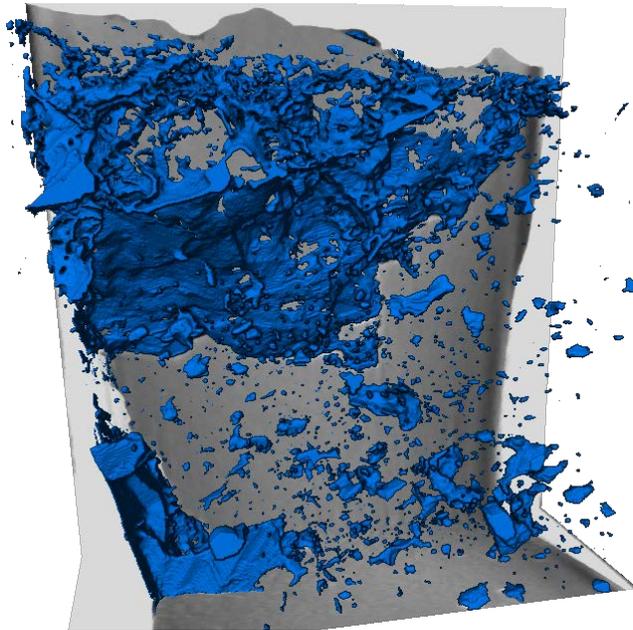


## Pore-backs segmentation in PerGeos



### Introduction

Imagery produced from FIBSEMs (Dualbeams) provides users with unique data in terms of resolution and sample size that are not available with other techniques. Despite the power of this analytical approach, some limitations in quantifying the textural data restrict the accuracy of data obtained from FIBSEM images.

These limitations are derived from artifacts that occur during the acquisition of the data. Collecting data using a FIBSEM is a destructive, serial sectioning technique. A thin slice of material is milled away, the resulting surface imaged, and the process repeated until the requested volume is generated. However, porous materials, by their very nature, create some issues in how to interpret the data that are produced. When each slice is imaged, the empty space (pores and large cracks) are included in the images. If the pore is not deep enough to trap electrons forming a “black” pore synonymous with empty space in SEM imaging, or if it has been filled with redeposited material as a result of the milling process, the back of the pore or other pore filling materials will be imaged. These “pore backs” often termed “pore shine” or “shine through” artifacts make defining the true area of a pore in 2D (volume in 3D) extremely difficult to quantify during post processing using image analysis software.

While ubiquitous, particularly in tight rocks and carbonates, these artifacts can be accounted for. This communication describes some workflows and approaches available using the PerGeos software for Digital Rock analysis. The workflows presented are easy to replicate and automate using PerGeos’ unique automation and processing capabilities and libraries. The workflows presented below are valid for 2D and 3D SEM/FIBSEM data.

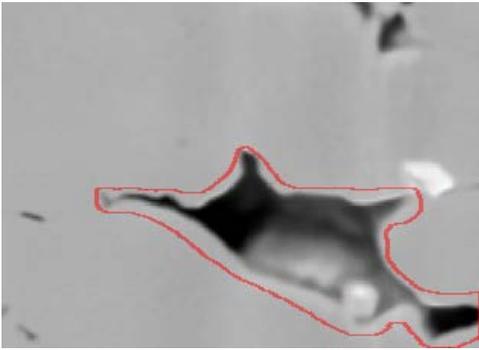


Figure 1 Highlighted pore back in a FIB/SEM slice

## Methodology

The pore-back segmentation will use a 2D expansion by a Watershed Transform from markers.

A 2D rather than 3D watershed is preferred in the case of FIB/SEM images, since the slice spacing is generally much bigger than the pixel size. The difference between 2 consecutive slices creates a high gradient in the Z direction, blocking the usage of a 3D Watershed.

If we use a threshold-based approach to add markers in the matrix, artefacts will appear in the pores-to-matrix slopes, since these regions share the same greyscale intensities:

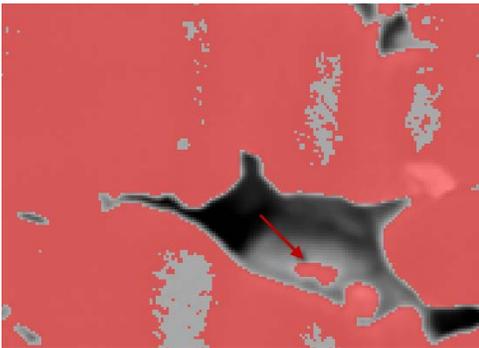
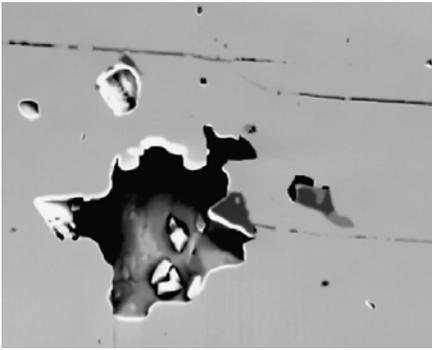


Figure 2 High value intensity thresholding for tentatively marking the matrix

The global idea of our method is to detect flat regions of the matrix with a non-local deviation filter, the variance filter, which unlike the gradient will not have a high intensity in the pore-to-matrix slopes. This way, marking artefacts are avoided, and the high intensity around the pores will make a Watershed Transform on a 2D gradient very effective.

The re-deposition or charging around the pores will even make the process stronger. A very high thresholding to enhance pore markers is then an interesting option.



**Figure 3 Re-deposition around the pores**

In addition to this intelligent workflow, the recipe mechanism of PerGeos makes it easily accessible to any user, repeatable and applicable with light modifications to any data.

The PerGeos recipe incorporates the following steps:

Compute the variance filter ( kernel size of 20-30 )

Mark the matrix with a low variance thresholding

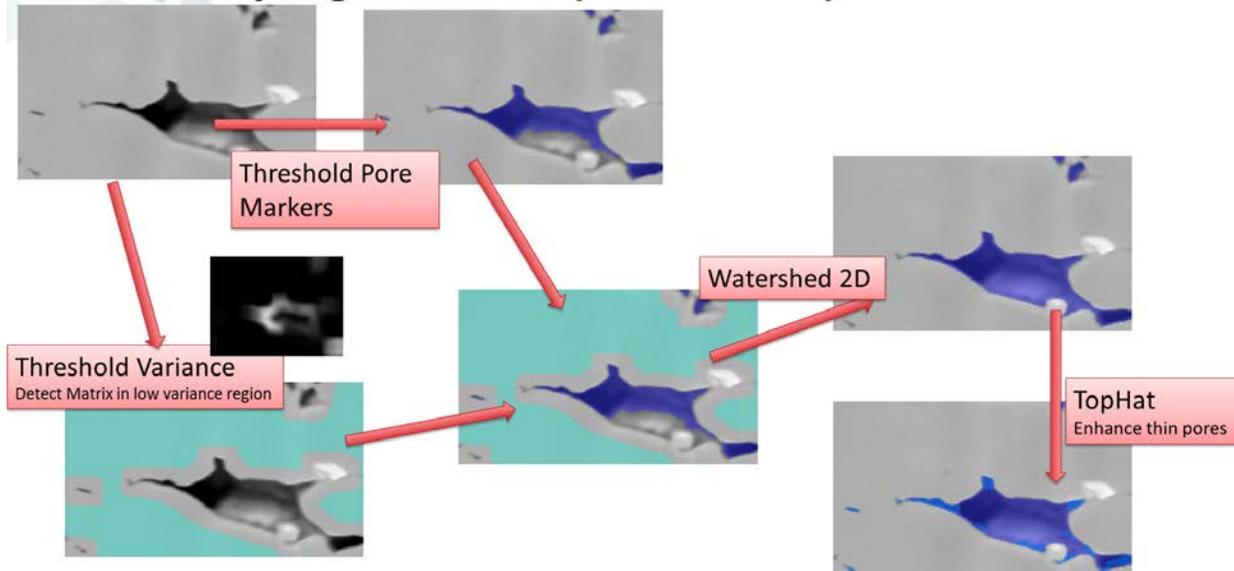
Mark the pores ( done in purpose after the matrix to override low variance pores detected in the previous step ) with low thresholding + optional black tophat

Enhance the pores with a high value thresholding ( optional )

Apply a 2D gradient-based Watershed Transform

Enhance the pores with a black TopHat

## SEM Porosity segmentation ( Pore-backs )



**Figure 4 PerGeos Pore back recipe**

The recipe into details

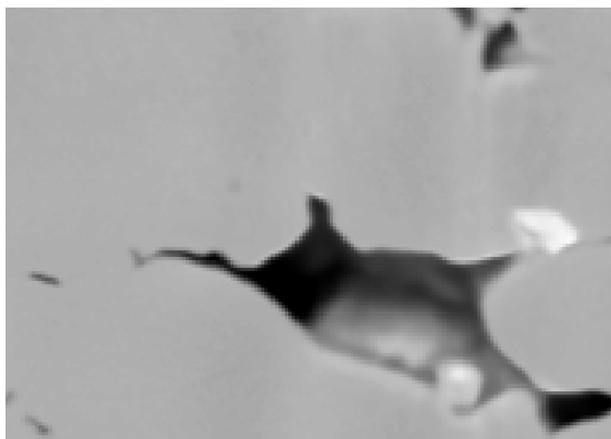


Figure 5 Greyscale image

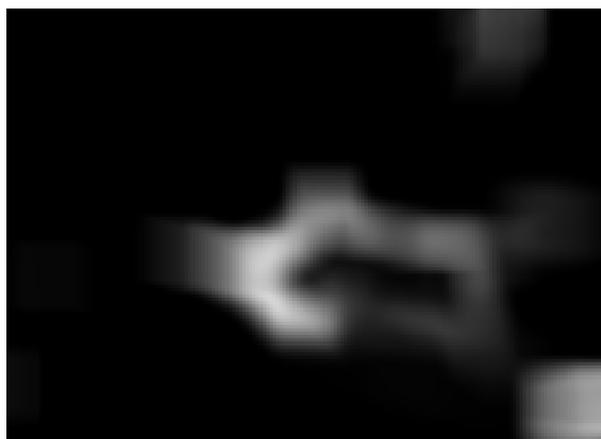


Figure 6 Variance filter (kernel size of 20)

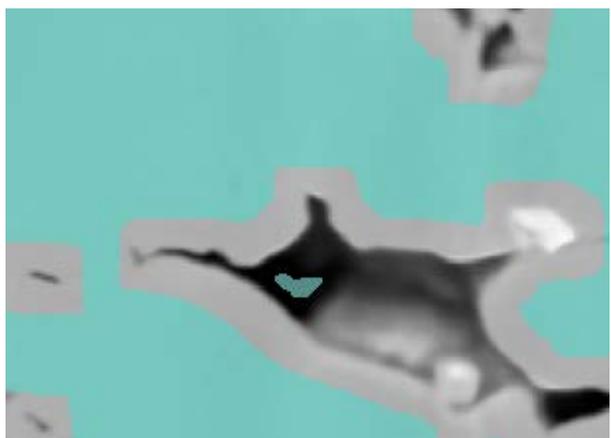


Figure 7 Matrix markers

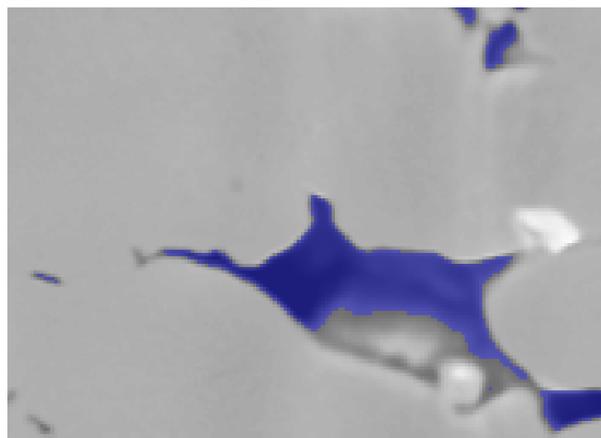


Figure 8 Pore markers after low thresholding

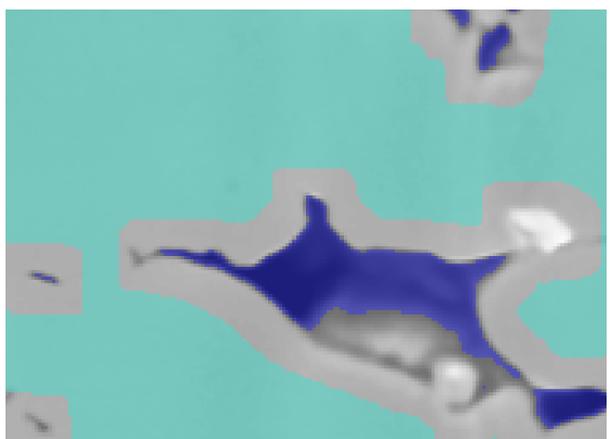


Figure 9 Merged markers

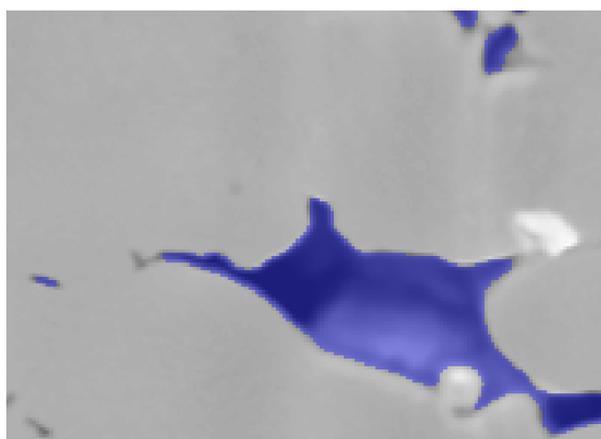
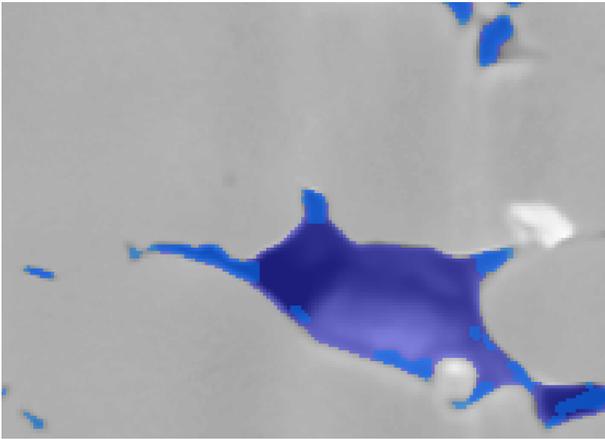


Figure 10 2D Gradient-based Watershed



*Figure 11 Enhancing the pores with a black topHat*

## Alternatives

As for many other segmentation workflows, some alternatives are sometimes interesting.

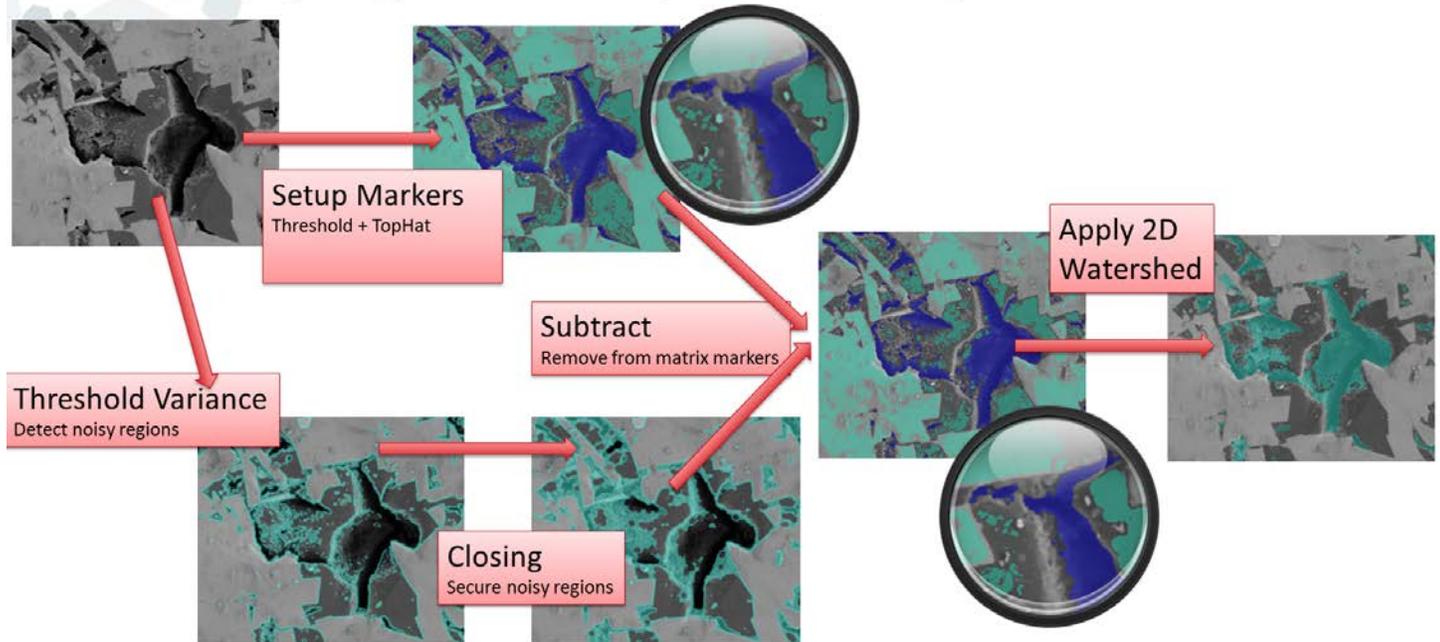
The following workflow has also proven its efficiency on some FIB/SEM data. The major difference is due to the heterogeneity of the matrix (mineral inclusions, organic matter all around the pores) that makes the use of a large variance kernel not possible.

On the opposite, a threshold in the pores is only catching some noise in the pore-to-matrix slopes.

This way, we can use a thresholding to mark both the pores and matrix (enhanced by a topHat), and use a variance with a small kernel, made bigger by a closing, to remove the noise or false markers.

Then, the 2D Watershed expands the markers and catches the pore-backs.

## SEM Porosity segmentation ( Pore-backs )



This PerGeos alternative recipe incorporates the following steps:

Compute the variance filter ( kernel size of 20-30 )

Mark the matrix and the pores with thresholding + optional black tophat

Detect noisy regions with a high variance thresholding

Apply a morphological closing to expand the noisy regions

Subtract the noisy regions from the markers

Apply a 2D gradient-based Watershed Transform