3D HIGH RESOLUTION X-RAY COMPUTED MICROTOMOGRAPHY IN LIMESTONE ROCKS OF THE ITABORAÍ BASIN STUDIES

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Abstract

In this work it was studied core plugs from Itaboraí basin that were collected in São José do Itaboraí, Rio de Janeiro. This formation is characterized by carbonate sequence was covered by rudaceous sediments of Eocene-Oligocene age. This is a sequence of clastic and chemically deposited travertine limestones that were vertically cut by fissure. Understanding the size, connectivity and distribution of the pore space system is important for the reliable description of the basin petrophysical parameters. Conventional petrophysical techniques limit the observation in two dimensions and needs a special sample preparation. This work illustrates how the X ray computed microtomography (µ-CT) is able to study the 3D inner characteriscts of the pore space system with small resolution (~ microns order) and provide the 3D quantification of pores. It was studied samples of travertine limestone taken at different depths of the well called 2-ITAB-1-RJ. The results obtained show the potential of the µ-CT to describe the connectivity and distribution of pores from the 2D and 3D images and the 3D data porosity estimation.

Introduction

X-ray microtomography (µ-CT) is a nondestructive technique that allows 3D visualization of the internal structure of objects, determined mainly by variations in density and atomic composition. This technique was originally developed by medical applications and due to its widespread use and application, µ-CT also has been a useful tool in geology studies. In accordance with M.Van Geet *et al*, (1999), many studies have demonstrated the power of µ-CT with respect to classical petrography in geological research**.** The µ-CT can be used for quantitative and qualitative analysis of inner characteristic of geological materials (Mees F. *et al*, 2003). The 3D characterization of porous medium from the core plug evaluation leads to petrophysical properties such as porosity, pore distribution and permeability.

Most of all oil and gas produced comes from accumulations in the pore spaces of reservoir rocks. The amount of oil or gas contained in a unit volume of the reservoir is the product of its porosity and the hydrocarbon saturation. Therefore, porosity is a very important petrophysical parameter of rocks (Schlumberger, 1991). Porosity is the pore volume per unit volume of formation. It is the fraction of the total volume of a sample that is occupied by pores or voids.

In this work it was studied core plugs from the well of *Itaboraí Basin* which were collected in *São José do Itaboraí*, *Rio de Janeiro* (figure 1). The basin was filled by a sequence of clastic and chemically deposited (travertine) limestones that were vertically cut by fissures, where most of the fossils were recovered. This carbonate sequence was covered by rudaceous sediments of Eocene-Oligocene age (e.g, Bergqvist, 2008).

Figure 1: Itaboraí basin

Method

The X-ray microtomography is a non-destructive imaging technique. This is the unique system that allows us to visualize and measure complete three-dimensional object structures without sample preparation or chemical fixation. The µ-CT measures the material density variations in the sample extend through the attenuation of X- ray beam transmitted.

The simplest common elements of µ-CT are an X ray source, an object which the X-rays pass through, and a detector that measure the extent to which the X ray signal has been attenuated by the object. In this technique the X-ray source and the detector are fixed, the intensity of the X-rays after passing through the object is expressed in equation 1.

$$I = I_o \exp(-\mu x) \qquad (1)$$

Where μ is the liner coefficient of the object and *x* the thickness.

The detector converts the X-ray intensity in a digital image proportional to the attenuation of thephotons.For this purpose,during the acquisition the object will rotate over 180 or 360 degrees with a fixed rotation step. At each angular position a transmission image will be acquired. The cone beam acquisition will save all these projection images as files on the disk (figure 2). With the projections images it is possible to reconstruct images of slices using a reconstruction algorithm. In reconstructed image, each pixel correspond the mean linear attenuation and the image is represents in gray scale. When the reconstruction finishes the different constituents of the object can be determined and pore or fractures can be noted, the 3D image can be generate with the reconstruction image.

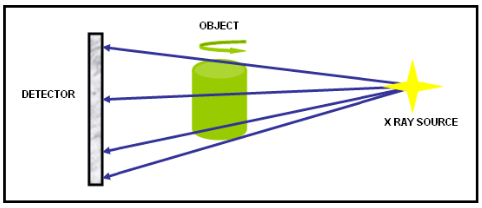

Figure 2: An Illustration of micro-CT acquisition

All the samples were scanned employing a Skyscan 1173 desktop μ-CT at Sedimentary Geology Laboratory, UFRJ. The scanner using a tungsten anode and operating at 130 kV and 61 μA (spot size < 5μm). The samples were analyzed using filter Al (1.0 mm) plus Cu (0.2 mm) and a Flat Panel detector. Total rotation angle was 180^o with rotation step size angle of 0.50^o. A total of 961 μ-CT slices were obtained with spatial resolution of the 26 μm.

Usually, the porosity estimate is performed using the image treatment software CtanR® The bidimensional image goes by a treatment where the region of interest (ROI) in the rocks is appointed. The image is binarised in grayscale and it is done the determination of the optimal threshold. The porosity is estimate from the 3D analysis of segmented image. It is the proportion of the volume of interest occupied by binarised porous sample.

$$\Phi = 1 - \frac{BV}{TV} \qquad (2)$$

Where BV is the volume of the rock matrix and TV is the total volume of the core. The image treatment software CTanR® provides confidence limits of 95% of the image voxels medium.

Results and Discussion

The travertine limestones recovered from 2-ITAB-1-RJ well characterized by inorganic origin are formed by an arrangement resembling banded stromatolitic structures with rose coloration. Its porosity is characterized by inter and intragranular pores distributed between the elongated vugs that reach the sample surface (figure 3 and 4).
The quantification of the 3D volume data is made from the cumulative histogram of all 2D slices. The values are presented in table 1 where total porosity is the total voids space present in the rock.

Figure 3: Limestone core recovered by 2-ITAB-1- RJ

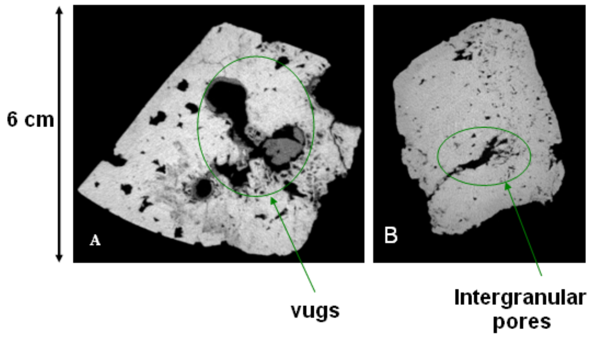

Figure 4: One slice of 2-D μ-CT visualization for A limestone 1 and B limestone 2

Table 1: Porosity values of limestone

SAMPLE	TOTAL POROSITY (ϕ)
Limestone 1	7.6%
Limestone 2	5.3 %

Pore space distribution and interconnectivity can be represented with such 3D visualization. Using the softwares CTVOL® and CTVOx® for processing image, the opacity of rock matrix material can be modified and the pore space can be visualized. The figure 5 illustrated this effect where the gray color represents the rock matrix and the yellow color the pore space. The figure 6 shows in gray scale the 3D visualization of the interconnecting pore space.

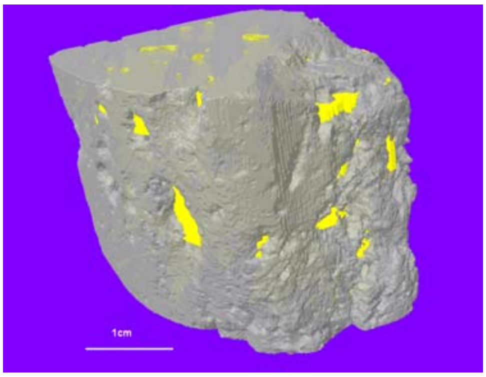

Figure 5: 3D visualization for Limestone 1 sample with 26μm.

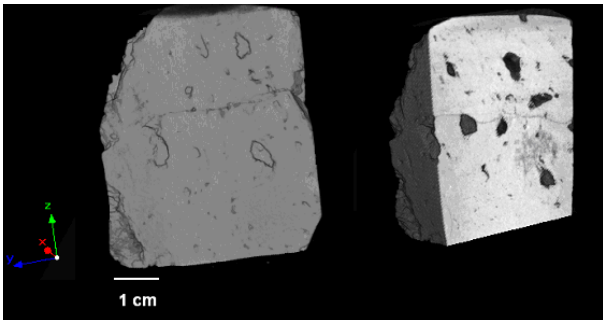

Figure 6: 3D visualization in gray scale of Limestone 1

Conclusions

The μ-CT technique is a useful tool in qualitative and quantitative analyses of geological materials providing excellent high resolution of pore space in core samples. Computed microtomography provides bidimensional and tridimensional visualization of the distribution and connectivity of porous presents in the rock without material damages. The volume data set provides the effective and total porosity. This characterization permits the understanding and modeling of the porous system.

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