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Morphology and geotechnical characterization of a phyllite weathering profile developed under tropical climate

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ABSTRACT: Weathering profiles have been studied in several parts of the world in an attempt to better understand geotechnical and geomechanical behaviour of the different materials occurring along these profiles, specially transitional materials, formed by different portions of soil and weathered and sound rock. To this behaviour one can also add anisotropy and heterogeneity, making the problem even more complex. In order to evaluate such phenomena under tropical climate, a phyllite weathering profile located at Iron Quadrangle, Minas Gerais State, Southeast Brazil was selected. The cut slope in which the rock outcrops was detailed described and material from W1 to W4 weathering class materials were recognised. A detailed morphology description was performed in order to identify the contacts between those different weathering materials and to evaluate the result of weathering on rock matrix and on rock mass. This manuscript presents the results of this morphological description, as well as results from Schmidt hammer field and lab tests performed in all weathered materials recognised within the profile. Weathering profile morphology shows the presence of more weathered terms intercalated with sound ones. Schmidt hammer results proved to be an easy and useful way to differ weathering materials along the profile.

1 INTRODUCTION

The esclerometer or Schmidt hammer is a non-destructive physical method, through which it is possible to analyze the rock quality, in terms of the parameter obtained R (Rebound). This parameter allows, through mathematical correlations, empirical obtaining of rock uniaxial compressive strength (UCS) and deformability (Young's modulus). The sclerometry is considered a practical, fast, cheap way to mechanically characterize in situ rock.
Given these advantages the authors have sought to use the above test as a way of preliminary assessment of the rocks resistance and how it varies with weathering. The study is justified by the lack of information in the scientific literature on geomechanical parameters of altered rocks, mainly for lower degree metamorphic, such as phyllites. Through the characterization of a sericitic phyllite rock alteration profile and performing in situ assays, the authors demonstrate the variability of constitutive parameters of the rock due to the evolution of the degree of alteration.

2 REGIONAL GEOLOGY

The Quadrilátero Ferrífero is located in the South Central region of the state of Minas Gerais, between the cities of Belo Horizonte and Ouro Preto. At present, the rocks in the region are grouped into three main geological units: the complex granite-gneiss, the Rio das Velhas Supergroup (of Archean age) and the Minas Supergroup (Paleoproterozoic), where the latter include the rocks studied in this article, which belong to the Piracicaba Group - Batatal Formation, characterized by phyllites sericitic sometimes carbonaceous or ferruginous.

3 METHODOLOGY

The methodology can be divided into two steps. The first concerns the characterization of the alteration profile, identification of mechanical classes (according to ISRM, 2007), collection of representative samples and implementation of sclerometry in situ; a second stage comprised the repetition of the sclerometry, but in the rock blocks, in order to evaluate the influence of the in situ condition for this assay.

3.1 *Field Geological mapping and definition of geomechanical degrees*

The geological surface mapping took place in the Mariana city region, near the km 140 of BR-356, the highway that connects the cities of Mariana (MG) and Ouro Preto (MG), Brazil, in a road cut where there exposing a phyllite sericitic weathering profile with some levels of localized quartzite and quartz pebbles (up to 10 cm), are spread on the ground surface. At this stage of mapping and recognition of the profile, at each point, the identification of the degree of change in sericitic phyllite was held, as well as structural data (fractures and foliation) from measurements with geological compass.

Figure 1. Weathering profile of phyllite rocks, in BR-356, MG – Brazil.

At the studied site (Figure 1) it was possible to identify five weathering levels, W1 to W4 and W5 (not included in the article), according to the ISRM (2007) classification criteria presented in the Table 1. 600 kg of sericitic phyllite samples were collected to characterize geological and geotechnical-geomechanical tests.

The characterization was performed throughout macroscopic analysis of mineralogy and mineralogical changes, color and variations thereof, grain size, rock matrix tests (evaluation of the degree of coherence), evaluation of fracture families, including characteristics such as spacing, openness and persistence and estimating RQD based on Jv ratio (number of cracks/m³). Disturbed and undisturbed samples (Figure 2) were collected directly from outcrops in road cuts. Note that due to the phyllites characteristics, such as the existence of clear parallels foliation plans, samples could not be molded in the form of standard blocks (30 cm x 30 cm x 30 cm), since during the extraction process, samples tend to suffer spalling.

3.2 *The Schmidt Hammer*

The rebound hammer or Schmidt hammer is a very useful device to get in situ compressive strength, as it is a simple and non-destructive test. It must be pointed out that the use of this test does not replace uniaxial compression tests in the laboratory, for example, but allows an estimate of that property.

Figure 2. Separation of samples collected for packaging in shipping boxes.

Table 1. Weathering rock classes (ISRM, 2015).

Term	*Description*	*Class*
Fresh rock	The rock material isn´t discolored and has its original aspect. The point of geological pick scratches the surface with many difficulties. When the hammer strikes the rock material a ringing sound is emitted	W1
Slightly weathered rock	Discoloration is present only near joint surface. The original mass structure is perfectly preserved. The point of geological pick scratches the surface with difficulty. When the hammer strikes the rock material a ringing sound is emitted.	W2
Moderately slightly weathered rock	The rock material is discolored, but locally the original color is present. The original mass structure is well preserved. The point of geological pick produces a scratch on the surface. The rock material makes a regular sound when is struck by a hammer.	W3
Highly slightly weathered rock	All rock material is discolored. The original mass structure is still present and largely intact. The point of geological pick not easily indents. When the hammer strikes the rock material a dull sound is emitted.	W4
Completely slightly weathered rock	All rock material is completely discolored and converted to soil, but the original mass structure is still visible. The point of geological pick not easily indents. When the hammer strikes the rock material a dull sound is emitted.	W5
Residual and colluvial soils	All rock material is converted to soil. The original rock structure is completely destroyed. The point of geological pick easily indents in depth. When the hammer strikes the rock material no sound is produced.	W6

Its operation is caused by the compression of a hammer rod through a spring, located inside the equipment. The hammer will stem retracts until it reaches the end of its course. At this time the rod is released instantly, being projected onto the surface, which is being applied. This impact generates a shock wave transmitted to the application surface, causing a kind of rebound, causing a mass shift, which is subsequently transmitted to the device, registering a dimensionless value (R, rebound) or rebound hammer index. This value varies depending on the hardness of the material, the higher the R value, the greater the hardness of the rock.

Questions concerning the influence of the anisotropy of the material can be evaluated by conducting the test in different directions. Basu and Aydin (2004), reports that in non-horizontal conditions the test may be influenced by gravity in the test.

Likewise, Day and Goudie (1977) suggest that for effectiveness of the test application points should be far from the border samples, avoiding much lower values due to energy dissipation. The ISRM standard (1978a) recommends that the dimensions of the samples tested should have edges with a length of 6 cm, while ASTM (2001) recommends a minimum length of 15 cm. For analysis on cylindrical specimens, both standards agree with a minimum diameter NX (54.7 mm). The impact application surface should be free of cracks up to 6 cm deep, leading to influence the propagation of the shock wave. The influence of the surface smoothness must also be evaluated as it may influence the value of R, as the impact hammer can crush asperities or irregularities on the surface, resulting in an additional loss of energy (Hucha, 1965). Katz, et al. (2000) noted that the degree of rock polishing could influence the magnitude and frequency of R values obtained in the tests. Other aspects that should also be considered are the presence of families of fractures or foliation plans, excluding loose surfaces for conducting the test, the penetration of the tip in very altered and friable materials, the presence of heterogeneous materials, and the stability of the sample when test is performed in the laboratory. For igneous rocks, also the evolution of weathering processes should be considered, as it can produce microstructural changes from discoloration to the collapse of the crystal structure (Aydin and Duzgoren-Aydin, 2002). Several methods of classification weathering are well known, in general based on subjective criteria, providing differentiation among weathering degrees. An index-based classification tests have great advantages, mainly related to sensitivity and consistency in classification. Aydin and Duzgoren-Aydin (2002) have cited many important studies related to Schmidt Hammer used for this purpose.

To obtain the rebound hammer index for phyllites, the authors have used a digital Proceq rebound hammer, N type (Figure 3), recommended for obtaining hardness in the field, and, based on the results, a prediction of the weathering degree, as well as to obtain the uniaxial compression strength (UCS) and Young's modulus, by using correlations presented in the literature.

Figure 3. Rebound hammer N type used in the field (Source: www.proceq.com).

Twenty hits were recorded for each area of 20 cm x 20 cm, providing an estimate of JCS based on Brazilian Standard (NBR 7584 - ABNT, 1995), always respecting the same inclination for the test. After preparation of the rock surface the head of the Schmidt hammer was performed both vertically and horizontally, when possible, i.e. perpendicular to foliation and parallel to it, in order to estimate the anisotropy behavior of the rock.

In a second step, lab tests were performed on rock samples (thickness greater than 100 mm) in the laboratory in order to compare the variation of in situ tests. It was used a rebound hammer N type, analogical, also from Proceq manufacturer (Figures 4 and 5).

Figure 4. Analogical rebound hammer N type used in lab tests.

Figure 5. Sclerometry test on W4 class samples in the laboratory –(LEMETRO – UFRJ).

4 RESULTS

Based on field observations, Table 2 presents a summary of the characteristics observed.
It is possible to note that there is a variation in the characteristics and properties as there is a progressive degree of rock weathering, such as a reduction of the brightness and coherence and an increase in aperture and spacing of fractures, as well as in Jv.
The R values obtained from Schmidt hammer, also shows good relationship with weathering, presenting a decrease with weathering, both for in situ and lab tests, as shown in Figure 6 and Figure 7, respectively. Schmidt hammer results for tests performed perpendicularly and parallel to foliation were just representative for sound materials, as shown on Figure 6. These results are in line with those from Marques and Williams (2015) for phyllites from Australia.

Table 2. Weathering profile characterization of phyllite rocks.

Weathe-ring Degree	W1	W2	W3	W4
Miner-alogy	Rock, in general, has a very thin mineralogy, practically aphanitic, brightness silver intense in W1 samples reducing the same, to matte, more altered degrees W4, silky appearance, with detachment of fine clay and sand residues the fragments centimeters in W4 levels through laminar spalling, following the natural foliation of the rock. Displays cleavages are more evident crenulation level in positions orthogonal to each other. Despite clear gradation of rock conditions change, you cannot see, macroscopically mineralogical variations, and this is most evident feature through color and mechanical variations thereof.			
Coher-ence	Coherent rock	Coherent a low coherent rock	Low coherent rock	Very low coherent rock
Color	Silver grey	Silver grey with reddish passages	Dark silver grey with yellow passages	Dark grey of variegated color, with dull luster portions
Frac-tures	The rock has fractures families, nearly orthogonal and parallel to the foliation.			
Aperture /Spacing	0 to 0,2 cm/6 cm - 2 m	0,2 to 0,5 cm 6 cm - 2 m	0,5 cm to 0,8 cm/6 cm - 2 m	0,8 mm to 2,0 cm/6 cm - 2 m
Jv	1 -3		3 -10	

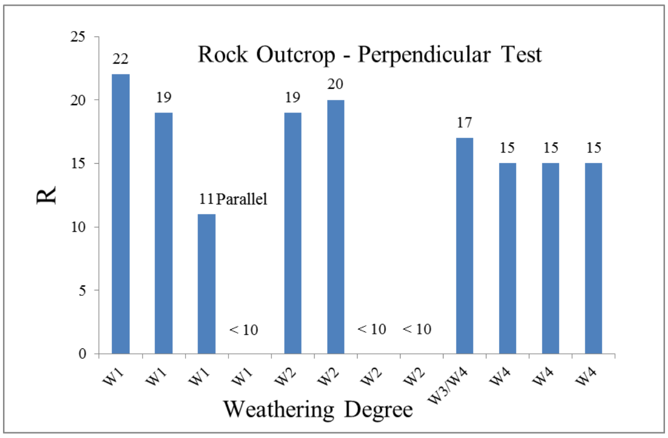

Figure 6. Schmidt Hammer in situ test.

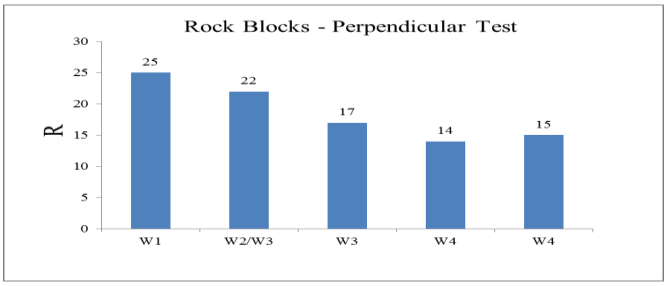

Figure 7. Schmidt Hammer test in rock blocks.

5 CONCLUSION

The results shows that the proposed methods used were able to produce data that can differentiate weathering materials for the phyllite under study, as it was possible to identify the variation of basic features such as color, brightness, physical properties of fractures, coherence and Jv. Also, Schmidt hammer results have proved to be used as an index parameter for the differentiation of weathering phyllite grades.

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