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Qualitative analysis of the porous network structure of a volcanic rock

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1. Introduction

The Paraná-Etendeka Igneous Province represents one of the major continental provinces of basaltic outcrops on a global scale [1]. Consequently, the exploration of groundwater and hydrocarbons in igneous rocks has been sidelined, mainly due to their heterogeneity [2] compared to clastic and carbonate sedimentary rocks [3]. However, there are still few studies on the petrophysical characterization of these types of unconventional reservoirs [4]. In this study, a multiscale qualitative analysis was conducted to compare X-ray microtomography and gamma-ray computed tomography, given that both techniques are non-destructive.

2. Methodology

The sample of vesicular volcanic rock was collected in the municipality of Guaporé, in the state of Rio Grande do Sul, as shown in Figure 1.

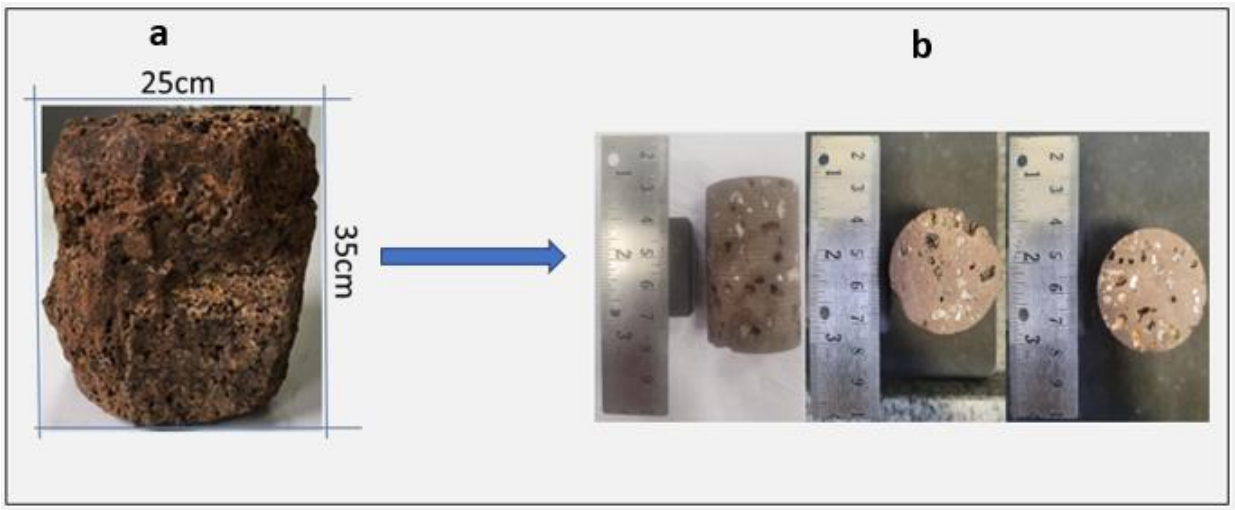


Figure 1: Sample of volcanic rock collected from Guapoé, in the interior of the state of Rio Grande do Sul. A. Core sample representing the upper part of a lava flow; B, Subsample of cylindrical dimensions (3.8cm or 1.5 inches in diameter and 8cm in height) extracted from the core samples illustrated on the part A of the image.

Figure 2 shows the reconstructed image of the multiphase phantom, which was created to convert the experimentally obtained linear attenuation coefficient into density. Based on this image, the average linear attenuation coefficient of the phantom's constituent materials was calculated, namely: PMMA ($\rho \approx 1.19$ g/cm³), air ($\rho \approx 0.00122$ g/cm³), glass ($\rho \approx 2.5$ g/cm³), aluminum ($\rho \approx 2.698$ g/cm³), and iron ($\rho \approx 7.8740$ g/cm³). Next, these were correlated with their respective densities, as shown in Figure 30.

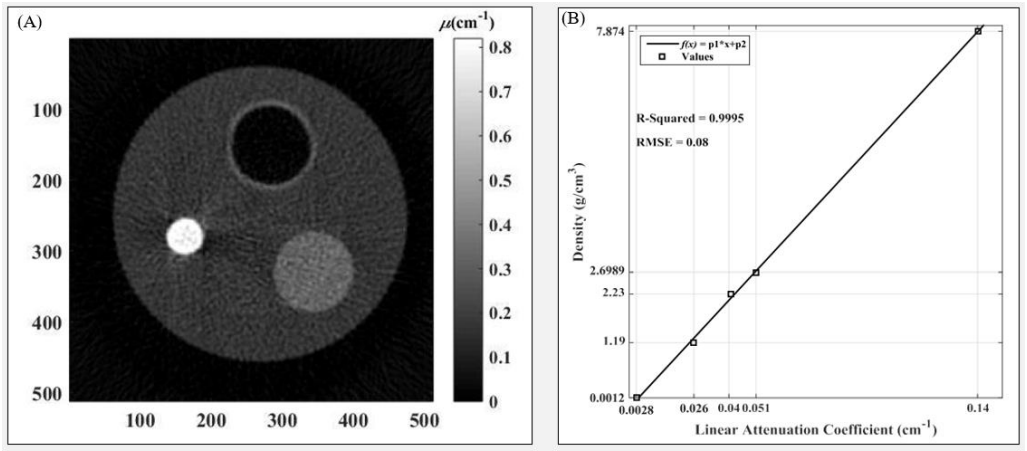


Figure 2: Illustration of the multiphase phantom made of acrylic (A). Schematic diagram of the phantom showing the dimensions of its components (B). 1—Air enclosed by a circular glass wall, 2—iron bar, and 3—aluminum bar.

The three-dimensional images from the cylindrical samples (Figure 1 part B) were acquired using a Skyscan 1275 micro-CT scanner at an energy of 85 kV and a current of 117 μA. The software used for image reconstruction was NRecon Version 1.7.4.6. Both image acquisition and reconstruction were performed at the Radiation Technology Center, located at IPEN/ CNEN-SP/USP.

Both gamma-ray computed tomography and X-ray microtomography were performed at the Radiation Technology Center, located at the Institute for Energy and Nuclear Research (IPEN/CNEN-SP).

3. Results and Discussion

The reconstructed image of the igneous rock sample, measured after collection, is shown in Figure 3. The value on the color bar represents the linear attenuation coefficient (μ (cm^{-1})). High spatial resolution was achieved in the tomography configuration with the selected parameters, as can be seen in Figure 31, although with low temporal resolution, requiring 17.5 hours to obtain each tomographic image. The distribution of porosity and permeability can be visualized in the image in Figure 31, showing small vesicles and their interconnections.

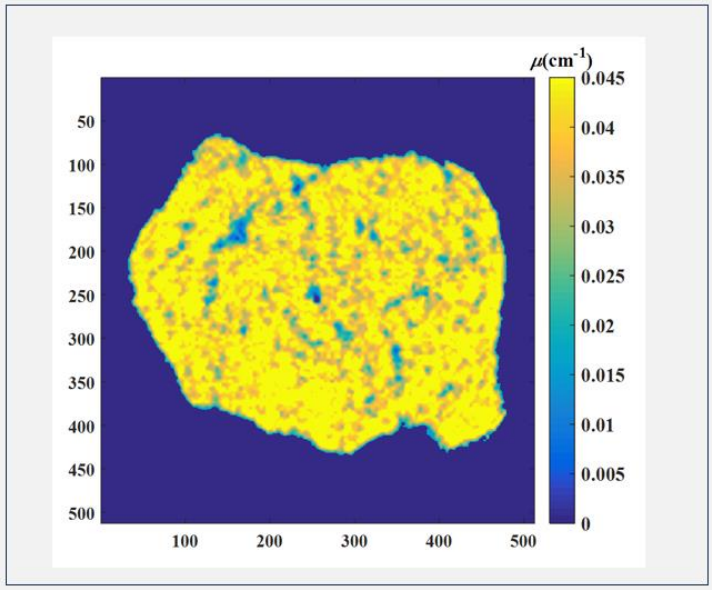


Figure 3: Reconstructed image of volcanic rock showing the interconnections between the vesicles, represented in blue.

Figure 4 shows a three-dimensional image of the basalt in which the internal distribution of pores and filling minerals can be seen. The size and geometry of the pores can be observe.

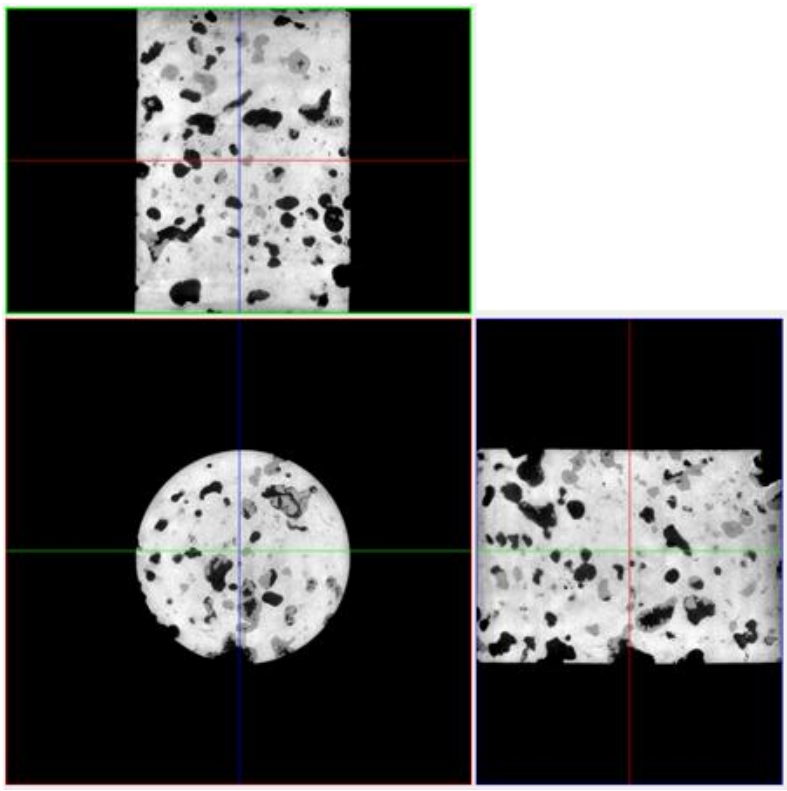


Figure 4: Three-dimensional image of amygdaloidal basalt obtained using an X-ray microtomograph.

4. Conclusions

Although gamma-ray computed tomography allows larger samples to be analyzed compared to X-ray microtomography, X-ray microtomography is more suitable for achieving higher resolution.

Because the linear attenuation coefficient can be visualized in the image acquired by the gamma-ray micrograph, it is possible to conduct a textural study of the rock matrix.

For future studies, combining both methods is of interest for conducting multiscale petrophysical studies in unconventional rocks.

Acknowledgements

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