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Moving Beyond Data-Driven Igneous Petrology

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Machine learning (ML) is moving from a niche approach to an integrated component of igneous petrology. However, progress is increasingly limited by fragmented datasets, a lack of reproducibility, and a growing need to strengthen data-driven discovery (e.g., Petrelli, 2024). Resilient, interoperable, and FAIR geochemical infrastructures, linking samples, instruments, workflows, and repositories through persistent identifiers, are a prerequisite for trustworthy ML at scale, and many researchers are working in this direction (e.g., IEDA2, GeoRoc, and Mindat). Among the different attempts, Orange-Volcanoes is an open, collaborative platform that brings compositional data analysis, multivariate statistics, and ML into visual programming workflows tailored to data-driven petrology and volcanology (Musu et al., 2025).

This talk aims to move beyond purely data-driven approaches by highlighting emerging directions in which ML can efficiently complement traditional petrological practice. I emphasize two high-value frontiers in petrology and volcanology: (1) building and integrating multimodal petrological datasets that combine chemistry, textures, and spatial imaging from microanalytical methods; and (2) developing physics-informed, ML-enabled petrological models.

Petrelli (2024), doi:10.1093/petrology/egae036
Musu et al. (2025), doi:10.1016/j.acags.2025.100270