan Subunit; 2 – Schematic stratigraphic column of Coșuștea Nappe; 3 – Schematic tectonic column of Lower Danubian Units. 4 – Runcului Gorges.

As in the studies of the last three decades, it was proved that Moesian Platform is overthrusted by Lower Daubian Units, the term "autochthonous" should be used with inverted commas for the Danubian complex and in order to show the tectonic relations with the Getic Nappe. The same thing should be done when we refer to the "allohtonous covers" or "Cerna Nappe" from the southern slope of Vâlcan Mts. The development on a long distance is not known for the so called "Cerna Nappe", and, also, the overlapping of these thrust sheets on the Cerna Unit and Coșuștea Nappe didn't highly altered the blocks involved. The term "overthrust sheets" is more appropriate for the out-of-sequence thrust sheets, rather than "nappe", which can be confusing as it shows no independent evolution. The out-of-sequence thrust sheets from Sohodolului Valley resulted through the propagation in-sequence thrusting (with time) of Getic Nappe and Severin Nappe from hinterland to foreland during the Laramide events. The stratigraphic successions of the Cerna Unit were cut upward relative to the direction of transport and, consequently, older rocks were placed over younger rocks. The continuous and closed branch-line of Coșuștea Nappe makes it entirely demarcated, while the branch-lines of the out-of-sequence thrust sheets from Stâncile Gogea are discontinuous and closed with a curled and isolated aspect. The geological constitution of the Sohodol Valley is the result of epeirogenic and orogenic movements. The rock types (limestones, sandstones and shales) of Cerna suggest passive continental margin deposits. The stratigraphic successions of Cerna unit contrasts with those of Coșuștea Nappe, which include sequences of greywacke, shales, tuffs and lavas (Seghedi & Oaie, 2014). The deposits of Cerna Unit suggest a shallow-water environment, while the deposits of Coșuștea Nappe are specific to deep marine environments (Seghedi & Oaie, 2014). The stratigraphic series, which were assigned to two distinct tectonic units, i.e. Cerna Unit (Stănoiu, 1997) and Coșuștea Nappe (Stănoiu, 1996), correspond to two paleogeographic zones, i.e. Cerna Zone and Coșuștea Zone (Codarcea, 1940). The deposits of Cerna Unit were formed during two sedimentary cycles, Liasic to Lower Cretaceous and Upper Cretaceous, and were described as Baia de Aramă formation, Vârful lui Stan formation, Cerna Vârf formation, Sohodol formation, Busești complex (Pocruia member, Sudoieșu member and Tismana member) and Nadanova formation (Stănoiu, 1997). The Hettangian-Sinemurian Baia de Aramă formation consists of siliciclastic (mainly arcosian) deposits in Gresten facies, of alluvial-lacustrine origin. Vârful lui Stan formation is represented by an echinoid limestone (Middle Jurassic). Cerna Vârf formation includes a calcarenite skeletal and peloidal, often dolomitized limestones (Oxfordian). Sohodol formation consists of a regressive alluvial-lacustrine siliciclastic red deposits (Upper Oxfordian-Lower Kimmeridgian). Busești complex is represented by calcarenite to calcilutite limestones frequently dolomitized (Kimmeridgian-Tithonian) – Pocruia member, and bioclastic oolitic limestone (Early Valanginian) – Sudoieșu member. Tismana member, part of Busești complex, is represented by limestones in Urgonian facies (Barremian-Lower Aptian). Nadanova formation comprises argillaceous limestone (Upper Albian-Middle Turonian).

The Coșuștea Nappe from the Sohodolului Valley was ascribed to two formations – Dejderiu and Balta (Stănoiu, 1996). The Dejderiu formation (Upper Turonian-Middle to Upper

Campanian) includes greywackes interbedded with siltstones and argillites. Balta formation (Lower Maastrichtian) consists of siliciclastic sandstones and gritty micro conglomerates.

4. Karst geomorphology of Runcului Gorges

Sohodol is a term derived from the the Old-Slavonic word “Sohodolŭ” meaning disappearing river or dry valley. “Sohodols” are temporary (largely seasonal), shallow, groundwater-fed valleys surrounded by a rocky rim and a bed with ponors, through which the water is replenished and drained in an underground complex of channels. They are strongly associated with zones of higher permeability in the aquifer in southern slope of Vâlcan Mts. (Iurkiewicz & Magin, 1994). Some good examples in the Vâlcan Mts. include sites such as Șușița Seacă Valley, Cartiu, Pârgavului Valley, just to mention a few of them.

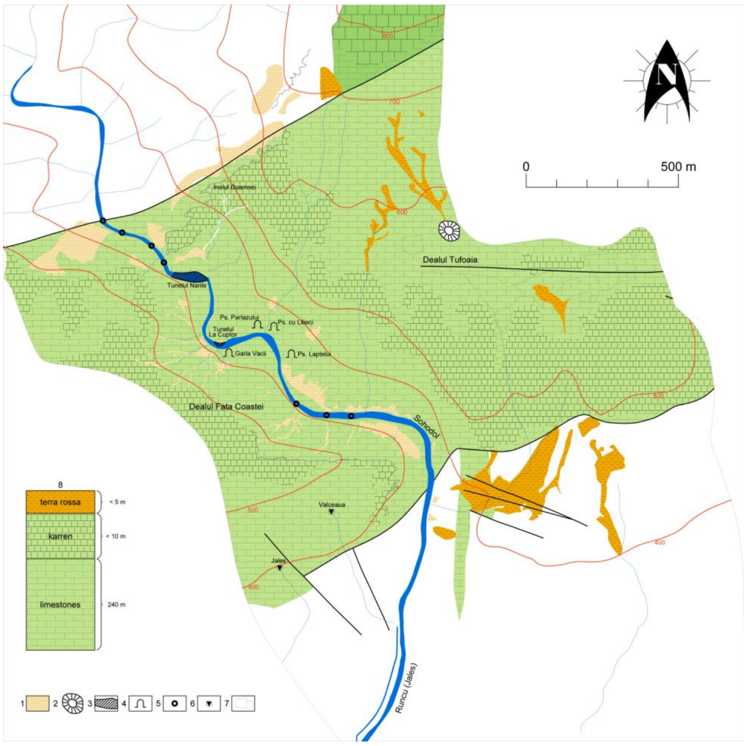

Figure 3. Karst map of Runcului Gorges. 1 – scree talus; 2 – dolina; 3 – tunnel; 3 – cave; 5 – ponor; 6 – spring; 7 – marching camps; 8 – schematic column.

A characteristic feature of Runcului Gorges which is related to karst (Fig. 3) is represented by scree talus deposits, largely a product of glacial erosion and subsequent soil loss. These deposits can be separated in two main scree talus types, depending on the inclination degree of exposed slopes and the active weathering process of limestone: large proluvial cones, which are less fed with debris, and incipient proluvial cones, which are developing on erosional stair-stepped terraces. The main source of these "stone rivers" is the unearthed karren, which was discovered from the already washed red soil (terra rossa).

These carbonate terrenes are susceptible to solution, which can eventually expose vertical lines of weakness in the limestone to form characteristic block-grike systems. The blocks or un-dissected rock fragments range from a few square centimetres to over 50 cm^2, with most ranging between 0.2 and 0.3 m^2. The grikes, or crevices that dissect them, are usually less than one meter deep and 3 to 15 centimetres wide, but extend down to several meters in exposed ridge zones. The block-grike system is developed by corrosive drainage along joints and cracks in the limestone. Karren terrenes, also known as lapies fields, are widespread on Runcului Gorges, in Dealul Tufoaia and Dealul Fața Coastei, and on Măcrișului Valley. Other occurrences are known in Piatra Boroșteni, Padina Crovurilor, Șesul Pietrei and În Padină, just to enumerate the karstic areas of Pargavului Valley, few kilometres west of Sohodolului Valley. The most common type of lapies which occurs on Sohodolului Valley are sharp-ridged grooves, also known as rillenkarren, and their larger, elongated relatives, rinnenkarren. The rounded runnells, called rundkarren, outcrops from terra rossa cover as well. With no preferences for the type of limestone, there can be observed the solutional hollows (kamenitzas). Secondary to rinnenkarst, there are developed some bigger holes with a horseshoe shaped stepped structures categorised as trittkarren. Randomly there can be seen the kluftkarren, a type of lapies characterised by deep cleft-like ruts. Not ultimately, the main feature of fractured and folded limestone from the slopes of Runcului Gorges, is the flachkarren, which is the evidence of a mature karst. Karren's shapes depend on the existent or former soil cover. The exposed karren features, that have a subaerial development, are much more fretted and rough. Rillenkarren is an example. The rounded and smooth shapes are formed under the acid soil cover. The rundkarren are brought to surface along the gullies, by the land subsidence of terra rossa.

On Runcului Gorges, few caves, tunnels and numerous cavities are known. The most important cave is Gârla Vacii, which is in hydrogeological relation, as measured by V. Sencu and B. Driga in 1965 (Sencu, 1972). The newer studies of Iurkiewicz & Magin (1994) were to confirm the underground relations. Two karstic tunnels are also known, one 57 m and the other 76 m long. Both Gârla Vacii cave and Nările tunnels are located on the right side of Runcului Gorges.

5. Geodiversity threats and national geoconservation context

The link between geodiversity and natural protected areas are well defined through the Geoparks recognised by the European Geoparks Network and Global Network of National Geoparks under the auspices of UNESCO. A Geopark corresponds generally to the definition of Natural Park and a geosite is similar to a nature reserve. While a Geopark refers to a bigger area, which comprises a natural zone and an anthropic one, a geosite is a natural surface delimited inside or outside of an existing National or Natural Park (*, 2007; **,2000). A Geopark si accredited and supervised only by the already mentioned organism, but the evaluations and establishments for new geosites, which are not found inside the limits of a Geopark, are made by The European Association for the Conservation of the Geological Heritage, shortly named ProGEO. In Romania, although the discussion is taken for four geoparks, only one is authorised (Hațeg Country Dinosaurs Geopark), for the other three no admission being known. The Natural Park Platoul Mehedinți is popularized as Platoul Mehedinți Geopark (Fig. 1), even though is not even listed for admission by European Geoparks Network. Another protected area, which is known for its submitted request is Buzău Land Geopark. It should be noted that as a consequence for the accreditation of a new area as Geopark, the governments offers the status of Natural Park to the same surface (***, 2007).

The use of the “Geopark” name for parks that do not have this status may lead to the diminution of the significance of the conservation of these territories in public consciousness. Geoparks are regularly monitored and evaluated by UNESCO's designated bodies. Any violation of established regulations and/or lack of promotion without the involvement of the local community lead to penalties. This is a threat to geodiversity. Geoparks and geosites are frames for protecting geodiversity according to the good practices of geoconservation. While the management of natural protected areas designed for biodiversity proved to be inappropriate or harmful for geodiversity, the conservation of geological diversity needs a specific approach. Issues concerning the geo conservationists regard that remarkable elements of geodiversity are at least theoretically well conserved inside a Natural or National Park but easily threatened in areas recognized only as sites of community importance. The management of such areas should comprise a specific interest for the geologic diversity, as the existence of biotic medium is strongly linked to it. The natural protected areas of the Natura 2000 network were established in order to bring conservancy policies and to prevent damaging activities such as logging, hunting and poaching. None of these goals seems to be respected on the southern slope of Vâlcan Mts. and this is a threat to geodiversity too. Deforestation caused habitat loss and surface run-off and flooding in Vidra and Pătrunsa Gorges. Also, deforestation should be prohibited in a wetland such as Sohodolului Valley on its entire length, as the waters of Sohodol are a capture water source. Deforestation removes the nutrients from the ecosystem and reduces evapotranspiration and all of those adverse effects are felt quickly in a karstic area. The non-involvement or disinterest of geologists in the delimitation and conservation of areas with special geology is also a threat to geodiversity. Geologists generally have not spent very much effort or time studying natural areas for geoconservation reasons because they

• Do not typically contain natural resources of high economic value.

• Have only become important in the last 10-15 years with the onset of significant regulations imposed by EU and UNESCO.

• Are overlapped by biodiversity protected areas and National Parks and that might appear to be enough.

• Are difficult to delimitate because many desirable locations are on private or communal property.

• Have been disturbed and modified due to development of forest logging and quarries.

• Are typically located on large tectonic regions and were considered too small and not as scientifically valuable as the geophysical investigation carried on long distances.

• Are very complex like any other locations to which some of the geologists dedicated all their life.

• Involve issues that may take years or decades to be noticed by the general or local community as compared with other more sudden activities of geological interest.

Links between geodiversity and local communities were mentioned and underlined by geographers, geologists and anthropologists. According to Conea (1932), the locals use dynamite for limestone exploitation from Runcului Gorges. Munteanu-Murgoci (1898) deplores the lack of protection of karst features, while Bernea (2007) gives details about the spiritual significance of stones such as chiselled crosses and ritual pebbles. Also, the GPS measurements made on Dealul Tufoaia were taking in considerations some ruins, which are believed by the locals to be the relics of marching camp walls built of limestone blocks. Their age might be attributed to the Roman conquest of Dacia, although there are some stories that place them in the time of the First World War.

The last paragraph is an argument that an area of ethnographic and historical value may overlap with the natural area, whose preservation must also take into account the links between landscape and society. Good protection of geodiversity and biodiversity also ensures the preservation of cultural heritage that has been discovered and more or less researched.

6. CONCLUSIONS

This paper presents an assessment of Sohodolului Valley geodiversity under several aspects. The first one regards the geology and tectonic setting and presents a geologic map redrawn on a new topographic base highlighting details about the relations between Coșuștea Nappe and Cerna Unit. The karstic map of Runcului Gorges, one of the most important parts of Sohodolului Valley, is the contribution of this paper from geomorphological point of view. The karst and geomorphologic features (scree talus, terra rossa, karren) were the object of GPS measurements carried out on the entire surface of the gorges. Threats to geodiversity were discussed, as well as the need of an adequate management and conservation, as the areas established for the protection of biodiversity show more threats than security.

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