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ROCK MASS RATING IN BÜKK MTS., N HUNGARY BASED ON PETROPHYSICAL PARAMETERS AND PARTING CONDITIONS

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Abstract
In the region of Bánkút and Ómassa, Bükk Mountains the strength of the rocks of 29 outcrops was studied based on Rock Mass Rating (RMR). Strength of the rock masses showed no correlation with the material of the Formations they exposed, however, correlation between the orientation of valleys and ridges and the location of the most deformed rocks and thus that of the rock masses with poorest qualification could be observed.

Keywords: unconfined compressive strength, parting, rock mass rating, Bükk Mts.

1. Introduction

Studying the relationship between geological conditions and the geomorphology of a landscape has always been in the focus of geomorphology research (Gerasimov 1946; Birot 1958; Twidale 1971). The relationship between structural and morphological elements was analysed on the basis of morphotectonic studies (Scheidegger 1980, 2001; McIntosh 2014) while others considered the relationship between the strength of rocks and slope conditions responsible for forming the morphology of an area (Selby 1980; Telbisz 1999; Püspöki et al. 2005; Demeter – Szabó 2008a, b). This latter group of research used generally one single parameter, unconfined compressive strength (UCS) to describe the strength of the geological medium forming an area. In the present paper an attempt is made to use rock strength determined on the basis of several parameters in studying the relationship between geology and morphology in a study area.

Parameters applied for determining rock strength are taken from engineering practice where they have been applied primarily for artificial rocks, drill cores and artificial establishments to be built in natural rock masses (road and railway cuts, tunnels, etc.). The authors believe that the strength of rocks forming the geological setting of an area could be described in a much more complex way using six parameters than on the basis of a single – frequently measured in laboratory – parameter.

2. Material and methods

Relationship between the geology and morphology of the study area located in the Bükk Mountains, North Hungary (Fig. 1) is studied on the basis of rating the rock mass of 29 outcrops (Table 1).

The study area located in and around the Garadna Valley between the Big and Little Plateaus is composed of numerous Palaeozoic

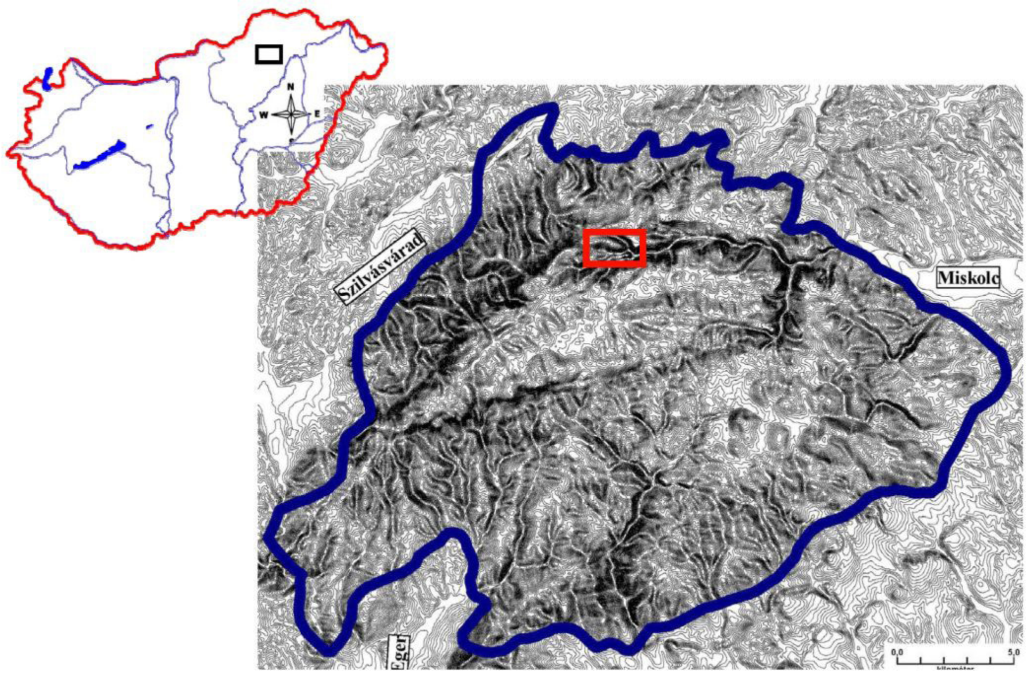

Fig. 1. Location of the study area in Bükk Mts., N Hungary

and Mesozoic formations. The limestone and dolomite rocks of 5 of these formations were involved in the field measurements (Table 2).

Studied outcrops were evaluated on the basis of 6 parameters in the Rock Mass Rating system (Table 1) established by Bieniawski (1973) and further developed by (Gálos – Vásárhelyi 2006). Unconfined compressive strength, RQD values and the distance between parting surfaces were directly measured in the outcrops. State of parting surfaces, presence of water and the direction of parting surfaces were evaluated by field inspection.

In order to estimate *unconfined compressive strength* in the field surface hardness measurements were performed using a Proceq Silverschmidt N type Schmidt hammer. Outcrops were divided into sections and 10 measurements were made in each section. Averages of the sections were also averaged for the entire outcrop.

Volume of parting was determined based on Rock Quality Designation (RQD) value developed by Deere (1969) initially for measuring cores. According to the formula below, the ratio of continuous sections longer than 10 cm (without parting) is calculated compared to the total length of the rock mass: where h10= length of the continuous rock sections longer than 10 cm without parting, h= length of the total studied outcrop section.

$$RQD = \frac{\Sigma h10}{h} 100[\%]$$

Both horizontal and vertical RQD values were measured and averaged.

Distance of partings was measured in every section of the outcrops and all sections were given a score in points that were averaged for the whole outcrop.

State of parting surfaces, the *presence of water* and the *orientation of partings* were evaluated for each section of the outcrops and for the whole outcrop as well.

Regarding the score of each parameter in the original RMR system a total of 100 points could be scored by one rock mass. In the system presented here, however, the maximum score is 120 points due to the

Table 1. Rock Mass Rating (RMR) system modified after Török (2007)

UCS (MPa)	*>250*	*100-250*	*50-100*	*25-50*	*5-25*	*1-5*	*<1*
score	15	12	7	4	2	1	0
Horizontal RQD (%)	*90-100*	*75-90*	*50-75*	*25-50*	*<50*		
score	20	17	13	8	3		
Vertical RQD (%)	*90-100*	*75-90*	*50-75*	*25-50*	*<50*		
score	20	17	13	8	3		
Distance between partings (m)	*>2*	*0.6-2*	*0.2-0.6*	*0.06-0.2*	*<0.06*		
score	20	15	10	8	5		
State of parting surface	*Very rugged, not continuous, fresh rock*	*Slightly rugged, open <1mm, slightly weathered*	*Slightly rugged, open <1mm, strongly weathered*	*Fault, open 1-5mm*	*Clay filled fault plane, open >5mm*		
score	30	25	20	10	0		
presence or water on parting surface	*dry*	*moist*	*wet*	*drops of water*	*flowing water*		
score	15	10	7	4	0		
Parting orientation	*very good*	*good*	*adequate*	*bad*	*very bad*		
score	0	-2	-7	-15	-25		
Class of rock mass	I	II	III	IV	V		
Qualification	very good	good	satisfactory	poor	very poor		
Rock Mass Rating	120-95	95-70	70-45	45-20	<20		

addition of horizontal RQD values therefore the original assessment categories have been slightly modified as well (Table 1).

Petrographic description of the rock samples is given on the basis of microscopic analysis performed using a Nikon Microphot SA research microscope in the laboratory of the Department of Mineralogy and Geology, University of Debrecen.

3. Results and discussion

Strength of natural rock masses in 29 outcrops has been studied in the Garadna Valley in the Bükk Mts. In the modified RMR system outcrops scored between 16 and 67 points (Table 2).

Table 2 shows that the outcrops are composed mainly of limestone and dolomite that are regarded to be very good considering rock strength in the literature. Rock masses with best score are exposed far from each other and their material is classified into different formations. Their score of 67 and 65 points classify them into the top part of the satisfactory category (category III). Almost 60% of the outcrops received this satisfactory qualification while almost 40% of them were qualified as poor (category IV). One outcrop (Borovnyák 18) was qualified very poor (category V). Unfortunately no outcrops scored higher than satisfactory qualification.

Based on literature data regarding the Bükk Mountains, the average unconfined compressive strength of Palaeozoic and Mesozoic carbonates is around 98 MPa (Püspöki et al. 2005) thus high strength was expected regarding the rocks of the studied outcrops. In contrast no outcrops scored

Table 2. Rock Mass Rating (RMR) system modified after Török (2007)

Outcrop name	*Rock Formation*	*RMR score*	*Rock of outcrop*	*Outcrop name*	*Rock Formation*	*RMR score*	*Rock of outcrop*
Mályinka 3A	Mályinkai Fm.	52	Limestone	Borovnyák 21	Ablakoskővölgyi Fm.	31	Limestone
Mályinka 3B	Mályinkai Fm.	67	Limestone	Borovnyák 22	Ablakoskővölgyi Fm.	53	Limestone
Mályinka 4	Mályinkai Fm.	58	Limestone	Borovnyák 23	Gerennavári Mészkő Fm	65	Limestone
Borovnyák 2	Ablakoskővölgyi Fm.	55	Limestone	Borovnyák 24	Ablakoskővölgyi Fm.	56,5	Limestone
Borovnyák 2a	Ablakoskővölgyi Fm.	58	Limestone	Bánkút 1	Nagyvisnyói Mészkő Fm.	41	Limestone
Borovnyák 5	Ablakoskővölgyi Fm.	38	Limestone	Bánkút 2	Nagyvisnyói Mészkő Fm.	50	Limestone
Borovnyák 7	Ablakoskővölgyi Fm.	53	Limestone	Ómassa 1	Ablakoskővölgyi Fm.	28	Limestone
Borovnyák 8	Ablakoskővölgyi Fm.	53	Limestone	Ómassa 2	Gerennavári Mészkő Fm	46	Limestone
Borovnyák 12	Ablakoskővölgyi Fm.	56	Limestone	Ómassa 3	Gerennavári Mészkő Fm	36	Limestone
Borovnyák 14	Ablakoskővölgyi Fm.	32	Limestone	Ómassa 4	Gerennavári Mészkő Fm	48	Limestone
Borovnyák 15	Ablakoskővölgyi Fm.	31	Limestone	Ómassa 5	Gerennavári Mészkő Fm	35	Limestone
Borovnyák 17	Hámori dolomit Fm.	43	Dolomite	Ómassa 6	Gerennavári Mészkő Fm	54	Limestone
Borovnyák 18	Hámori dolomit Fm.	16	Dolomite	Ómassa village 1	Hámori dolomit Fm.	48	Dolomite
Borovnyák 19	Hámori dolomit Fm.	38	Dolomite	Ómassa village 2	Hámori dolomit Fm.	47	Dolomite
Borovnyák 20	Hámori dolomit Fm.	43	Dolomite				

better than satisfactory. This can be explained on the one hand by much smaller in situ UCS values for the rocks of the outcrops and on the other hand by the high ratio of partings in the rock mass reducing its rock strength.

Carbonates in the studied outcrops suffered from deformation caused by several stress fields (Fodor 1988; Csontos 1999; Kozák et al. 2001; Németh 2005; McIntosh 2014). Signs of strong deformation are clearly visible in both the outcrops and the texture of the rocks revealed by microscopic analyses (Pelikán 2005). Strong shearing is indicated by sigma clasts enclosed in the orientated texture (Fig. 2) of a rock sample. Twin lamina of calcite crystals (Fig. 3) also indicate that pressure was applied on the rock while calcite veins crossing each other and the orientated texture suggest that multiple stress fields deformed the rock sample.

Strong deformation with multiple stages and directions increases the number of partings in the rock mass and reduces UCS. As a result "good" qualification was not achieved by either rock masses of the studied outcrops. Even is the most compact rock masses appears a large fault with clayey slickenside (Fig. 4) or a joint (Fig. 5).

Table 2 reveals that rock masses with best qualification belong not to one formation. Similarly outcrops with poorest qualification expose the rock masses of different formations. Based on the results the RMR qualification of rock masses is not dependent on formations. RMR values vary in wide range even within one rock formation. For example, one outcrop exposing Hámor Dolomite Formation scored 16 points while another scored 48 points.

Similarly rock masses of Ablakoskővölgy Formation are exposed in outcrops scoring 31 points and 58 points as well. Therefore

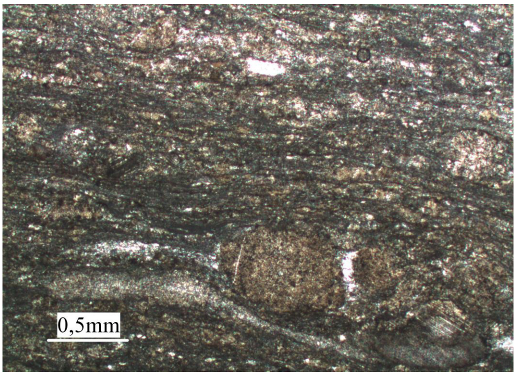

Fig. 2. Sigma clasts in strongly orientated texture in the rocks of Ablakoskővölgy Formation (II N)

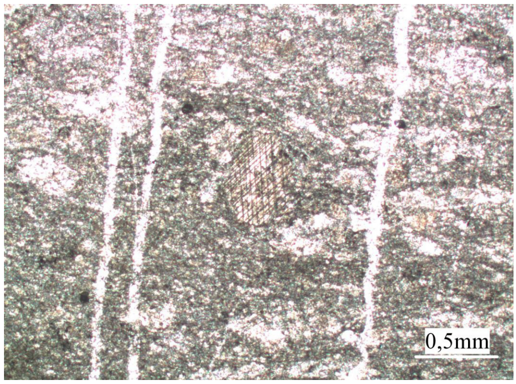

Fig. 3. Calcite crystal with twin lamina and calcite filled veins crossing the orientated texture in Gerennavár Limestone near Ómassa (II N)

RMR qualification of outcrops depends on local conditions, however, it shows spatial regularities. In Figure 6 rock masses in areas marked by green rectangles and circle (marked as 1, 2 and 3) are stable having relatively high strength in the study area and qualified as satisfactory. In contrast, areas enclosed by red rectangles (marked as 4 and 5) and two outcrops (Borovnyák 18, Ómassa-1) have the poorest RMR qualification. Areas with best qualification are located in the northern edge (area marked as 1) and southern margin (marked as 3) of Nyárjú Hill and along the ridge trending NW–SE running into Ómassa. Areas and outcrops with poorest qualification can be found in the Garadna Valley (and in its northern continuation, the Száraz Valley) at places where tributary valleys join the main valley trending E–W (area marked as 4 and outcrop Ómassa-1) or where particularly weak zones with strongly fractured, deformation and brecciated rocks occur (outcrop Borovnyák 18 and the area marked as 5).

Both the Garadna Valley and the Száraz Valley were formed along major fractures and the smaller tributary valleys also represent fractures. Rocks are most deformed and fractured at places where fractures and joints cross each other (Kozák et al. 2001; McIntosh 2014). Outcrop Borovnyák 18 with the poorest rock mass is located at the eastern termination of the main mass of Nyárjú Hill (at the intersection of the N-S trending Angyal Valley and the Száraz Valley) where it meets the ridge of Borovnyák-tető running towards NE. In the transition zone between the two ridges at the intersection of two structural lines represented by two valleys the rock mass with strongest deformation and greatest volume of parting and also with small UCS and thus with very small RMR value (Table 2) can be found (Fig. 6).


Fig. 4. Clay filled fault in Hámor Dolomite outcrop near Ómassa

Fig. 5. Rock mass with united appearance near Bánkút (Nagyvisnyó Limestone Formation)

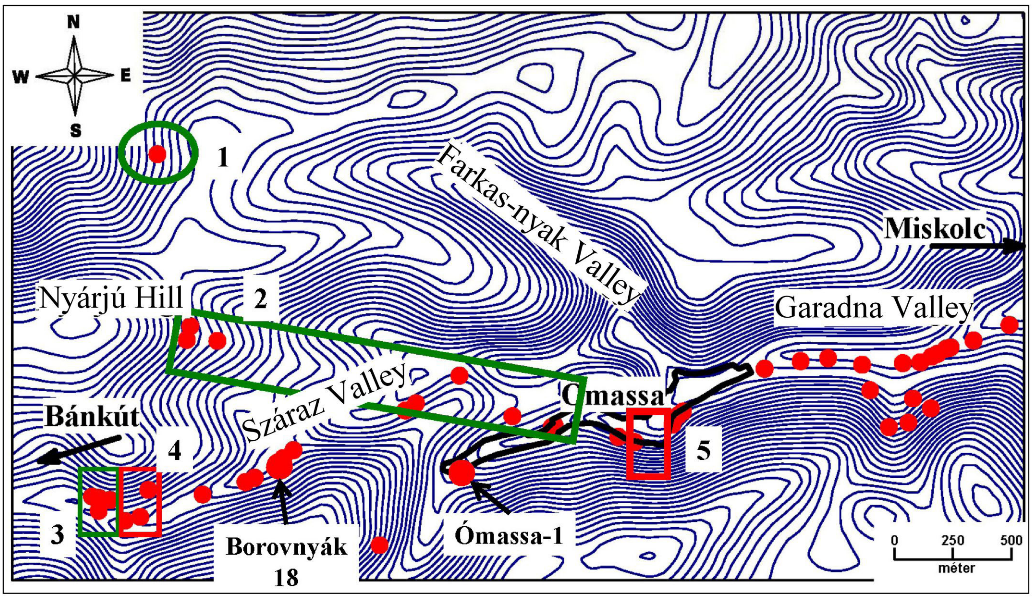

Fig. 6. Spatial distribution of rock mass having higher and smaller strength in the valley head of Garadna Valley in the vicinity of Bánkút and Ómassa

Outcrop Ómassa-1 is located at the intersection of the Garadna Valley and one of its tributary valleys (Fig. 6), i.e. at the intersection of two joints where the rock mass is strongly fractured and brecciated thus showing high volume of partings.

Area 5 is found on a steep valley side where ravines developed. Two springs also appear in this area that drive water down into the Garadna Valley every now and again. Opposite this zone of weakness on the northern side of Ómassa Farkas-nyak Valley joins the Garadna Valley suggesting that this area is also located at the intersection of two major structural lines.

4. Conclusions

Based on the RMR evaluation of 29 outcrops in the Bükk Mts. the following conclusions can be made:

- The 6 parameters including UCS, RQD value, parting distances, state of parting surfaces, presence of water and the orientation of partings can be applied successfully in describing the strength of natural rock mass;
- RMR scores of outcrops do not depend on the formation the rocks of which are exposed by the outcrop;
- RMR qualification shows relationship with morphology. Outcrops with highest RMR score are located in united morphological elements composed of compact and less deformed rock mass. Outcrops with poorest qualification are located in zones of strongest deformation, generally at the intersection of major fractures or structural lines occurring in the form of intersecting valleys in the morphology.

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