MaP
Microstructure and Pores

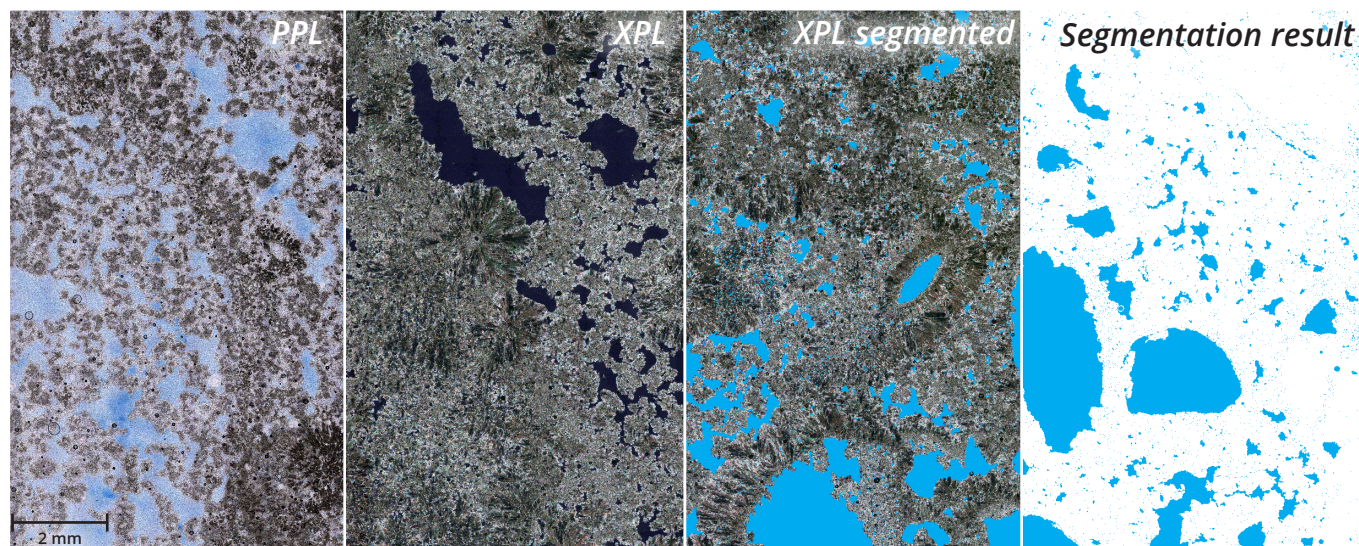# Multi-Scale Imaging and Quantification of Pores in Carbonate Rocks

Figure 1: Plane polarized light, cross polarized light, cross polarized light with segmentation and pore segmentation gigapixel map following the ViP scanning.

Summary

Characterization of the wide range of pore sizes present in many carbonate rock types requires the integration of optical and electron microscopy. At MaP we developed such a routine in order to capture the porosity in a representative way. At first, automated optical microscopy imaging using the Virtual Petrograph (ViP) allows quantification of the macroporosity. Quantification of the microporosity is obtained by analyzing SEM images recorded from BIB-polished sample cross-sections. Pore space is segmented from the ViP and BIB-SEM image data using advanced image processing algorithms. From the integration of both outcomes we can obtain the porosity, pore size distribution and pore geometry and undertake pore type characterization and classification. Additional Liquid Metal Injection (LMI) followed by BIB-SEM surveys the connectivity of the macro- and microporosity.

Aim

The aim of this study is to derive the pore size distribution and the total porosity of a set of quaternary continental carbonate samples (travertines). In addition, the pore connectivity is evaluated to improve understanding of electrical resistivity.

ViP Macroporosity

The ViP is a fully automated optical microscope with a high precision table allowing to image the exact same location at highest possible optical resolution with different polarization angles across the entire thin section. Porosity is segmented from the derived gigapixel map, based on the non-existing extinction behavior of the pore space (Figure 1 and 2). It is corrected for the organic matter, segmented from the plane polarized map. This way we are able to segment hundred thousands of pores accurately within a short time.

BIB-SEM Microporosity

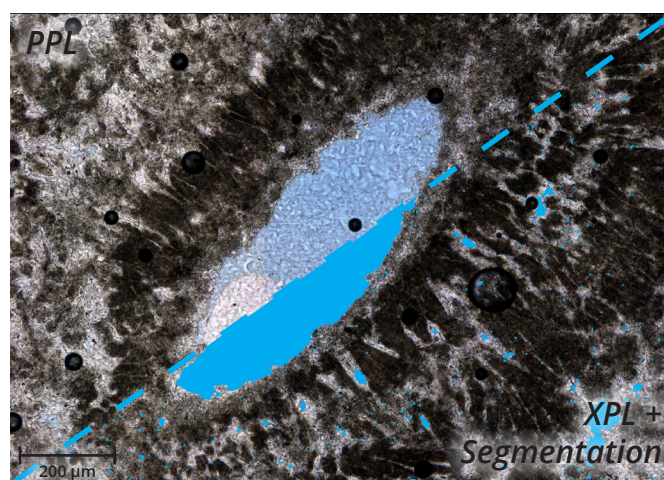The argon ion sputtered surface allows Gigapixel image

Figure 2: Plane polarized light (a) and crossed polarized light (b) image showing pore details and segmentation.

mapping at nano-scale resolution of the microstructure followed by image processing to segment the microporosity (Figure 3). Applying BIB-SEM on an LMI sample allows distinguishing the connected and unconnected pore space down the several nanometers.

Pore Size Analysis

Over 100,000 were segmented from the thin-section and more than 17,000 pores from the BIB-SEM image data. Plotting the number of pores – normalized by the imaged area - versus the pore area shows a linear trend in a log-log diagram (Figure 4) indicating fractal distribution of the pore sizes. Moreover, the best fits show a comparable trend, indicating the representativeness of the data. Adding the microporosity acquired by BIB-SEM to the macroporosity acquired by ViP results in a visible porosity of 19 % (Figure 5). Extrapolating the cumulative porosity down to the nano-pore sizes results in a porosity of 20%. The LMI sample indicates, however, that a significant part of the microporosity is isolated (Figure 6).

Take home message

Multiscale porosity analysis is achieved by combining ViP and BIB-SEM Gigapixel mapping technology resulting in representative pore statistics. LMI provides a viable tool in pore connectivity assessment of the heterogeneous pore networks.
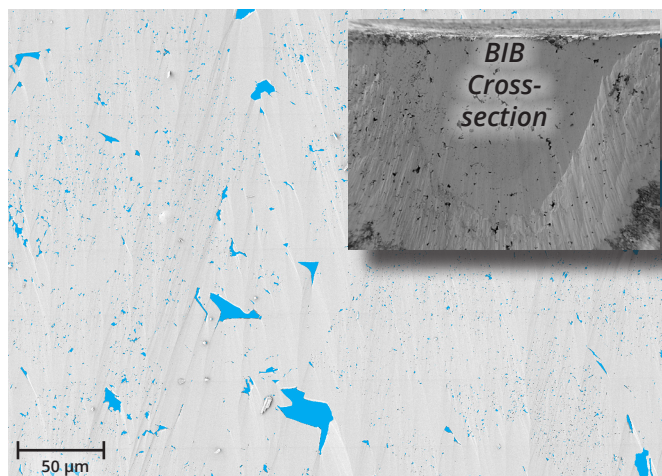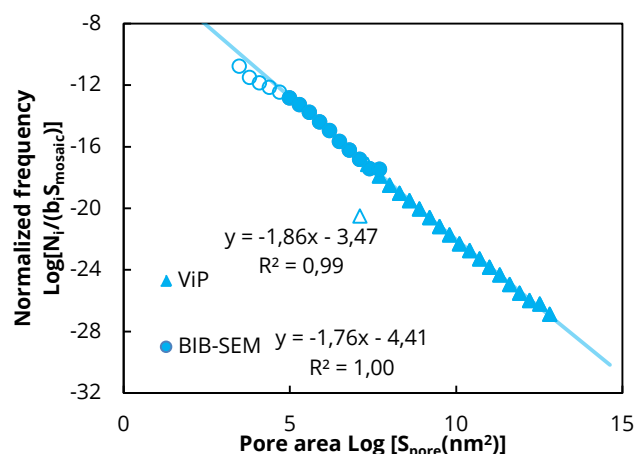

Figure 3: Microporsity is shown by the BIB-SEM mapping.

$$y = -1{,}86x - 3{,}47$$
$$R^2 = 0{,}99$$

▲ ViP

● BIB-SEM $y = -1{,}76x - 4{,}41$
$$R^2 = 1{,}00$$

Figure 4: Normalized pore size distribution.

Figure 5: Cumulative porosity vs. pore diameter.
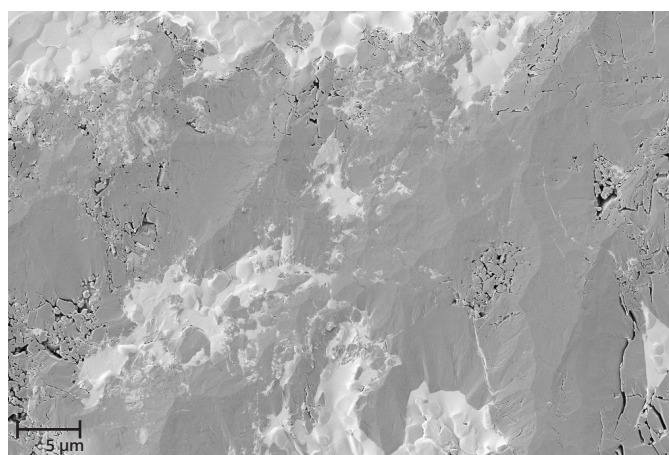
Figure 6: Connected microporosity is indicated by the bright appearance of the injected metal.

Find all of our publications at m-a-p.expert