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Ore Deposit Science: The Emergence of Context

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The early years of Earth Science were restricted to surface observations and were dominated by geological mapping. As a result, our view was very much “top-down,” and ore deposit science was largely conducted at the deposit to district scale. Plate Tectonic Theory revolutionised our understanding of both the planet and ore deposit genesis, opening the door to a prediction-based approach to targeting utilising diverse geoscience information from multiple scales. In more recent decades, emergent technologies and the ease of information transfer have opened the door to a more comprehensive and informed understanding of continents and Earth processes. Multi-disciplinary (geological, petrographic, geochemical, geophysical, geochronological, and isotopic) study of both the Sub-Continental Lithospheric Mantle (SCLM) and overlying crust allows us to map the architecture and tectonothermal evolution of the entire 60- to 280-km-thick continental lithosphere. We find that the SCLM originated dominantly in the Archean, and that outside the cratons, this ancient SCLM is strongly modified and subdivided into microcontinental blocks generally bounded by steep Trans-Lithospheric Faults (TLFs). Geodynamic processes, dominated by Plate Tectonics, have resulted in physical and chemical changes to the lithosphere, fundamentally influencing ore deposit formation and preservation.

Mineral deposit genesis is now viewed through the prism of Mineral Systems that operate at the scale of the entire lithosphere (e.g., Griffin et al., 2013, Nature Geoscience 6, 905-910) and are influenced by global geodynamic processes (e.g., Begg et al., 2018, In Processes and Ore Deposits of Ultramafic-Mafic Magmas through Space and Time; Mondal & Griffin (eds), Elsevier). The latter dictate lithospheric architectural and tectonic settings and availability of metal sources, and act as temporal triggers for the ore-forming stage(s) of the Mineral System. For example, magmatic Ni-Cu systems are controlled by supercontinent cycles, global patterns of whole-mantle convection, lithospheric architecture (including craton margins and variations in lithospheric thickness), and Plate Tectonic-driven stress states, including stress switching. Whilst Porphyry Copper systems are dependent on convergent margin processes, it is the spatial and temporal arrangement of zones of most intense shortening, and their moments of relaxation, that activate the ore-forming stages. Otherwise ordinary sub-arc magmas are transformed into Cu-fertile melts that ascend into the upper crust. Gold deposits arise from a two-stage process. The first, through the action of low-degree partial melting induced by changing physiochemical conditions, is the creation of zones of metasomatized mantle with enhanced frequency of gold-bearing veinlets. The second involves selective melting of such veinlets, through the agency of changing P-T conditions induced by tectonic triggers. Fluids exsolved from such melts at deep crustal levels migrate to shallower levels where deposits form at sharp P-T-X gradients.

Economic geology has evolved from its early deposit- and upper-crustal-centric focus to embrace structure and Mineral System processes at lithospheric-scale in 4D, and to an intimate connection with the global geodynamic system. This has raised a whole new set of questions and fertile areas for future research. The door to the next century of investigation and discovery is open.