MONITORING OF WEATHERING PROCESS IN GRANITOID AND METAMORPHIC ROCKS

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Abstract: Direct and indirect harms caused by undesirable weathering processes in some regions of Slovakia may become a spotlight within the research and evaluation of geologic factors of the environment.
Monitoring of weathering process is a constituent of a "Partial Monitoring System of Environment of Slovak Republic" (Klukanová, Liščák, 1997). The authors present results achieved by innovating methods in granitoid and metamorphic rocks.

1 INTRODUCTION

All rocks of the Earth surface are exposed to natural weathering processes, which lead to their gradual decomposition and decay. Undergoing the anthropogenic impact, within the rock masses with a low resistance against weathering, the processes of decomposition and decay can be accelerated. Chemical alterations of minerals distinctly influence the mechanical properties of rocks, therefore, it is necessary to study also the chemical alterations in rocks and/or in minerals which differ in their degree of weathering and to correlate these chemical alterations with the change in their mechanical properties.

This will enable:

- to enhance the knowledge about the lawfulness of weathering phenomenon development
- to apply the acquired knowledge in prediction of possible changes of the geologic environment due to man-made impacts
- a reasonable utilisation of the environment and its protection against unfavourable human activities.

The data gained by systematic monitoring of weathering processes will provide information for oriented anthropogenic impacts into environment in order to reach the minimum degradation of rock masses to prevent the slope stability jeopardising and to protect engineering structures.

2 THE ESSENTIAL METHODOLOGIC APPROACHES

We bore upon selection of methods suitable for the monitoring of weathering processes. We favoured a combination of several simple field and laboratory methods and modest measuring equipment. We subjected the selection of particular methods to three basic tasks, which the monitoring of weathering processes fixates:

1. determination of a weathering degree and a delineation of weathering zones
2. monitoring of the weathering dynamics (its rapidity)
3. classification of rock resistance to weathering, i.e. a prognosis of a weathering process development.

Determination of a weathering degree and a delineation of weathering zones we can estimate as a fiducial line for monitoring of weathering processes. To assess a starting state for weathering processes we used methods of quantitative and qualitative estimation of the rock mass and rock material. Laboratory methods were focused on determination of the physico-mechanical properties of rocks and their weathered products.

Monitoring of the rapidity of weathering processes, i.e. a change of a weathering degree in time is an overriding interest of monitoring. A time needed for registration of measurable changes differs for various rock types. The attention was devoted mainly to semisolid rocks, because they use to weather relatively quickly and their monitoring is for engineering of essential importance.

Interesting results were achieved using a micronivelationmeter, which was designed and constructed by the author of this paper, Mrs. Jánová (Jánová – Liščák, 1998). The device measures micronivelation changes on the outcrop surface, which are caused by gradual weathering and denudation of rock material. The device consists of duralumin beam with holes, two steel pins fixed into massif, measuring rod and Vernier depth gauge (enabling accuracy of measurement up to 0,02mm). In fresh semisolid or altered solid rocks it is possible to get reliable results in 2 – 3 years. Measurements could be carried out in arbitrary intervals. Fixed steel pins serve for measurements in the exactly same points of rock massif. Profiles could be oriented in different directions, crossing schistosity and bedding at various angles. The scheme of a device is on Fig.1.

Fig. 1: Scheme of micronivelationmeter measurement

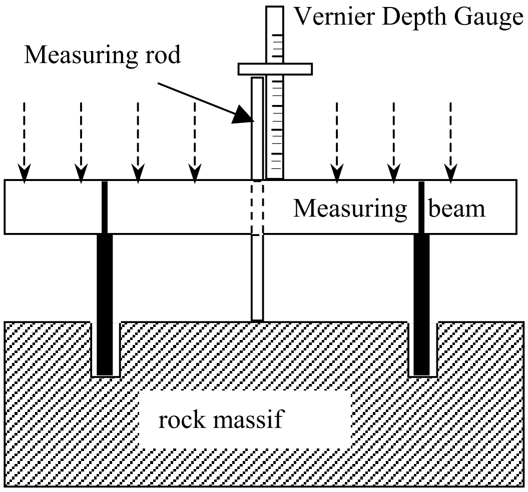
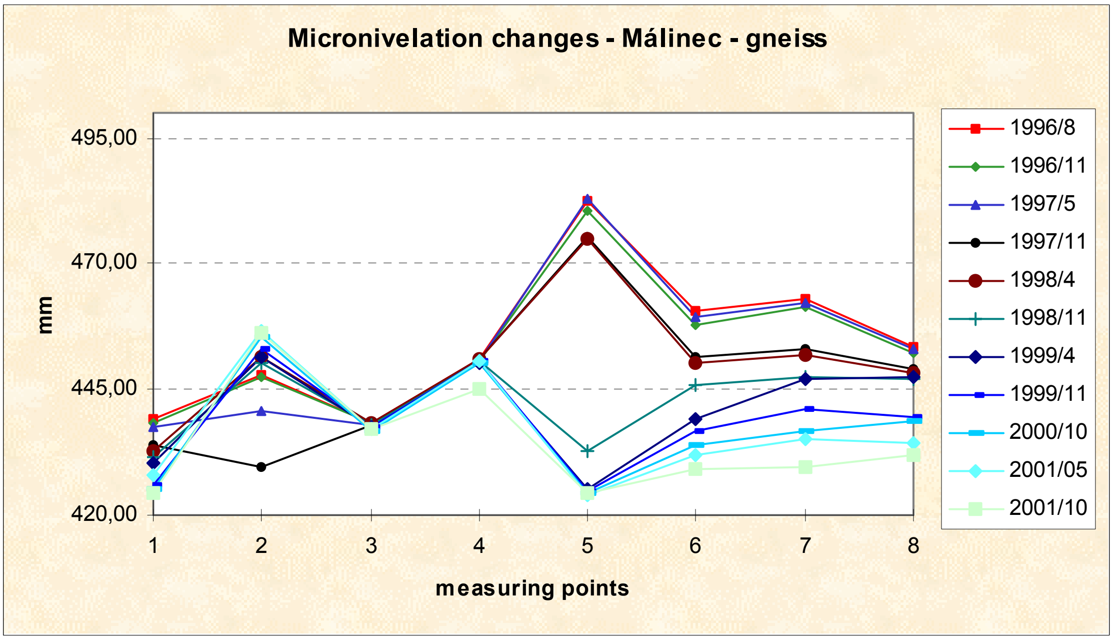


Fig.2 Micronivelation changes in gneiss at the Málinec site



Laboratory methods were oriented on the determination of physico-mechanical properties of rocks monitored, their mineralogical composition and accelerated laboratory tests simulating hyper-geneous conditions.
For the first time within the subsystem we tried to compare the physical and mechanical properties of the weathering profile at the Pezinská Baba site (gneiss) with isotope the $^{87}Sr/^{86}Sr$ ratio. The monitoring of this site was established in 2000. To prepare the samples for isotope analysis, 3-5 kg samples were collected from weathered profile and stored in low-density polyethylene (LDPE) bags. Regolith sample were dried at 50 ^{o}C and sieved through 0.25 mm mesh. Wolfram-carbide jaws were used during samples crushing. 100 g aliquots were taken by automatic splitter and then powdered. Oxides content, Rb and Sr concentration were determined by X-ray fluorescence method. For Sr isotope analysis, 0.1 g of sample were digested using HF and HNO_3 (4:1,Suprapure® grade) in Teflon© crucibles and taken to dryness. Samples were then digested in 6 M HCl and centrifuged at 3500 rpm for 20 minutes to remove traces of insoluble residues. Clear solution was removed and taken to dryness again. Natural strontium was eluted through ca 10 ml quartz columns using Biorad AG50W-X8 200-400 mesh resin with 2.5 M HCl. In all steps, pure acids (Merck Suprapure® grade) and 18.3 MΩ water was used. Procedural blank was better then 2 ng. Approximately 1 μg of Sr was loaded on Ta filament with 1 M H_3PO_4. Isotopic composition of strontium was measured in dynamic multicollector mode (80 - 100 ratios) on VG Sector 54E thermal ionisation mass spectrometer.

3 THE ACQUIRED RESULTS

Selecting the sites, the emphasis was put on the link of the weathering processes with the problem of slope stability. In major cases, road- and railcuts, known for intense weathering and denudation on exposed rock walls, were selected. A list of monitored sites of granitoid and metamorphic rocks is in Table 1.

Tab.1: Preview of monitored sites in granitoid and metamorphic rocks

Site	Outcrop	Rock type	Tectonic unit	Monitored from
1	roadcut	granodiorite, mylonite	Málinec, Kohút Zone	1996
2	railway	granodiorite	Bratislava Massif	1998
3	roadcut	gneisses	Pezinská Baba	2000

The micronivelationmeter has been on all above sites. Relatively high values of the loss of the material at the exposure were measured in granodiorites of the Málinec site (up to 24 mm/yr) and in mylonites of the Málinec site (up to 18,06 mm/yr). At the Železná Studnička site built of Bratislava non-weathered fresh granodiorite the annual loss reached only 0,2 to 0,4 mm/year in the 3–years period of measurements. The measurements at the Pezinská Baba are relatively very young, the maximum 38 mm/year measurement has to be confirmed by future measurements. However, because of the well-investigated geochemical properties of rocks from the Pezinská Baba site and its surrounds, we present the comparison of field and laboratory testing of rocks from this site, oriented either on chemical as well as physical and mechanical properties. We made a profile through the studied exposure, taking the following samples according to the degree of weathering:

Samples from the Pezinská Baba site:
PB-1 : totally disintegrated gneiss (soil with gneiss detritus)
PB-1F : grain size fraction below 0.2 mm
PB-2 : weathered mylonite with a tectonic clay
PB-3 : strongly weathered tectonised gneiss

PB-4 : slightly weathered gneiss

Products of weathering of original minerals (biotite, albite):
PB-1: illite, chlorite, (hematite)
PB-1F: illite, chlorite, (montmorillonite)
PB-2: illite, chlorite, (hematite)
PB-3: illite, chlorite
PB-4: illite, chlorite, (calcite)

The samples were tested in the Laboratory of Engineering Geology Department at GS SR. The results of apparent porosity, degree of saturation and Point Load Test show clear tendency of deterioration of engineering-geological properties from the slightly weathered towards intense weathered to decomposed rocks.

Tab.2. Physical and mechanical properties of tested gneiss from the Pezinská Baba site.

Sample	Specific Gravity r_s (g.cm$^{-3)}$	Bulk Density r_d (g.cm$^{-3)}$	Degree of Saturation NV_{48} (%)	Apparent Porosity NV_V (%)	PLT σ_c (MPa)
PB1	2,701				
PB2	2,761	2,651	1,141	3,023	34,100
PB3	2,742	2,674	1,090	2,915	58,100
PB4	2,739	2,630	0,446	1,172	66,600

The similar trend was confirmed also by isotope study. Though the macroscopic differences in the degree of weathering are rather great, the degree of disintegration does not show any substantial change in the concentration of main and minority minerals. However, the changes in the Sr concentration combined with isotope ratio $^{87}Sr/^{86}Sr$ are distinct. The $^{87}Sr/^{86}Sr$ ratio was normalised to $^{86}Sr/^{88}Sr$ = 0.1194. During period of analyses, SRM-987 yielded a grand mean ratio $^{87}Sr/^{86}Sr$ of 0.710244±14 and all $^{87}Sr/^{86}Sr$ ratios in Tab.4 were corrected to value of SRM-987 = 0.710248.

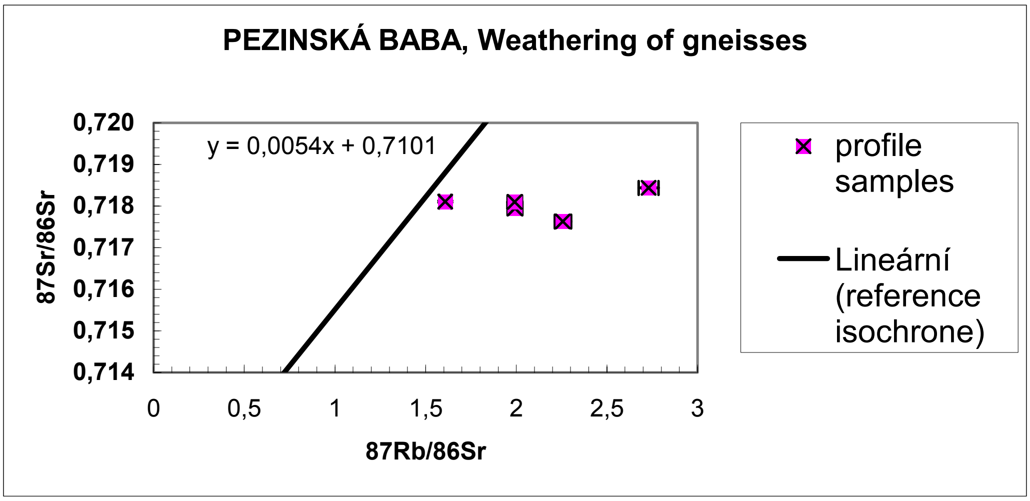
Tab. 3: Chemical composition of the samples studied (in relative weight %).

oxide	PB-1	PB-1F	PB-2	PB-3	PB-4
SiO_2	60,71	53,36	61,37	61,35	61,06
TiO_2	0,917	1,073	0,922	0,906	0,912
Al_2O_3	17,03	18,76	17,16	17,42	17,53
Fe_2O_3	7,46	9,71	7,19	7,35	7,54
CaO	1,07	1,01	1,09	1,15	1,47
MgO	2,38	2,58	2,41	2,37	2,68
MnO	0,108	0,170	0,107	0,117	0,146
K_2O	2,96	2,93	3,17	3,09	3,14
Na_2O	2,87	1,98	2,70	2,42	2,77
P_2O_5	0,15	0,17	0,14	0,14	0,15
Str. žíh.	4,09	8,00	3,52	3,44	2,33
$H2O^-$	1,27	2,89	1,57	0,99	0,48

Tab. 4: Isotope analysis of the samples studied.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	2 SE(%)
PB-1	97	141	1.99	0.717943	0.0018
PB-1F	115	122	2.73	0.718440	0.0011
PB-2	106	136	2.26	0.717628	0.0035
PB-3	99	144	1.99	0.718100	0.0026
PB-4	101	182	1.61	0.718110	0.0025

Fig. 3: Position of analysed rocks in the classical Rb-Sr isochron diagram. The reference isochron was adopted from the minimum weathered samples of metamorphic rocks of the Malé Karpaty Mts. crystalline dated back to 380 Ma (Bagdasaryan et al. 1983).



4 CONCLUSION

The data acquired by the systematic monitoring of the weathering processes, for rocks with a low resistance to weathering, predominantly, enable to orient planned anthropogenic impact into environment with limited degradation of exposed rocks, and, consequently, without jeopardising stability of slopes and cuts. The acquired data of a complex monitoring of weathering effects in gneiss at the Pezinská Baba site have shown good correlation between physical and mechanical properties in relation to decomposition of Ca-bearing minerals. From the chemical and isotope point of view the dominant feature is a Sr loss, which led to increased Rb/Sr ratio. Herein, the main process is linked with weathering of plagioclase and its alteration to illite. Ultimately, it leads to the change in physical and mechanical properties.

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