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100th Anniversary Special Paper: Secular Changes in Global Tectonic Processes and Their Influence on the Temporal Distribution of Gold-Bearing Mineral Deposits

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Abstract

Mineral deposit types commonly have a distinctive temporal distribution with peaks at specific periods of Earth history. Deposits of less redox-sensitive metals, such as gold, show long-term temporal patterns that relate to first-order changes in an evolving Earth, as a result of progressively declining heat production and attendant changes in global tectonic processes. Despite abundant evidence for plate tectonics in the early Precambrian, it is evident that plume events were more abundant in a hotter Earth.

Episodic growth of juvenile continental crust appears to have been related to short-lived (<100 m.y.) catastrophic mantle-plume events and formation of supercontinents, whereas shielding mantle-plume events correlated with their breakup. Different mineral deposit types are associated with this cycle of supercontinent formation and breakup. Broadly synchronous with juvenile continental crust formation was the development of subcontinental lithospheric mantle, which evolved due to progressively declining heat flow and decreasing plume activity. Archean subcontinental lithospheric mantle has a distinct mineralogical composition and is buoyant, whereas later lithosphere was progressively more dense. Changes in the buoyancy of both oceanic lithosphere and subcontinental lithospheric mantle led to evolution of tectonic scenarios in which buoyant, roughly equidimensional, early Precambrian cratons were rimmed by Proterozoic or Phanerozoic linear elongate belts of neutral to negative buoyancy.

Orogenic gold deposits, which formed over at least 3.4 b.y., had the highest preservation potential of any gold deposit type. The pattern of formation and preservation, from episodic to more cyclic, broadly mirrors that of crustal growth. Early Precambrian (mostly ca. 2.7 and 2.0–1.8 Ga) deposits, protected from uplift and erosion in the centers of buoyant cratons, are rare between ca. 1.7 Ga and 600 Ma due to the change to more modern-style plate tectonic processes, with nonpreservation of deposits of this age due to uplift and erosion of more vulnerable orogenic belts. Volcanic-hosted massive sulfide (VHMS) deposits were accreted into the convergent margin terranes in which orogenic gold deposits were forming. Their temporal distribution, from strongly episodic to more cyclic peaks, also supports a model of selective preservation.

The first appearance of iron-oxide copper-gold (IOCG) deposits at ~2.55 Ga closely follows development of early Precambrian subcontinental lithosphere mantle. Their genesis involved melting of metasomatized subcontinental lithosphere mantle, so they could not form until such metasomatized mantle evolved below cratons with buoyant lithosphere. Giant Precambrian paleoplacer gold deposits probably formed by effective fluvial sorting under extreme climatic conditions but were largely preserved due to early buoyant subcontinental lithospheric mantle below hosting foreland basins. Unequivocal intrusion-related gold deposits are related to complex felsic intrusions with a mixed mantle-crustal signature, which intruded deformed shelf sedimentary sequences close to but outside craton margins. Given that post-Paleoproterozoic uplift and erosion is likely in vulnerable orogenic belts with negatively buoyant lithosphere, this deposit type is likely to be rare in Paleozoic and older terranes.

Gold-bearing deposit types thus display distinctive temporal distributions related to change from a more buoyant plate tectonic style in the early hotter Earth to a modern plate tectonic style typical of the

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Phanerozoic. Late Archean formation of buoyant subcontinental lithospheric mantle was particularly important in the anomalous preservation of some earlier formed deposit types located inboard of craton margins and in providing critical conditions for the formation of others. Development of negatively buoyant subcontinental lithospheric mantle can explain the lack of preservation of some deposit types that formed in the later Proterozoic. A single fundamental concept of coupled episodic crustal growth and preservation in the Archean and Paleoproterozoic, evolving to decoupled episodes of growth and preservation from the Mesoproterozoic onward, can thus explain the temporal distribution of a number of gold-bearing mineral deposit types.