

Multimodal Integration of XRF Geochemistry and Core Imagery for Scalable, Automated Lithological Logging

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Lithological logging of drill core underpins mineral exploration and resource modelling, yet remains inherently subjective and time-intensive. The increasing availability of continuous X-ray fluorescence (XRF) geochemical data alongside high-resolution core imagery provides an opportunity to improve the consistency, resolution, and scalability of lithological interpretation through integrated, data-driven methods.

This study evaluates four machine learning approaches for automated lithology classification: (1) a random forest model using XRF geochemical data, (2) a convolutional neural network (CNN) trained on core imagery, and (3–4) two multimodal CNN architectures that combine both data sources. The multimodal models differ in their data fusion strategies, including a late fusion approach with geochemical information appended to extracted image features deep in the CNN, and a feature-wise linear modulation (FiLM) framework, in which geochemical inputs are used to condition intermediate feature representations within the image model.

All models are trained and validated against expert geological logs from drill core datasets. Results indicate that unimodal models capture distinct but incomplete aspects of lithological variability, whereas multimodal approaches consistently improve classification performance. The FiLM-based model achieves the strongest results, suggesting that earlier and more tightly coupled integration of geochemical information enhances the network's ability to resolve subtle compositional and textural differences.

These results demonstrate the practical value of combining XRF and imagery data for automated lithological logging. The proposed approach offers a scalable pathway to more consistent geological interpretation, with direct applications in exploration workflows, improved domain definition, and more robust resource modelling.