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Chapter 8

The Mineral System Concept: The Key to Exploration Targeting

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Abstract

To aid conceptual targeting, the past two decades have seen the emergence of the mineral systems concept, whereby ore deposits are viewed as small-scale expressions of a range of earth processes that take place at different temporal and spatial scales. The mineral systems approach has been spurred by three main drivers: the recognition of patterns of mineralization in increasingly available large geoscience datasets; advances in geographic information system (GIS) technologies to spatially query these datasets; and marked advances in understanding the evolution of earth systems and geodynamics that provide context for mineralization patterns. An understanding of mineral systems and the scale-dependent processes that form them is important for guiding exploration strategies and further research efforts.

Giant ore deposits are zones of focused mass and energy flux. Advances in understanding of the physics of complex systems—self organized critical systems—leads to a new understanding of how fluid flow is organized in the crust and how high-quality orebodies are formed. Key elements for exploration targeting include understanding and mapping threshold barriers to fluid flow that form extreme pressure gradients, and mapping the transient exit pathways in which orebodies form.

It is proposed that all mineral systems comprise four critical elements that must combine in nested scales in space and time. These include whole lithosphere architecture, transient favorable geodynamics, fertility, and preservation of the primary depositional zone. Giant mineral deposits have an association with large, long-lived deeply penetrating and steeply dipping structures that commonly juxtapose distinctly different basement domains. These structures are vertically accretive in nature, often having limited or subtle expressions at or above the level of ore deposition.

Three transient geodynamic scenarios are recognized that are common to many mineral systems: anomalous compression, initial stages of extension, and switches in the prevailing far-field stress. In each of these scenarios, ”threshold barriers” are established which produce extreme energy and fluid/magma pressure gradients that trigger self-organized critical behavior and ore formation.

Fertility is defined as the tendency for a particular geologic region or time period to be better endowed than otherwise equivalent geologic regions. Fertility comprises four major components: secular Earth evolution (variations in the Earth’s atmosphere-hydrosphere-biosphere-lithosphere through geologic history that result in formation of deposits), lithospheric enrichment, geodynamic context, and paleolatitude (in specific mineral systems).

The primary depositional zone is usually within the upper 10 km of the Earth’s surface, where large P-T-X gradients can be established over short distances and time scales. The variable preservation of this zone through subsequent orogeny explains the secular distribution of many ore deposit types.

The mineral system approach has advantages in exploration targeting compared to approaches that use deposit models. Emphasizing common ore-forming processes, it links many large ore systems (e.g., VMS-epithermal, porphyry-orogenic gold) that are currently considered disparate deposit models and relates these ore systems in a predictable way to their large-scale geodynamic context. Moreover, it focuses mineral exploration strategies on incorporating primary datasets that can map the critical elements of mineral systems at a variety of scales, and particularly the regional to camp scales needed to make exploration decisions.

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