PETROGRAPHIC AND TECHNOLOGIC EVALUATION OF THE GARNET LEUCOGNEISS LEPTNITO UTILIZED IN THE BUILT HERITAGE OF RIO DE JANEIRO

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ABSTRACT

This paper focused on the study of Leptinito (garnet leucogneiss) and aims to understand the physical mechanical behavior, and the morphologies of alteration that the rock may undergo in the face of weathering conditions of the urban environment. Leptinito was characterized by petrography, microfissure density, surface hardness, color, brightness, apparent density, porosity and water absorption. Rock deterioration features in monuments have also been identified. The microfissure density values were correlated with porosity and water absorption. Despite the low density of microfissures, the foliation of the rock and the few percentage of filled fractures contribute to an increase in porosity values. Eighteen cycles partial immersion in saline solution combined with thermal shock were performed on a cube of the rock; until the present moment, darkening its surface and provoking the release of mafic minerals. Petrographic thin sections from the collection were immersed in acid solutions, generating superficial stains on feldspars and gradual discoloration of biotite lamellae.

Keywords: Leptinito, accelerated weathering tests, ornamental rocks.

1. INTRODUCTION

The city of Rio de Janeiro, country's former capital, encompasses a wide variety of monuments of historical and cultural value. The abundance of massifs supported by high resistance rocks encouraged the use of local gneisses in the construction of these monuments (Almeida & Porto Jr, 2012). Therefore, to provide technical support in the conservation of these works, an in-depth knowledge of weathering processes of the gneisses in Rio de Janeiro is necessary; since different lithologies and environment conditions imply different forms of deterioration. For this, accelerated weathering tests are performed, which simulate the effects of external agents that affect the rock integrity. However, these changes are processed on an exponential time scale, not always being perceived by the naked eye at first. In this sense, an optical microscopy is a great tool, allowing to easily identify aspects of rock fabric, fracture patterns, presence of secondary minerals, among other conditions. The focus was given to a garnet leucogneiss, from the center/south zone of the city known as Leptinito (old lithotype's name in Portuguese). The rock is light colored, foliated, fine to medium grained, composed essentially of quartz and feldspar. The work refers to a continuation of LACON researches, with the ambit of defining a weathering profile for this lithology.

2. OBJECTIVES

Characterization of Leptinito and its different stages of weathering, with identification of the consequent changes and mineralogical phases.

3. METHODOLOGY

Four Leptinito samples were previously subjected for 447 days to total immersion tests in H_2SO_4 and NaCl solutions, at the Laboratory of Conservation and Alterability of Construction Materials (LACON/CETEM). The weathering processes during this period of more than a year were very subtle, leading to the completion of the experiment (Santos, 2019). This study started with a final characterization of these samples, through: macroscopic and microscopic petrography (microscope of Zeiss brand, from the Rio de Janeiro State University), measurement of surface hardness (rebound meter Equotip 3 from PROCEQ), color and brightness (portable colorimeter from BYK spectro-guide), in addition to porosity, bulk density and water absorption (ABNT NBR 158452, 2015).

After data integration, and a bibliographic review, it was decided to carry out a more accelerated rock weathering test, in order to obtain more significant results in a time scale compatible with the work. A 64 cm^3 cubic sample of Leptinito was used; donated by the Monastery of São Bento. Before carrying out the accelerated change cycles in the rock, surface hardness, color, brightness, and initial weight were measured to observe the variation of these parameters throughout the experiment. Each cycle consisted of: heating the sample to 105 °C partially immersed in saline solution (20% NaCl) on a petri dish, for 5 hours; washing in water at 20 °C, to contribute for thermal shock and unblocking of the pores; and rest, on the same saline solution for 15 to 20 hours. The partial immersion was designed in detriment of the total, to allow the liquid rise by capillarity in the pores of the rock (Frasca & Yamamoto, 2003); in addition to facilitating the evaporation of the solution and crystallization of salts. The abundance of quartz in the rock was also taken into account; mineral with a high coefficient of expansion, capable of generating fractures in the rock with sudden changes in temperature (Freire *et al*., 2016). The release of minerals from the rock was perceived over the petri dish. The experiment is currently in its eighteenth cycle, still in progress.

Based on the ideas of Simão & Silva (1995); two petrographic thin sections of Leptinito from the collection were immersed in solutions of sulfuric acid (H_2SO_4) and nitric acid (HNO_3), at concentrations of 51% and 63% respectively. Two weekly cycles were imposed to them; consisting of: One day in full immersion, and six days with the thin sections out of the solution; covered with a thin film of acid.

Technical visits to stone monuments in the municipality were carried out, which contributed to the knowledge of the state and degree of alteration of Rio de Janeiro's gneisses. The classification of mass loss processes was based on the Illustrated Glossary On Stone Deterioration Patterns, ICOMOS, (2008).

4. RESULTS AND DISCUSSION

4.1. Technological Characterization and Optical Petrography of Leptinito (Fresh Rock)

The gneiss highlights technological parameters consistent with most granitic rocks (Mattos *et al*., 2013). The rock comprises surface hardness values of around 760-800 HLD. It also presents apparent density of 2623.63 kg/m^3; open porosity of 0.69% and water absorption of 0.26%. The color of the rock exhibits characteristic white/light gray tones, with parameters L = 68,87, a = 0,21, b = 4,86 and G = 1,28.

In an optical microscope, it was possible to verify that the juncture between the minerals is preferably made by convex concave contacts in the shape of lobes, with minor straight contacts. The mineral proportion of the rock consists of 41% quartz, 38% microcline, 13% plagioclase, 5%

biotite, 2% garnet, and 1% opaque minerals. Due to the abundance of felsic minerals and the low alterability of quartz, the state of the mineral feldspar is generally what defines rock stability. Its crystals initially break in sets of 3 to 5 straight intragranular fractures (inside the grain), transversal to the length of the crystal; and with the advance of weathering, they start to develop more irregular patterns, with the development of transgranular fractures. The fracture of feldspar is influenced by the inherent cleavage, in addition to the presence of twins and perthites (Freire *et al.*, 2016). Plagioclase in particular, when zoned, tends to develop secondary minerals preferentially from its core (of calcium composition, more unstable) in detriment of the rim (of sodium composition). Garnet crystals are severely fractured, but these fractures rarely communicate with the rock matrix. Clay minerals arise through the alteration of feldspar, garnet, and less commonly of biotite, which commonly tends to form iron oxides and hydroxides with the advance of weathering.

Following the classification of Frasca (2003), the degree of fracturing on the rock is weak, presenting 0.19 microfissures/mm², with an average size of 0.29 mm. Among them, 84% are intragranular, while 16% are intergranular and transgranular. Microfissures in the rock have low communicability. Filled fractures occur in 10% of the total number, filled by micas, goethite (next to ferromagnesian minerals), clay minerals and opaque minerals (both in garnet). The formation of intergranular fractures usually arises from terminations in biotite lamellae.

Microfissure density results were correlated with porosity and water absorption, subsequently being compared with data from different rocks in the literature, such as Mattos *et al.* (2013) and Azevedo *et al.* (2015). The porosity and water absorption values found are low, but still somewhat elevated when considering the low degree of fracture of the rock. This can be justified by the anisotropy of the rock and by the stretched crystals due to foliation, in addition to the low proportion of filled fractures. Taking into account that the method for measuring microfissures in the rock was indirect, later on, the aim is to carry out analysis such as x-ray tomography for a better quantification of this parameter.

4.2. Thermal Shock Conjugated With Salt Immersion Tests

Macroscopic changes in the rock include: Saline efflorescence, significant discoloration of the rock, oxidation stains, detachment of biotite (after the fifth cycle) and garnet (after the eleventh cycle). Surface hardness values remain constant (around 770 HLD), and there was no loss of weight, requiring more cycles for significant changes to be made in these parameters. It should be noted that due to the pandemic, the weathering tests had to be interrupted before reaching a reasonable number to establish a decline in physical and mechanical parameters.

Figure 1: MSB 2 sample before and after 17 cycles of saline immersion and thermal shock.

4.3. Deterioration Patterns in Monuments

In the field, the tendency of Leptinito gneiss is to acquire a yellowish color, due to oxidation, with the progression of weathering. The release of garnet porphyries from the rock is also seen quite frequently, including in fresh looking rocks. Due to its massive structure, with fine and uniform granulation, the most common tendencies of mass loss processes in monuments are peeling and delamination; analogous to spheroidal exfoliation in nature. A more advanced stage of degradation of the rock is granular disaggregation. It can occur in response to the internal argilization of the rock matrix, in combination with the pressure of crystallization of salts in a porous medium. This effect has serious consequences on the stability of the substrate, which may eventually lead to the rupture of the stone monument.

4.4. Acid immersion of petrographic thin sections

After a one-week cycle, immersed in H_2SO_4, the color of biotite was bleached, observed at natural light of the optical microscope. In polarized light (crossed nicols), lamellae started to present colors from first to second order; birefringence not characteristic of biotite, which commonly displays colors from third to fourth order. The discoloration had been gradual; its progression observed between the first and second cycles. The acid also developed superficial stains on feldspar crystals. Such features commonly propagate from trans and intragranular fractures in the crystals. The HNO_3 solution immersion test also showed similar products, with bleaching also being observed in chlorite lamellae. However, excessive detachment of the glue sheet from the section prevented the fulfillment of further cycles.

The results are similar to those of Frasca (2003), who describes discoloration of biotite lamellae, and widening of mineral fractures, after exposure of rocks to a sulfur dioxide chamber. The changes observed under a microscope suggest the ionization of the basic components present in the minerals of the section. Pereira (2013) describes reactions of H_2SO_4 and HNO_3 with potassium feldspar; releasing kaolinite from potassium leaching, in a short time scale. Luo *et al.* (2015) also describes the formation of silica gels (allophane) from experimental reactions of H_2SO_4 and biotite. It is therefore expected that the leaching of elements from the biotite lamellae may eventually produce some kind of clay mineral.

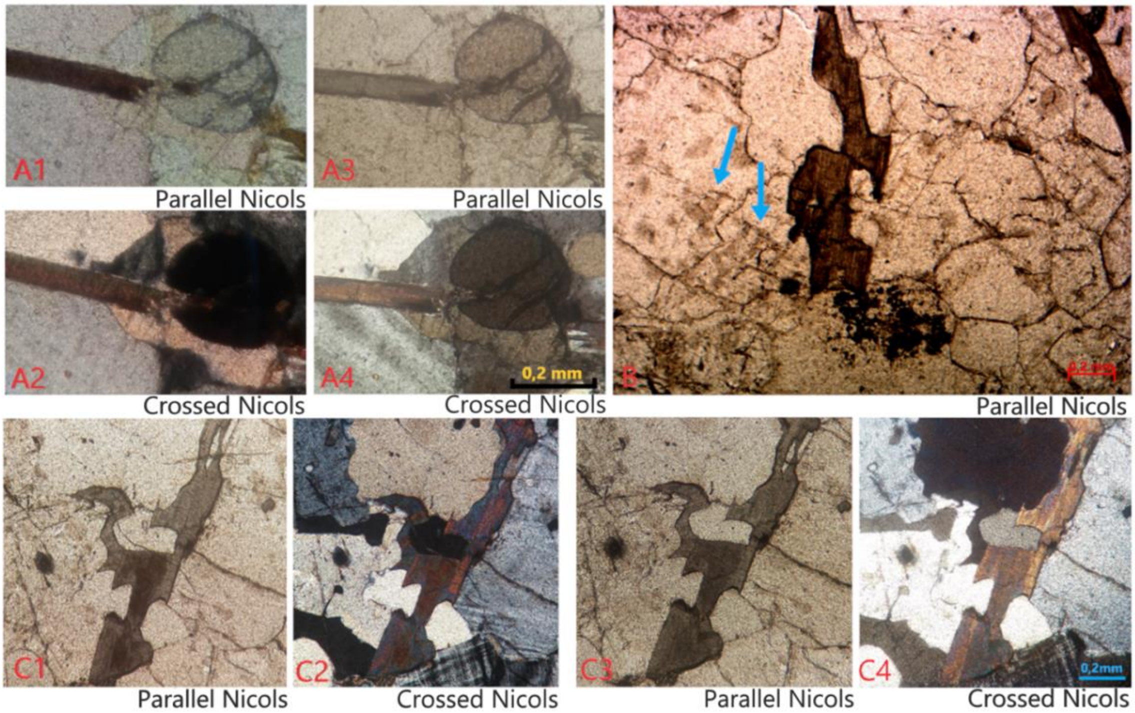

Figure 2: A. Bleaching of biotite lamella due to acid immersion (A1 and A2 - pre-test; A3 and A4 - first cycle). B. Surface staining of feldspar crystals close to microfissures. C. Gradual bleaching of the biotite lamella core (C1 and C2 - first cycle; C3 and C4 - second cycle)

5. CONCLUSION

The reactions of minerals with acid solutions, in a short time period of study were able to make significant changes, yet little noticeable on a macroscopic scale. The experiments of saline attack with thermal shock developed visible changes; however the apparent stability of the rock remained practically the same. Even so, the delay in the conduction of weathering processes on the rock is a positive result; indicating the good applicability of Leptinito as a building material. The experimental results will eventually be compared with the field results, in order to give more support to the preliminary observations described in this paper.

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