Taking Carbonate Microfacies Classification to the Next-Level with Self-Supervised Vision Transformers

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Abstract

The accurate classification of carbonate microfacies plays a pivotal role in understanding depositional history and predicting reservoir characteristics for energy exploration. Traditional manual classification methods are time- consuming and subjective, prompting the need for robust automated approaches. While recent works have shown the potential of supervised deep learning in optimizing carbonate microfacies classification, the limited availability of high-quality labeled dataset remains a significant challenge. Here, we introduced a novel methodology for Dunham-based carbonate microfacies classification by leveraging the power of self-supervised learning, allowing the model to learn from unlabeled data efficiently using a self-supervised vision transformer (ViT) architecture, specifically self-distillation with no label architecture (DINO). The unlabeled dataset (> 5,000 images) was obtained from various publicly available resources and further augmented with generative AI to enhance the number and variability of images without manually collecting the images. In our self-supervised training, we used 20% of the labeled dataset and validated and tested on 80% of the dataset. Our results demonstrate that the proposed model can match and often times outperform conventional supervised deep learning models, reaching an F-1 score up to 92%, showcasing the efficacy of self-supervised learning in carbonate microfacies classification. We further observed that image augmentation by creating realistic synthetic images using generative AI generally provides better performance improvement than standard image augmentation. This research contributes to the growing intersection of geoscience and artificial intelligence, paving the way for more sophisticated and automated methodologies in subsurface characterization. The self- supervised vision transformer framework presented in this study holds promise for broader applications in the interpretation of geological data, automating complex geological processes, and underscores the transformative impact of AI in the field of sedimentary geology.