Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.30868

Automated Quantification of Modal Layering in Ancient Lower Oceanic Crust Using Computer Vision

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Computer vision is a field of artificial intelligence that enables machines to process and analyse visual data, allowing for the automated interpretation of complex imagery. In the geosciences, it has emerged as a powerful tool for classifying geological materials based on their optical properties, offering an efficient alternative to traditional manual approaches. This work presents a method capable of extrapolating petrological, mineralogical and geochemical properties from a relatively small number of discrete sample analyses by leveraging high-resolution computer vision classifications. Using this method, we provide a standardised approach to quantifying modal layering within drill core images from the mid-to-lower cumulate crust of the Samail Ophiolite. We utilised a spatially guided contrastive learning model (GeoCLR) to objectively classify two >400 m long core intervals from Oman Drilling Project Holes GT1A and GT2A. By leveraging GeoCLR's capacity to classify rock textures based on modal olivine abundance, we generated a continuous, centimetre-scale record of olivine concentration throughout both drill cores. This AI-driven classification workflow, anchored by expert annotations, offers an efficient and scalable alternative to traditional labour-intensive approaches. The high-resolution olivine concentration dataset was further integrated with discrete sample geochemical data to model variations in bulk Ni content. These calculated geochemical variations allowed an estimation to be made of the melt lens thicknesses responsible for cumulate layer formation via a simple mass balance approach. By combining advanced computer vision techniques and discrete sample analysis, this work represents a substantial advancement in Earth and planetary sciences, providing a novel toolkit for high-resolution and objective interrogation of geological systems.