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Performance of the SEM (Scanning Electron Microscope), Raman Spectroscopy, and Industrial Computed Tomography used for characterization of the vesicular volcanic rock as applied in Carbon Capture and Storage (CCS)

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1. Introduction

According to the International Energy Agency (IEA), carbon dioxide mineralization can reduce about 10–15% of total global emissions, according to the International Energy Agency (IEA) [1].

Igneous rock reservoirs exist in more than 20 countries and in more than 300 basins or blocks around the world. In contrast to sedimentary formations where silicate minerals represent a mineral retention gap, injection of CO_2 into suitable igneous (volcanic) rocks such as basalt can create rapid carbonation and mineral retention [1].

Vesicles, in this type of rock, are gas bubbles formed in supersaturated volatile lava (especially water vapor), after rising to the surface [3].

In this case, gamma radiation tomography provides a detailed two-dimensional view of the distribution of minerals in the pores, while scanning electron microscopy allows high-resolution analysis of mineral morphology and texture. Furthermore, Raman spectroscopy provides information about the crystalline structure of the minerals present in the sample.

2. Methodology

The samples of vesiculated volcanic rocks were collected in the municipalities of Guaporé and Vista Alegre do Prata, in the State of Rio Grande do Sul.

Petrography considers aspects such as texture, degree of crystallinity, visibility, geometry, arrangement (plot), size of crystals, characterization of porosity and alteration products. The topography and morphology of the minerals that make up the rock will be evaluated using a scanning electron microscope (SEM).

By changing the frequency of a small fraction of the incident radiation, when it is mirrored by crystalline structures, Raman spectroscopy was used on small basalt fragments of approximately 1 cm^3.

Thus, the tomographic measurement will be carried out in the natural shape and size of the rock, without requiring any processing to carry out the tomographic measurements. Through the results obtained by tomographic measurements, the following will be estimated: (1) estimated the density of the constituent minerals of the rock; (2) the geometry of the vesicles; and (3) visualized the interconnection of the vesicles.

3. Results and Discussion

The presence of secondary minerals can reduce pore connectivity and limit the pathways available for fluid flow. This occurs, especially when secondary minerals fill the spaces between the grains and crystallize, forming a more cohesive and compact matrix, as can be seen in Figure 1.

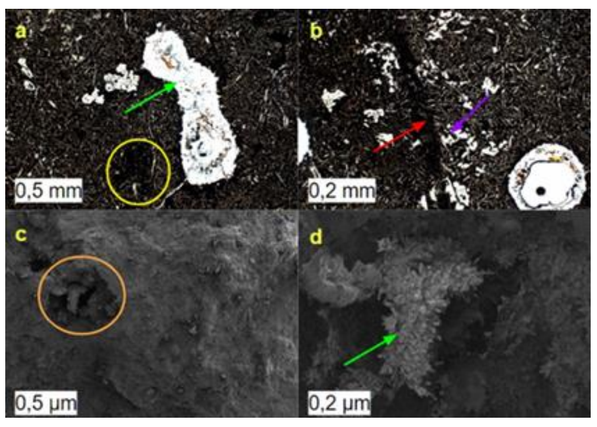

Figure 1: (a): Dikitaxitic texture (yellow circle) and vesicle (green arrow). (b) Intergranular texture (purple arrow) and secondary porosity (red arrow). (c) Partially filled vesicle (orange circle). (d) zeolite (green arrow).

The most soluble minerals, such as olivine and pyroxene, may be the first to be affected by this dissolution process under normal pressure and temperature conditions. Figure 2 illustrates wavelength spectra relating to: augite, calcite, albite, chalcedony and zeolite.

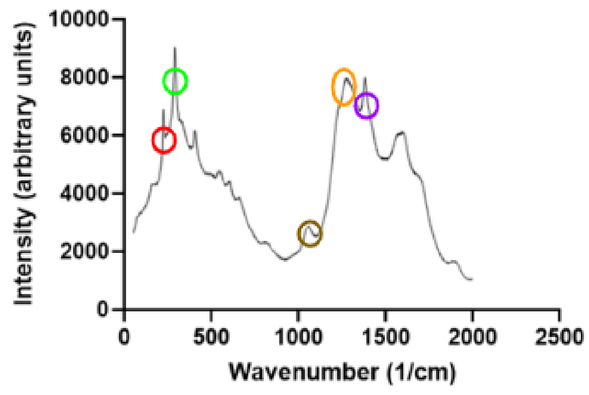

Figure 2: Raman spectroscopy. Augite (green), calcite (brown), albite (orange), chalcedony (red) and zeolite (purple).

Zeolites are formed from the combination of metal ions with aluminosilicates present in the solution.

These fluids can contain calcium and carbonate ions that precipitate in the basalt rock, forming calcite. The action of weathering processes, can concentrate silica in basalt gaps and cavities. This silica can then crystallize and form chalcedony.

The distribution of porosity and permeability can be visualized in the image in Figure 3, observing small vesicles and their interconnections.

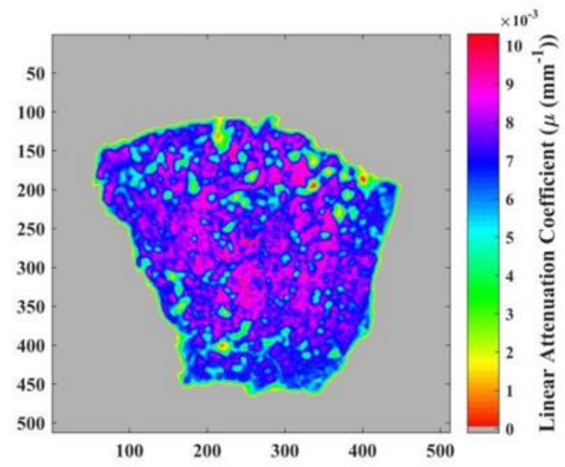

Figure 3: Reconstructed image of volcanic rock.

4. Conclusions

The formation of secondary minerals can change the distribution and size of pores in the rock, thus affecting its ability to transmit fluids.

Secondary minerals can fill the void spaces between the basalt's primary mineral grains, there by reducing the total volume of porosity available for fluid flow. This can decrease the effective permeability of the rock, making it less permeable.

Understanding these processes is crucial for an accurate assessment of basalt permeability by carrying out different types of experiments and for comparison with tomography

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