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Machine Learning for Mineral Segmentation and Accessibility Quantification in Scanning Electron Microscopy Images

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Reactive transport models are powerful tools to simulate mineral reactions, aqueous solution speciation, and mass transport in a range of reactive systems. Simulations are constructed based on knowledge of mineral abundances and surface areas where imaging has shown utility for quantifying such information. Typically, images are manually processed by domain experts, which is time-consuming, labor intensive, and subjective. Thus, emerging techniques such as machine learning based image processing that can potentially address the limitations and accelerate image processing are desired. The performance of these for accurate sample characterization has not been completely evaluated. This study evaluates the potential of machine learning methods for mineral characterization of five sandstone samples over various 2D scanning electron microscopy (SEM) image resolutions. First, Random Forest and the U-Net method were trained and evaluated for semantic segmentation of SEM-backscatter electron (BSE) and energy dispersive x-ray spectroscopy images (EDS) images of thin sections captured at different resolutions. Using the produced mineral map, the porosity, mineral abundances, and mineral accessibilities were quantified by pixel counting. The results show both methods have an acceptable performance with the U-Net model outperforming Random Forest due to the ability to consider spatial as well as pixel-wise information. Varying imaging resolutions results in small variations of mineral abundances of relatively bigger granular classes (e.g., quartz) compared to minority classes. Mineral accessibilities of clays (smectite/illite) decreased due to misclassification of pores and clays, resulted in accessibilities for the majority classes.