Petrophysic and Petrologic Characterization of Carbonate Rocks of the São José do Itaboraí Basin, RJ.

Renato Mota Xavier de Meneses, UFRJ; Carlos Jorge Abreu, UnB; Júlio Cezar Mendes, UFRJ and Paula L. Ferrucio da Rocha, UFR/UnB.

Abstract

The utilization of routine petrographic techniques such as thin section descriptions, images on scanning electronic microscope (SEM) and x-ray diffractometry (XRD) integrated with measurements of porosity and inferred permeability of different carbonate facies of the sedimentary basin São José do Itaboraí had as main objective the comprehension of the porosity systems of carbonate rocks. Travertine carbonate (predominant), carbonate breccia and oolitic grainstone (minors) have extremely low porosities and absolute permeablity due to cementation and their predominantly chemical origin, presenting porosities smaller than 2.5% and permeability fractions of milidarcys. The integration of petrography with petrophysical results is essential to understand the porosity systems, mainly of calcareous rocks, and to proceed possible correlation with well logs and seismic.

Key-Words: 1- São José do Itaboraí basin 2 - Carbonate rocks 3 - Petrography 4 - Petrophysics.

Introduction

This work deals with petrography and petrophysics of the carbonate rocks of the São José do Itaboraí basin, a very small graben (Riccomini, 1989; Ferrari, 2001) which size is approximately 1.0 km^2 filled by carbonate breccia, travertine and oolitic grainstone, among others siliciclastics. This basin is situated close to the small village São José do Itaboraí (22º44'51" S e 42º51'21" W), in the Rio de Janeiro state (Fig. 1). A detailed geological description of the basin can be found in Tibana *et al* (1984), Francisco, (1989), Francisco, *et al.* (1992), Ferrari (2001) and Bergqvist, *et al.* (2009).

The analyzed rocks belong to the sequences S1 and S2 (Table 1) of the graben, which total thickness was approximately 125m originally. Most of the carbonates were used to produce cement for construction.

The main objective of this study is to attain a better understanding of the porosity systems of these rocks integrated with their petrophysic properties.

The understanding of the values of permeabilities and porosities of rocks requires a detailed knowledgement of the pore systems. This necessity is stronger when studying carbonate rocks because their diagenesis is much more complicated, mainly because the mineral composition is more uniform ($CaCO_3$) but with great variety of constituents (oolite, bioclasts, pellets, micrite, calcite cement) of the rocks, compared to siliciclastics (Al, Si, O, K, Na, Ca) but in few minerals such as quartz, feldspars and lithic fragments. These different minerals prevent a generalized dissolution, for example, simultaneously.

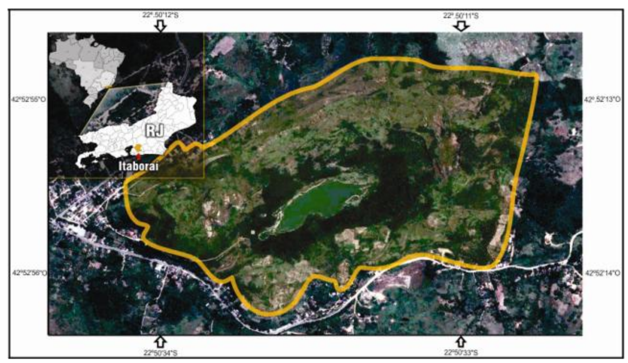

Figure 1- Google image of the São José do Itaboraí sedimentary basin. Yellow line circles the Itaboraí basin (Meneses, 2012).

Table 1 – Stratigraphy of the S.J. do Itaboraí basin. Modified from Leinz (1938) and Bergqvist *et al.* (2009).

Seq.	Age	Litho Unit	Description
S3	Paleocene To Recent	Macacu Fm.	Terrigenous conglomeratic/clayey sandstone; Ankaramite emplacement
S2	Paleocene		Reworked S1 facies collapsed breccia, marls and rests of plants, reptiles and birds
S1	Paleocene	Itaboraí Fm.	Travertine, gray limestone and oolitic grainstone
	Pre-Cambrian	Basem.	Gneiss & marble

Method and Material

The conventional petrophysic measurements were performed in plugs of 2.5 cm diameter with both, equipment Coretest AP 608, using helio gas and Ultra Pore 300 from CoreLab and the permeability at the Ultra Perm 500 also from CoreLab, using nitrogen. The effective porosity and permeability were measured using 1000 PSI confinement pressure. Samples did not require cleaning because there was no oil or salt water present within the pores.

At the beginning of the analyses helio was injected at a pressure of 200 PSI. Stabilization of this pressure indicated all pore spaces had been filled, and grain volume of the sample was determined through the difference between the plug volume (sample) and the volume of the injected gas.

When measuring the porosity volume helio gas was injected in the sample (inside the holder) and using the difference between injection pressure in and out (P1V1 = P2V2) the difference of volume was calculated, that is it, the volume of gas that had occupied the empty spaces, then reaching the effective porous volume.

Using the same core-holder and the same confinement pressure, used for porosity, the permeability was measured using an entry pressure of 200 PSI.
The porosity obtained in thin sections impregnated with blue-epoxy, to better visualize the pores, was estimated by counting them under microscope.

The observation on texture and the mineralogy were also made in thin sections. The framework, matrix and the pore filling minerals were analyzed. The types of pores were identified according to the Choquette and Pray (1970) and Scholle *et al* (2003) classifications.

X-ray diffraction and SEM were performed at the University of São Paulo Laboratory, where the identification of minerals in the carbonate breccia and travertine, as well as their semi-quantification has facilitated.

Results

The main observation on the three carbonate facies analyzed indicates that all of them are poorly porous and extremely low permeable rocks. Another observation concerned with methodology, was that the equipment has different degree of resolution, Coretest, giving higher estimates than Corelab.

The carbonate breccia (Fig. 2) consists of marl fragments cement in coarse calcite, partially to totally filling the fractures. Sometimes this fine-grained matrix includes terrigenous grains of quartz and feldspars. Porosity of the breccia facies averages 0.31% and 0.75% with Corelab and Coretest equipment, respectively (Table 2) and permeability is extremely low. Estimation of the identified minerals with X-ray diffraction at the breccia facies indicates 45% plagioclase, 45% de calcite and 10% quartz. Total density is 2.66 g/cm$^{3.}$ This facies has been formed by dissolution and collapse of previous carbonate rocks bearing some siliciclastic minerals of the sequence 1 (Table 1).

Typical travertine of the Itaboraí basin is thinly laminated with of different colors due to some siliciclastic-rich laminae intercalated with pure carbonate ones (Fig. 3). They can have micro-fractures completely or partially filled by iron hydroxide (goethite) crystals formed diagenetically, which composition is FeO(OH) (Figs. 4 and 5). Total density is 2.70 g/cm^3 and estimated composition of this facies based on X-ray analyses presented 2% magnetite (altered to goethite?), 5% quartz and 93% calcite. The presence of recrystallized calcite has drastically reduced the porosity reaching up to 2.5% and averaging 0.67% (Table 2). Travertine is the most closed here, with very tight crystals of calcite and aggregates of goethite (Fig. 5).

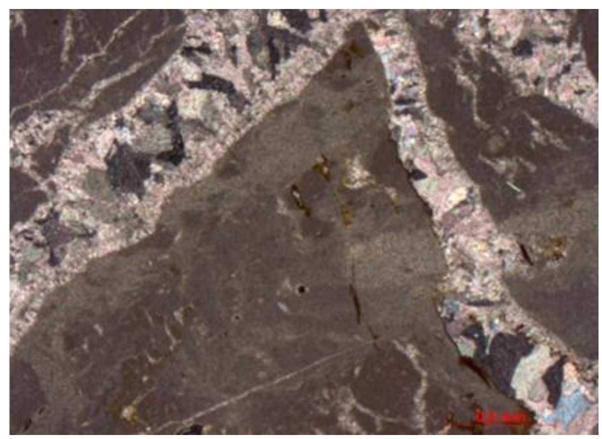

Figure 2 –Carbonate breccia consisting of marls fragments (dark color) welded by coarse calcite cement totally filling the fractures. Porosity smaller than 2.0% and extremely low permeability, fractions of mD.

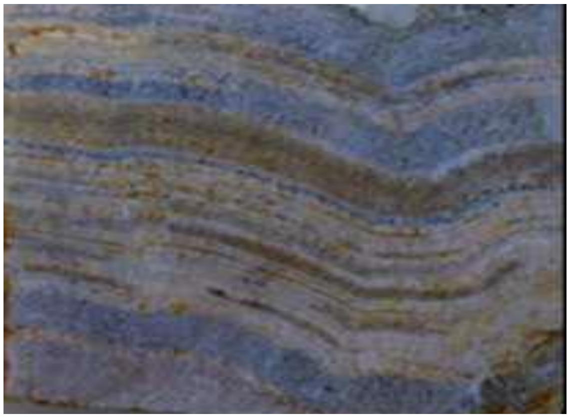

Figure 3 - Typical travertine of the Itaboraí basin. Thinly laminated with different colors due to some siliciclastic rich-laminae intercalated with pure carbonate ones. Photo is 6 cm high.

The oolitic grainstone is strongly cemented by coarse calcite, but presenting some intragranular porosity in the grain rim (Figure 6). Compaction before the early coarse calcite cementation was weak because grain contacts are not tight. Total density is 2.67 g/cm^3. At this facies porosity was estimated reaching 5% and fractions of mD, because porosity is not effective.

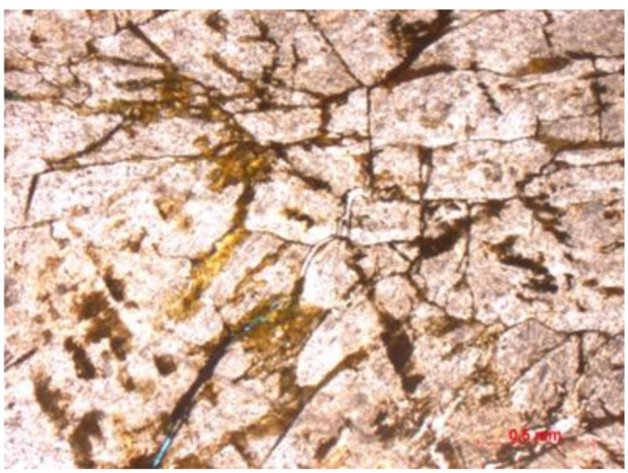

Figure 4- Some travertine original facies were deformed resulting micro-fracture porosities later filled by iron hydroxide, leaving only few pores (blue at lower-left), 2.5%, averaging 0.67%.

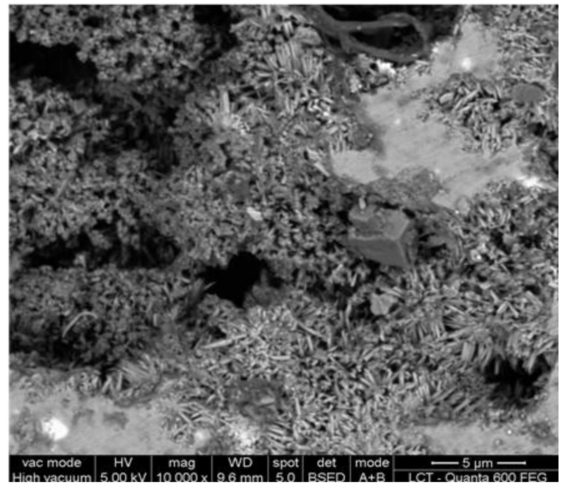

Figure 5 – Pores (black areas) remained after diagenetic goethite (aggregates of acicular crystals) has precipitated within the micro-fractures of the travertine facies. SEM 10000X magnification.

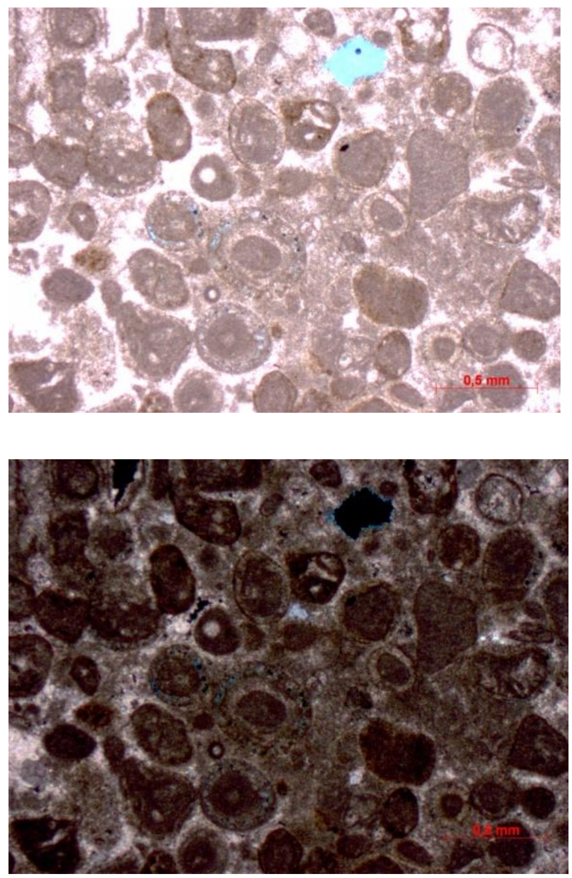

Figure 6 - Oolitic grainstone strongly cemented by calcite, but presenting some intragranular porosity (upper picture). Estimated porosity approximately 5.0% and milli-mD permeability. Single pore due to feldspar dissolution in the upper part (blue).

Table 2 – Porosity results of travertine and breccia carbonates.

Travertine		Breccia	
Corelab	Coretest	Corelab	Coretest
0.1310	0.0322	0.4234	1.6112
0.5360	0.0480	0.8428	1.7442
1.9797	0.4594	0.0000	0.1890
0.5964	2.1116	0.0000	0.4614
0.6282	2.5248		
0.2213	0.0559		
0.1954	0.0722		
Average 0.613	Average 0.6699	Average 0.3166	Average 0.7515

Conclusions

The three carbonate facies of the São José do Itaboraí basin are travertine with highest density, 2.70 g/cm^3 carbonate breccia with 2.66 g/cm^3 and oolitic grainstone with 2.67 g/cm^3. These values are high for sedimentary rocks because all these facies are calcareous. However the highest value of the travertine is due the presence of diagenetic goethite and low porosity.

Much of the porosity, not visible under microscope, is represented by its extremely small pores (micropores smaller than 2 nanomicrons), however, they are registered on gas petrophysics.

The extremely low permeability, which made it difficult to be measured, is explained by the strong cementation, and disconnection of pores. Compaction of all facies was too low.

SEM images allowed the determination of minerals that fill the pores, such as goethite in the oolitic grainstone facies and coarse calcite in the breccia and oolitic facies.

Results of this study reinforce the knowledge that petrographic analyses in thin section complemented by SEM and X-ray diffraction among others, coupled with petrophysics are still the most effective way to understand the porous systems of rocks. Understanding the porous system is crucial to understand the fluid flow in reservoir rocks, as well as their physic properties.

Acknowledgments

The authors are grateful to Maria Antonieta Rodrigues and Sérgio Bergamaschi for supplying some rock samples; Giovanni Stael for the support on petrophysics and Jane Nobre for comments on carbonate rocks; to Henrique Kanh and Giuliana Ratti and Ana Gauza for helping original dissertation and to the Graduation Program of the Universidade Federal do Rio de Janeiro. To Emmy Lammertsma for the careful text review.

References

Bergqvist, L. P. Mansur, K.; Rodrigues, M.A.; Rodrigues-Francisco B.H., Perez, R. Beltrão, M.C. 2009. Bacia São José do Itaboraí, RJ. Berço dos mamíferos no Brasil. In: Winge, M. *et al*. (Ed.). Sítios geológicos e paleontológicos do Brasil. Brasília: CPRM, 2009. v. 2. 515p. Available at http://sigep.cprm.gov.br/sitio123/sitio123.pdf in 10/03/2012.

Choquette, P.W. And pray, L.C. 1970. Geological nomenclature and classification of porosity in sedimentary carbonates. American Association of Petroleum Geologists Bulletin 54, p. 207-250.

Ferrari, A. L. 2001. Evolução tectônica do graben da Guanabara. 2001. 412p. Tese Doutorado em Geologia Sedimentar – USP, Departamento de Geologia, São Paulo, 264 p.

Francisco, B. H. R. 1989. Estratigrafia da bacia de São José do Itaboraí. Rio de Janeiro: UFRJ, (Anuário do Instituto de Geociências, v.12).

Francisco, B. H. R.; GONZÁLEZ, B. B. 1992. Contribuição à petrografia da bacia de São José, município do Itaboraí (RJ). *In:* XXXVII Congresso Brasileiro de Geologia, São Paulo. Bulletin of expanded abstracts, p. 47-48.

Leinz, V. 1938. Os calcários de São José, Niterói, Estado do Rio. Mineração e Metalurgia, v. 3, n. 15, p. 153-155.

Meneses, R. M. X. 2012. Estudo da porosidade em rochas carbonáticas da bacia de São José do Itaboraí-Rj utilizando técnicas Mineralógicas como Ferramenta Complementar. Dissertação de Mestrado, IGEO, UFRJ, 68 p.

Riccomini, C. 1989. Rifte Continental do sudeste do Brasil. Tese Doutorado – USP/Instituto de Geociências, São Paulo, 256 p.

Scholle P. A; Ulmer-Scholle, D. S. 2003. Color guide to the petrography of carbonate rocks: grains, textures, porosity, diagenesis. Oklahoma: American Association of Petroleum Geologists, AAPG Memoir 77, 474 p.

Tibana, P.; Castro, J. C.; Barrocas, S. L. S. 1984. Bacia de Itaboraí. In: XXXIII Congresso Brasileiro de Geologia, Rio de Janeiro. Anais, Sociedade Brasileira de Geologia, p. 5309–5316.