

# Object Detection in SEM Images Using Convolutional Neural Networks: Application on Pyrite Framboid Size-Distribution in Fine-Grained Sediments

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## Abstract

Pyrite framboids have widespread occurrence in sediments of all geological ages. The external spherical or spheroidal (ellipsoidal) form and the internal discrete and equant microcrystalline architecture are the two main characteristics of a framboidal pyrite. Framboid size distribution is fixed very early during diagenesis, and the framboids tend to be preserved through advanced stages of diagenesis. Size-distribution of framboids can be used to infer depositional redox conditions in both modern and ancient sediments. Sixty five scanning electron microscope (SEM) images at instrument magnification of 500X to 3200X from 14 locations across a range of burial depth in the Marcellus Shale were obtained. Around 3200 framboids were manually traced using JMicroVision to unravel the changes in water column oxygenation during the deposition of the Marcellus Shale. The objective of the study is to replace repetitive and time-consuming tasks with machines. Results from manually traced and automation were compared. Deep learning techniques such as convolutional neural network (CNN) are a powerful approach for image analysis. Specifically, CNN can replace manual tracing and significantly shorten the time for object detection and image segmentation. We used Inception and Resnet CNN architectures in this work. We found that the most representative magnification of the SEM dataset is between 1000X to 3000X. Among 65 images, 13 were tested and 52 were used for training. As a result, the CNN can detect ~ 99% of total framboids traced manually, and ~ 60% of framboids with 95%

confidence. Current accuracy of a framboid equivalent diameter detection is less than 4.5%. A few preliminary conclusions can be made: (1) Application of machine learning techniques (CNN) can increase the robustness of object extraction in SEM images. The approach provides quantitative data from SEM images in a time-efficient manner. (2) Optimal image size or magnification for pyrite framboid size detection is between 1000X to 3000X in manual mode (3) To improve image detection accuracy, it is necessary to increase the numbers of training images. On-going efforts include incorporating labeled compositional SEM-EDS maps to achieve better segmentation among different objects, and to extend this work more broadly to other geological fabrics.