PoreViT: Automated Pore Classification in Carbonates Using Vision Transformers

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Abstract

Pore classification in carbonates is crucial for subsurface characterization, including carbon capture and storage, and hydrocarbon extraction. The classification and quantification of porosity textures enable a deeper understanding of the mechanisms involved in porosity evolution, as well as the grouping of flow units.

Carbonates have complex pore morphologies influenced by depositional and diagenetic processes. Traditionally, pore classification involves manual identification within thin sections according to established schemas like Choquette and Pray (1970), Lucia (1983, 1995), and Lonoy (2006), often performed in a qualitative or semi- quantitative manner using methods such as point-counting. However, manual approaches are hampered by inefficiencies, subjectivity, and a lack of scalability. Integrating qualitative descriptions into reservoir characterization poses a critical challenge due to the quantitative nature of other data inputs. Despite recent efforts to automate petrographic pore-typing through artificial intelligence (AI) and computer vision (CV), concerns persist regarding their efficacy and validity, mostly with the prevailing assumption that pores can be distinguished into genetic classes solely based on size and shape features, which is most often not the case. To address this nuanced classification problem, our study presents an enhanced CNN framework by integrating advanced feature extraction techniques that emphasize texture, contrast, and edge delineation to classify macropores into their respective Choquette and Pray (1970) and Lucia (1983, 1995) classes. Notably, our approach leveraged neighborhood information to show interconnections, recognizing that pore types cannot be solely classified based on shape but also require consideration of the spatial context involving skeletal, depositional, and diagenetic components. Through analysis of 20 high-resolution carbonate thin sections and the use of a balanced labeled dataset, our model successfully classified pores with improved reliability. The enhanced CNN model demonstrated a significant increase in precision and recall rates compared to traditional methods, underscoring the potential of deep learning in complex geological classifications. Our model serves as a useful tool for the automated classification of complex carbonate macropores and can further be extended to identify microporosity and diagenetic units leading to holistic classification of thin sections.