## Global Controls on the Formation of Porphyry Systems: Insights from Machine Learning and Plate Tectonic Reconstructions

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Porphyry systems account for the majority of global copper production and host significant gold and molybdenum resources. As demand for copper grows, driven by the expansion of renewable energy technologies, understanding the controls on porphyry formation has become increasingly important. These deposits are typically associated with subduction-related volcanoplutonic arcs, but a limited understanding of the processes within the subducting and overriding plates, as well as the mantle wedge, constrains our ability to improve prospectivity mapping and exploration targeting. In this study, we develop a global prospectivity model for porphyry mineralisation using a machine learning approach trained on a global database of porphyry occurrences. This model incorporates spatiotemporal features from a global plate tectonic reconstruction, including ocean basin evolution from 540 Ma to the present. Our results highlight three primary factors influencing porphyry formation: total carbon density of the subducting plate, distance to the trench, and pelagic sediment thickness on the downgoing slab. Porphyry deposits are most commonly found 200–400 km from the trench, typically associated with subducting slabs that have carbon densities exceeding 10 t/m² and carry pelagic sediments thicker than 200 m. We postulate that high carbon densities may be related to volatile release into the mantle wedge, promoting metasomatism, magmatism, and mineralisation. Trench distance likely reflects slab dip, with the degree of mechanical coupling between the subducting and overriding plates as a secondary factor influencing crustal deformation and volatile pathways. Thick pelagic sediments may indicate higher water content subducted with the slab, which is released as fluids that metasomatize the overlying asthenospheric mantle wedge—conditions favourable for the redistribution and enrichment of soluble metals (e.g., Cu, Au, Pd) in metasomatised mantle regions. These findings offer new quantitative insights into the tectonic and geochemical controls on porphyry formation, establishing a robust framework for global-scale exploration targeting.