

Optical Image Analysis applied to pore network quantification of sandstones under experimental CO₂ injection



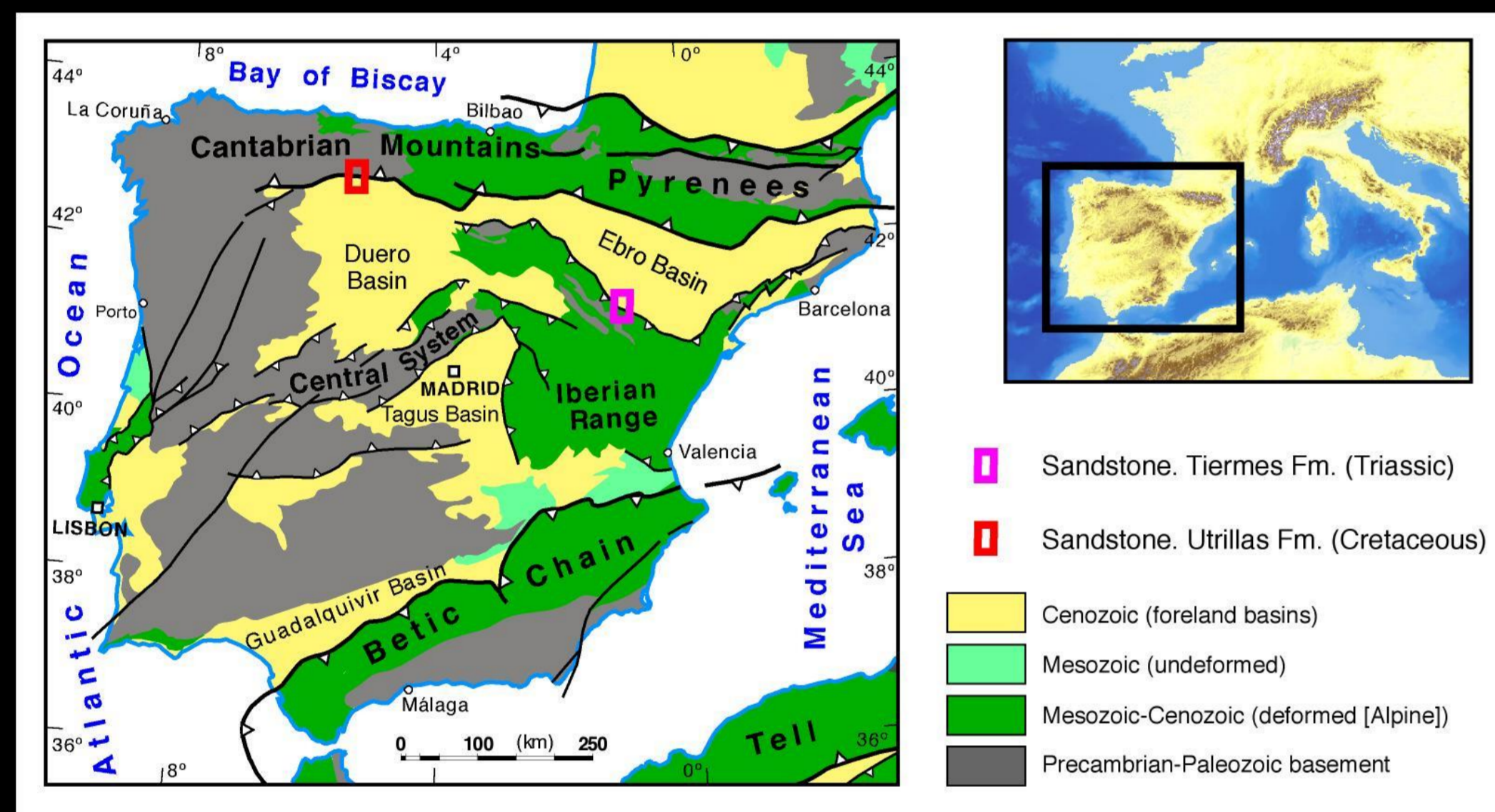
I. Techniques in Pore Quantification

Automated-image identification and quantification of pores with petrographic analysis (minerals and textures) can be applied to improve pore system characterization in sedimentary rocks. In this research, Optical Image Analysis (OIA) has been applied to study the evolution of rock pore network subjected to SC-CO₂ injection. We propose an OIA protocol that guarantees measurement reproducibility and reliability.

II. Targets

- ◆ OIA application focused to measure pore space changes.
- ◆ Quantification of petrographic parameters to thin section scale.
- ◆ Pore system characterization of rocks before and after the CO₂ injection: sedimentary formations in Spain.

III. Materials and Techniques



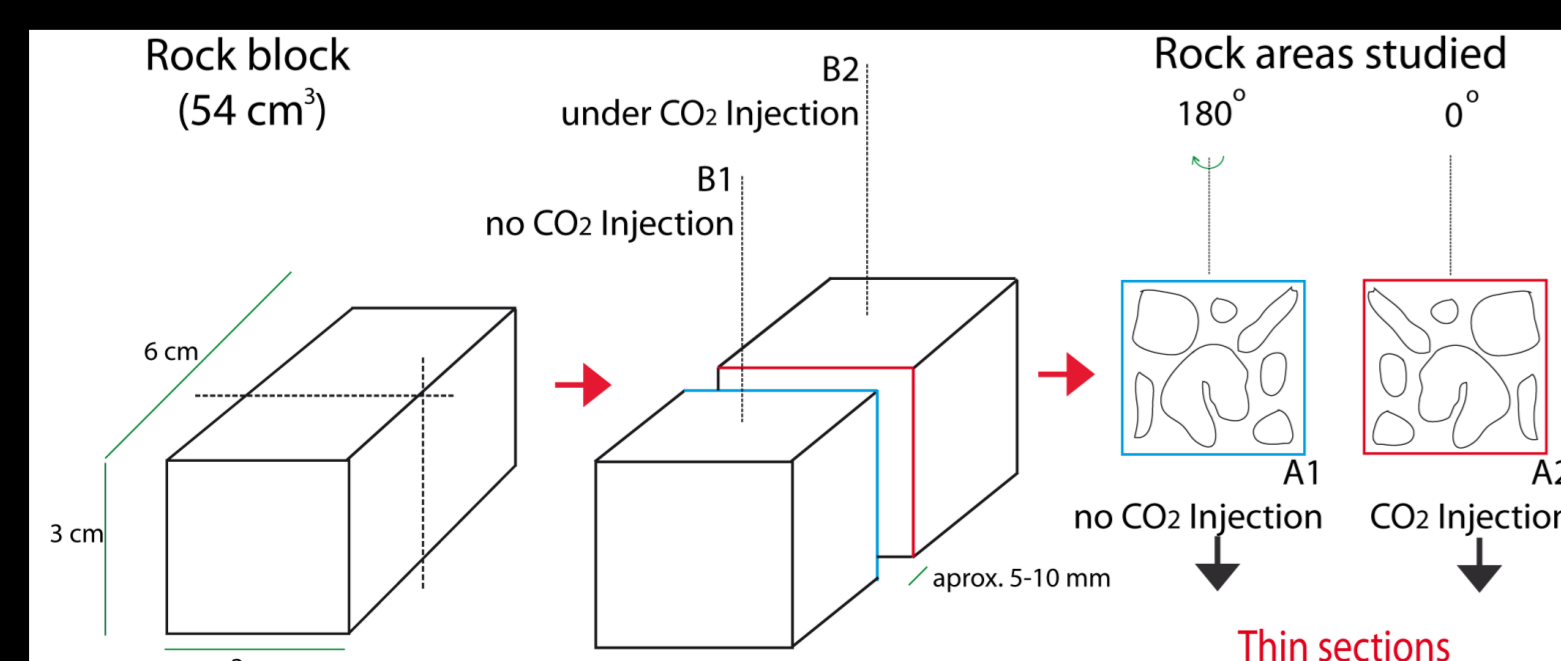
SPAIN (Europe)



- Preliminary studies (CO₂ Geol. Storage Projects).
- Description of regional geology and selection of representative sandstones.
- Rock characterization before CO₂: OpM, SEM, OIA and complementary analysis (XRD/XRF).
- Sample preparation: rock and brine.
- Configuration Test:
CO₂+Sample ⇒ P: 75 bar, T: 35°C, t: 12 to 970 h.
CO₂+Sample+Brine ⇒ P: 78 bar, T: 38°C, t: 24 h.
- Rock characterization after CO₂: OpM, SEM, OIA and complementary analysis (XRD/XRF).

Two contiguous blocks were prepared from sedimentary rock samples.

The two block samples (one before and other after the experimental CO₂ injections) were studied by optical microscopy and OIA on thin sections (30 μm thick).



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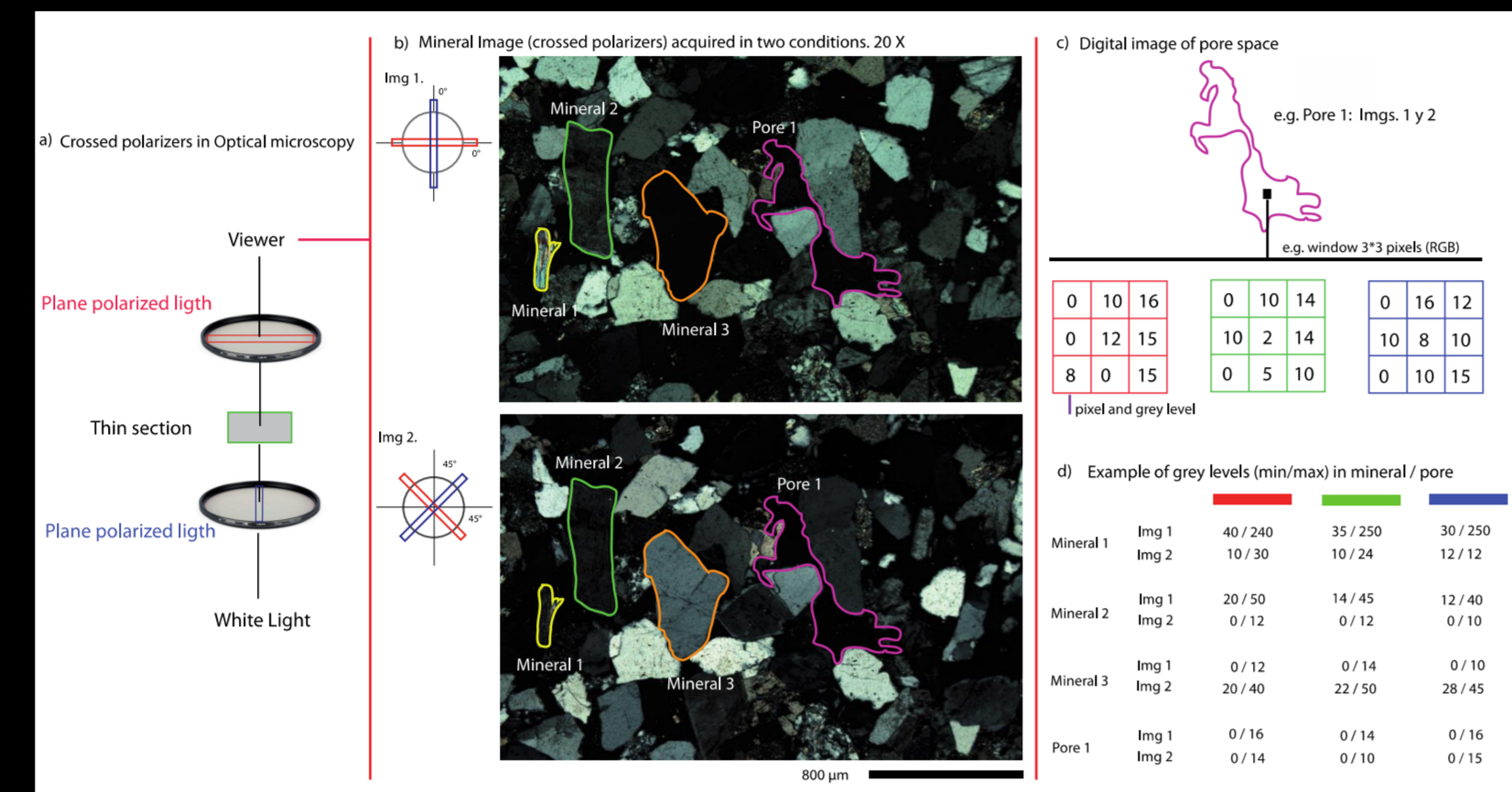
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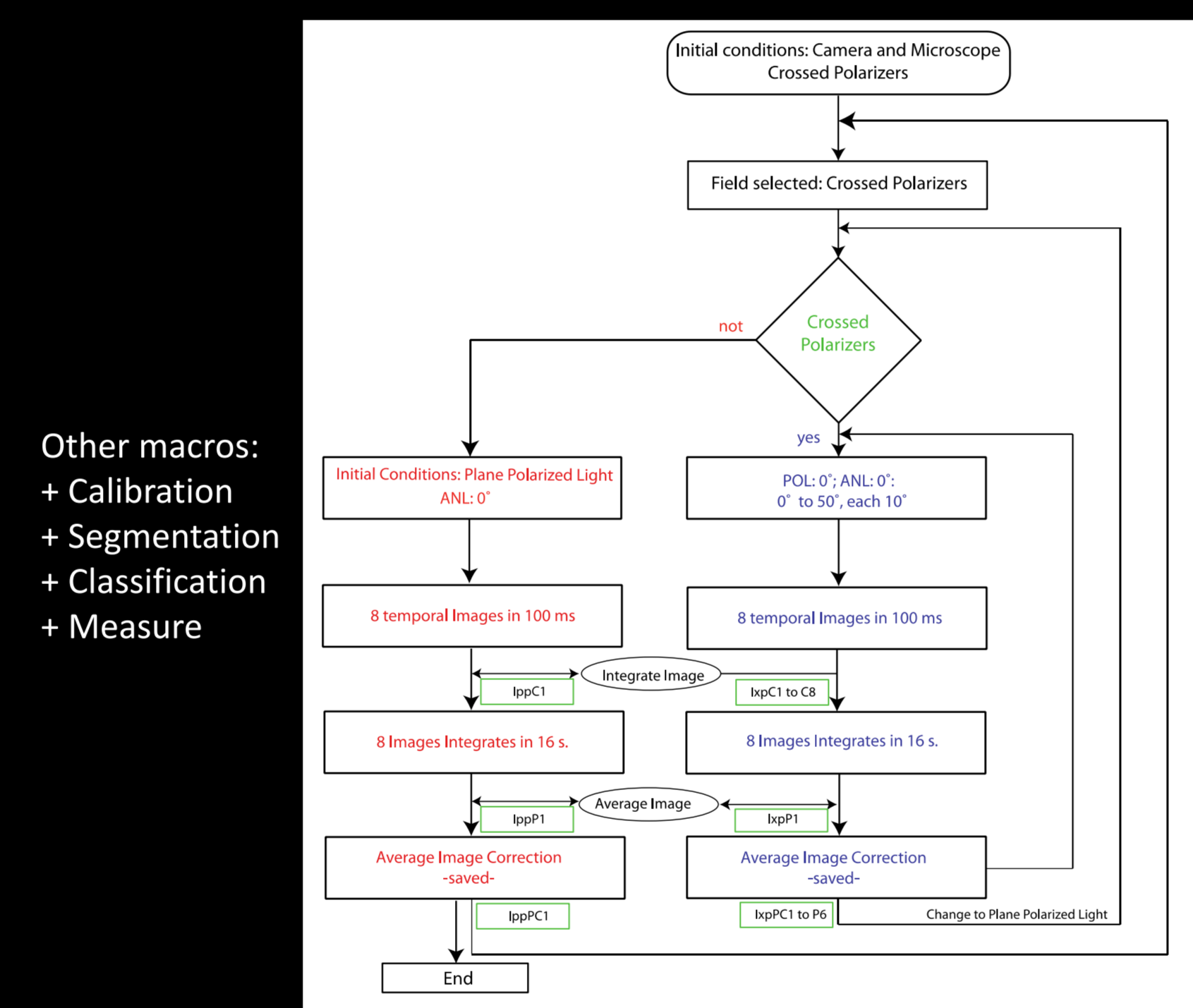
IV. How we measure the pore changes

a) Setting up OIA System

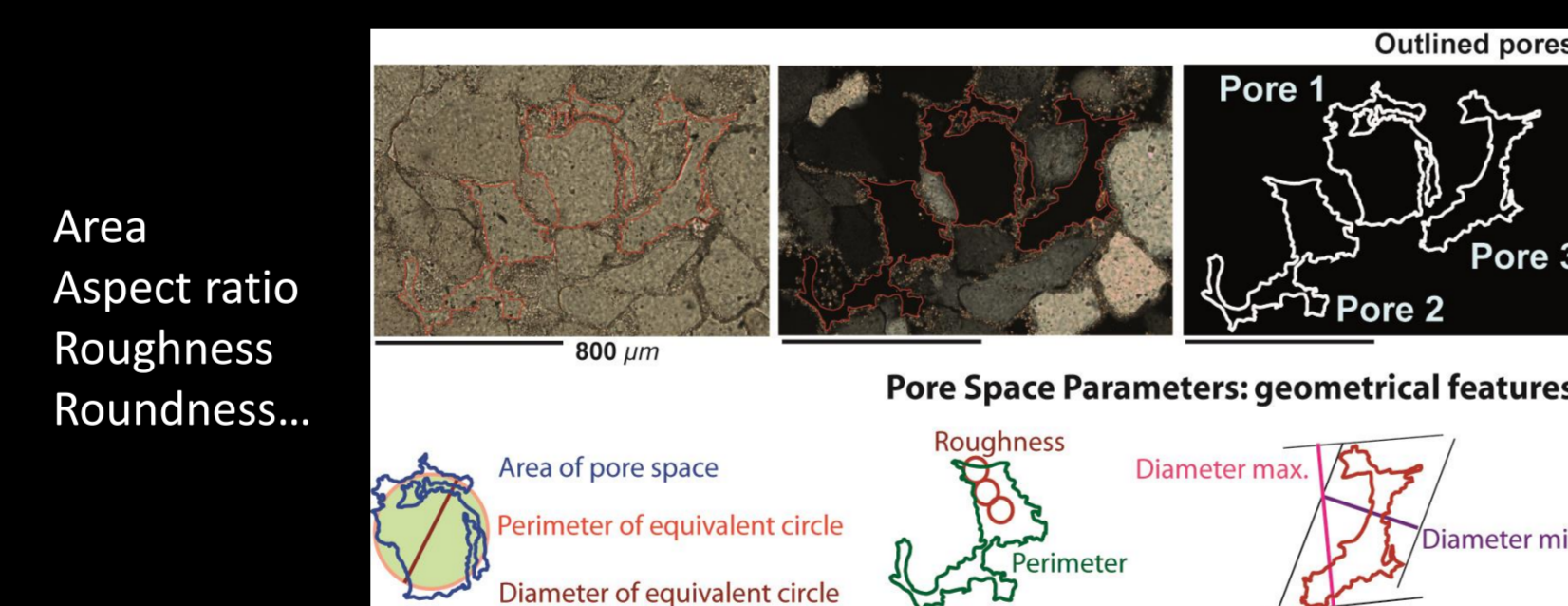
Calibration of CCD and OpM light:
+ Spatial and temporal drift
+ Gain
+ White balance
+ Resolution



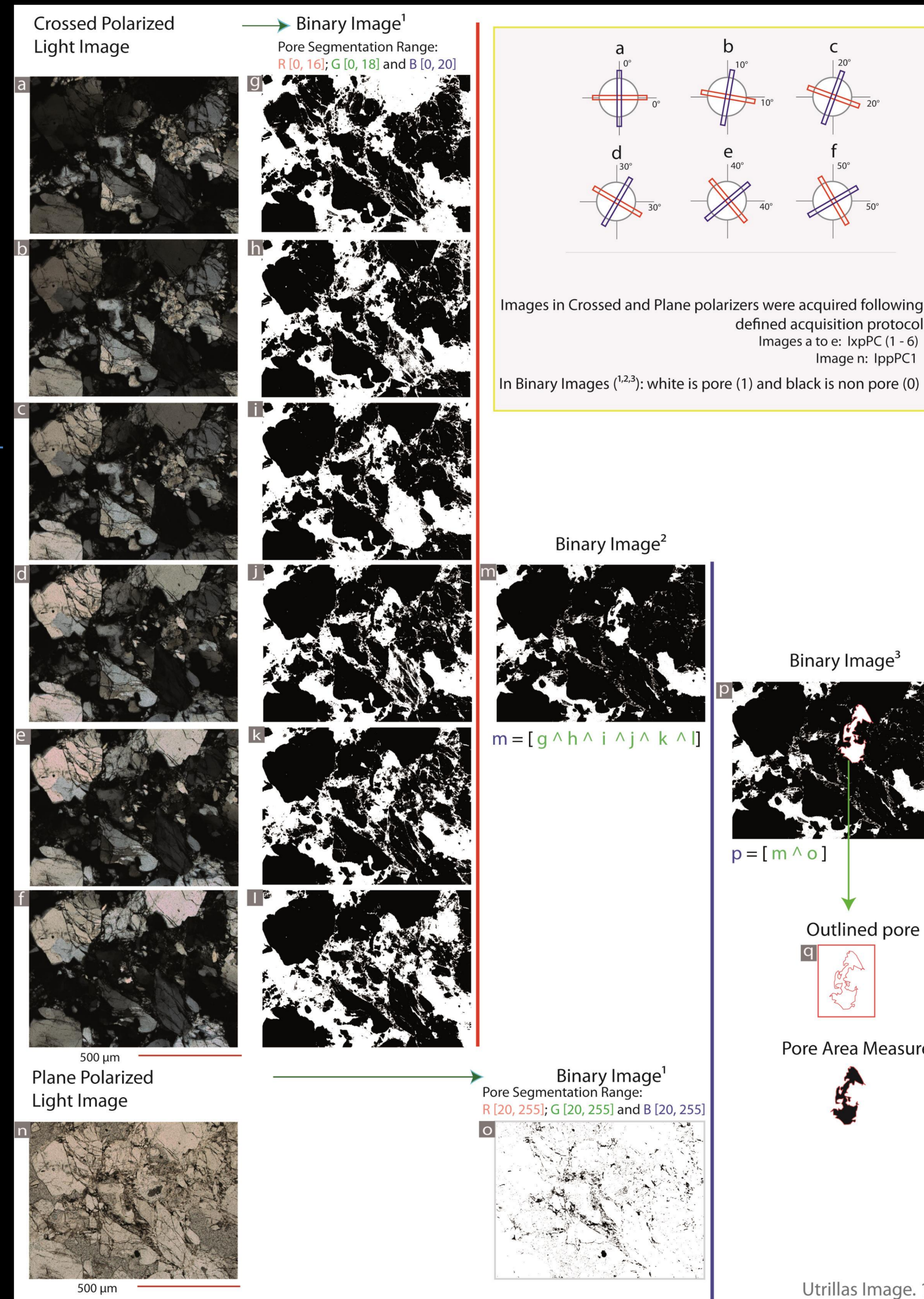
b) Image acquisition Algorithm



d) Parameters to measure



c) Sequence of image Segmentation / Classification / Measure



✓ Updating of OIA tools for the CCD camera and Optical Microscope was done evaluating and adjusting factors like: noises, spatial and temporal drifts, colour calibration, gain, white colour fine tune, geometric calibration, etc.

✓ Algorithm: images acquired using Image Pro+ software (Visual basic Language). Digitalization of information (mineral scenes) in optimal conditions (taking into account camera warming times, light source, image average, etc.). Acquisition of 7 different images (6 in crossed polarizers and 1 in plane polarizers) of the same petrographic scene (synchronized movement of polarizer and analyser every 10 degrees).

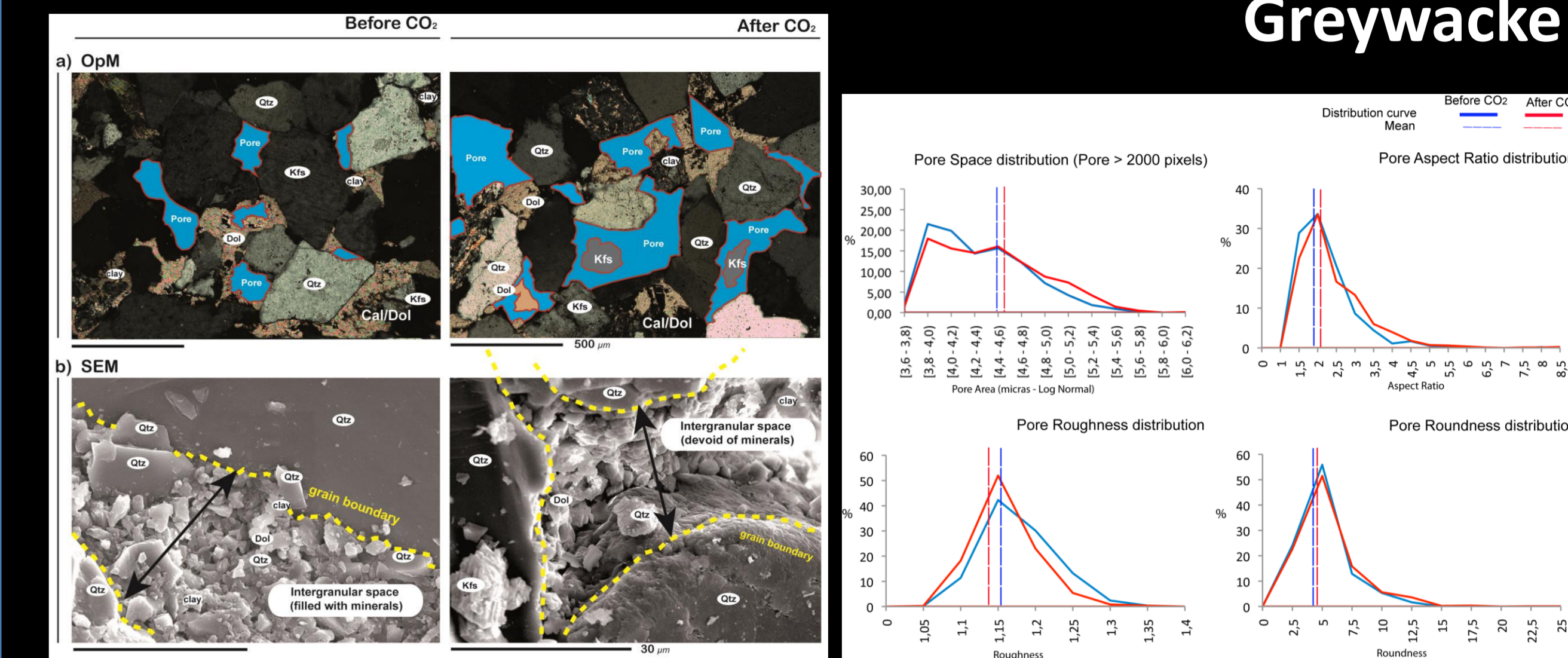
✓ Pore classification, based on regions segmentation, was obtained from intersection of the 7 partial classifications. Interactive correction under supervised expert control. Representative pores in thin section studied were selected and then acquired/measured in windows samples (10x10 pixels). 100 windows were considered for each of the 7 different images. Once the image acquisition was correct (representative, reliable and reproducible) pore segmentation is undertaken. Pore segmentation ranges were obtained for each of different image.

Automated Quantification

- ✓ The developed and presented sequence of work represents an effective process of general application for the automated recognition and quantification, by OIA, of the porous system in a thin section scale.
- ✓ It is applied to rock samples without any pre-treatment highlight porosity (e.g. blue-resin impregnated thin sections) and regarding transmitted light studies and proposed as a semi-automated procedure, obtaining quantitative data of the pore system and geometrical features extracted from each pore space, expanding the possibilities to advanced petrographic studies and mineralogical characterization of the porous system in 2D.

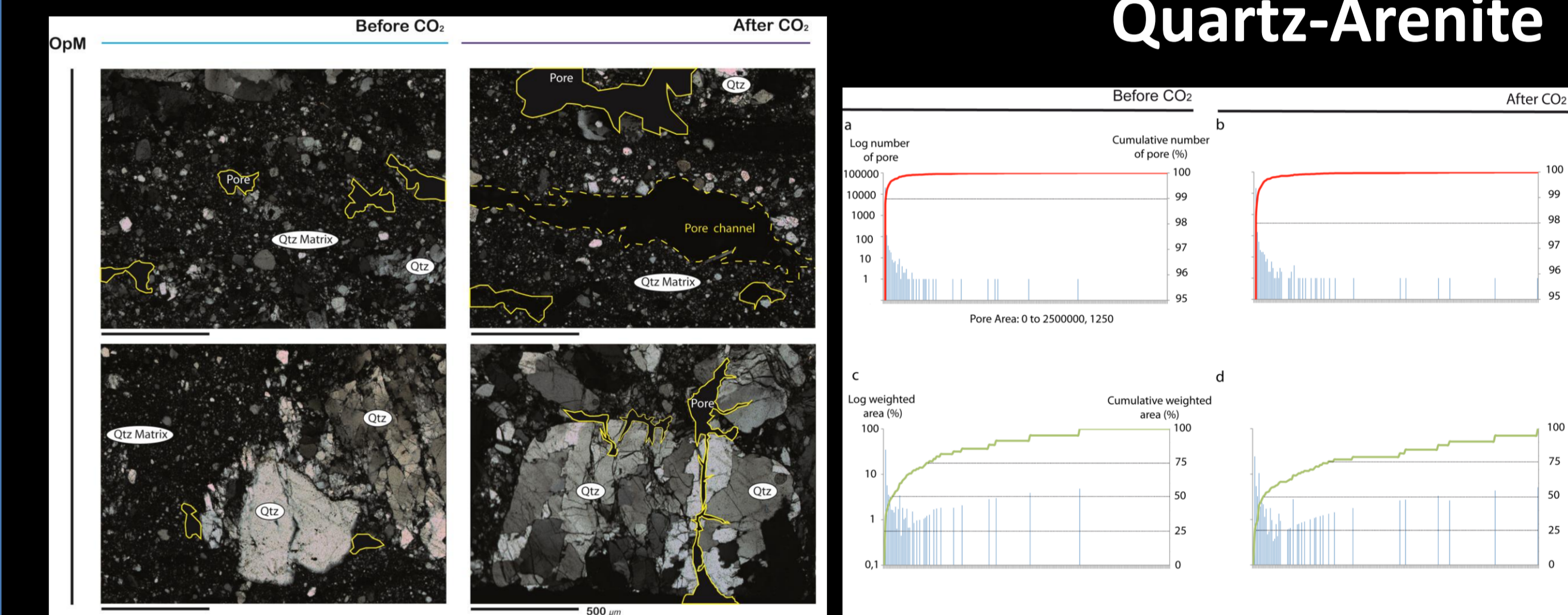
V. Experiments – Pore Space Quantification

A) Rock + CO₂ (970 hours)



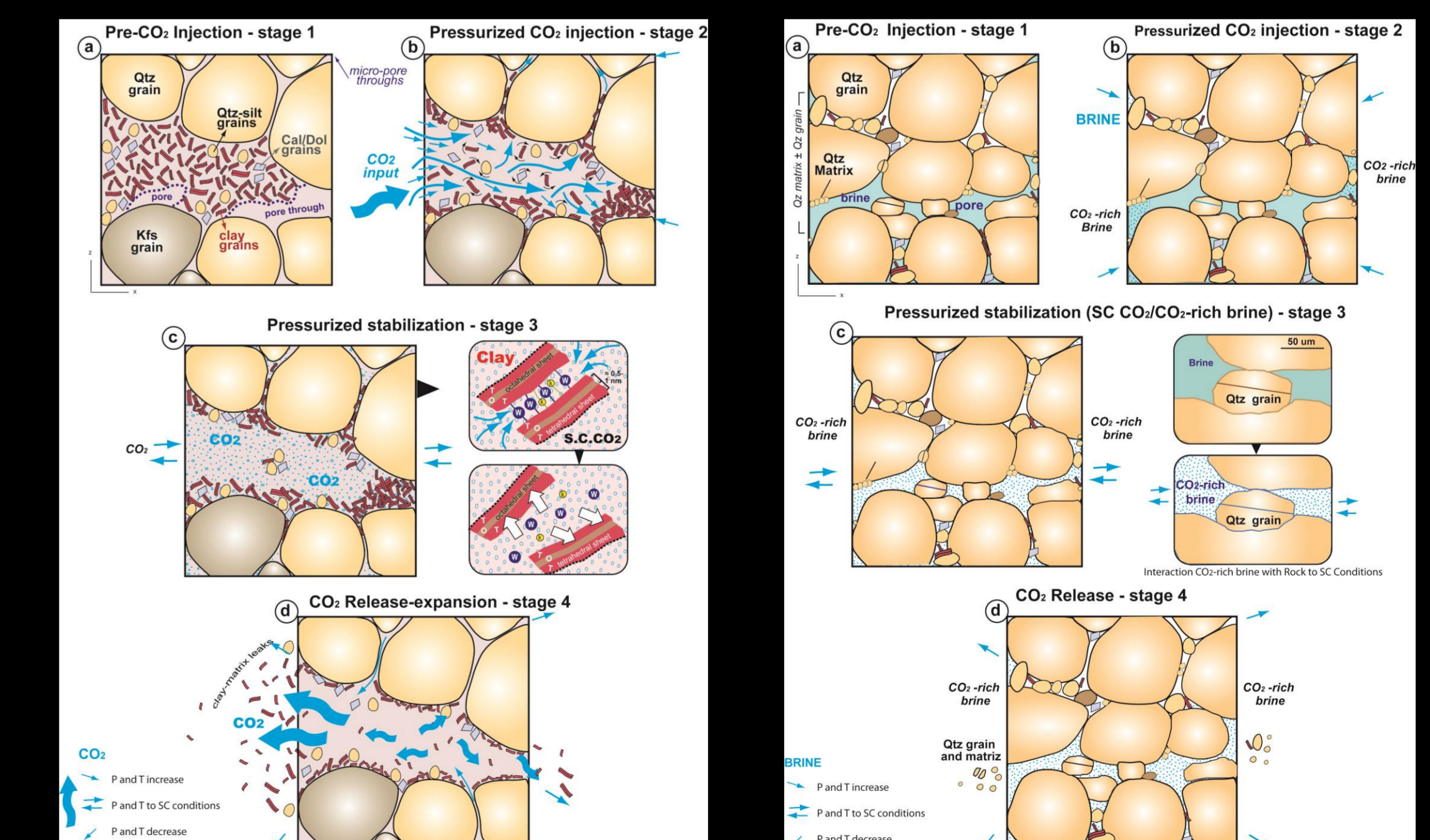
- Increase of number of pores (53 %).
 - Total pore area increased 2.16-4 %.
 - Aspect ratio and roundness of pores increase.
 - Roughness of pores decreases.
- Generation of new pores and size increase of the previous pores.
Pore increase is related to loss of clay matrix.

B) Rock + Brine + CO₂ (24 hours)



- Increase of average pore area (from 168 to 278 μm²).
 - Increase the fracturing and total pore area increased 0.3-2.16 %.
 - pH reduction (7.2 to 5.2).
 - Brine and whole rock chemical changes.
- Generation of new pores and/or no increase of the previous porosity.
Pore increase is related to CO₂-rich brine chemical interactions.

Mineralogical/textural changes after CO₂ injection (A-B)



- ✓ Original rock composition and texture are very important and lead to different effects of the SC CO₂/brine exposure in the experiments.
- ✓ The study of pore changes is performed at rock matrix scale. Quantitative petrography and mineralogy by OIA are important tools to provide numerical values as a key to the successful interpretation of the rock texture and mineralogy.