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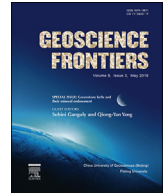


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Editorial

Greenstone belts and their mineral endowment: Preface



The granite-greenstone terranes nested in Archean cratonic nuclei of continents over the world are composed of variably metamorphosed igneous and sedimentary remnants of ancient ocean basins. These rocks preserve distinct geological and geochemical imprints of mantle evolution and differentiation of primordial crust, varying conditions of magmatism and fluid generation, plume-arc interaction, subduction-accretion, tectonic cycles of ocean closure and continent generation; hydrothermal fluid activity, remobilization and mineralization of precious metals over geological time. The notion of mineral endowment of Archean greenstone belts invokes a conjunction of magmatic, sedimentary and metamorphic processes that operated in different geodynamic settings and collectively contributed towards the nature and diversity of mineralization. The spatial and temporal distribution of metallogenic associations in greenstone belts is marked by a heterogeneity as recorded by (i) Pb- and sulfate-rich Volcanogenic Massive Sulphides (VMS), porphyry-style Mo-Cu and evaporative barite deposits of 3.5–3.3 Ga and 3.0–2.7 Ga greenstone sequences conforming to shallow marine to subaerial environments and (ii) komatiite-associated Ni-Cu deposits, VMS, base metal and gold mineralization associated with greenstones formed in deeper basins. Iron and manganese mineralization have been attributed to hydrothermal processes associated with mid-oceanic ridge-rift system. In contrast, gold, Cu porphyry and VMS Cu-Zn deposits show prominent affinity towards metallogenic processes operative in Archean subduction environments. Hence, diverse geodynamic conditions including mantle plume activity, divergent and convergent margin processes substantiate the heterogeneous mineral endowment of Archean greenstone belts.

In this special issue of *Geoscience Frontiers* on “Greenstone belts and their mineral endowment”, we compile seven scholarly contributions addressing the intriguing questions on Archean plate tectonics and mantle dynamics, fluid-crust-mantle interactions and tectonic control on greenstone hosted mineralization thereby providing advanced perceptions towards understanding of the evolution of asthenosphere-lithosphere system over geological time and its involvement in crustal growth and metallogenic processes associated with Archean greenstone belts. The relative influence of plate and stagnant lid tectonics in the thermotectonic evolution of the Earth has triggered debatable issues and invoked a geodynamic transition from early Hadean stage stagnant-lid convection tectonics to a short-term episodic style of subduction tectonics during Archean consistent with gradual decrease of mantle

temperature and thickening of lithosphere. It has been further envisaged that subduction tectonics during Archean was marked by intermittent plate motions and flat subduction of hot young oceanic lithosphere where frequent slab break-off events prevented a modern-style long-lived subduction system and resulted in frequent cessation and re-initiation of the subduction process. The first two articles of this issue address the contentions on the magmatic and geodynamic processes that sketched the evolutionary history of the Earth including existence of subduction-driven plate tectonics during Archean. The first paper of this issue by [de Wit et al. \(2018\)](#) presents a comparative account of different crust generation processes construed from geological, structural, geochemical, geochronological and geophysical data for seven ultramafic-mafic-felsic complexes of Barberton greenstone belt, South Africa and constrains the validity of plume or plate tectonic models in a Paleoproterozoic environment. These magmatic complexes, separated by gold-hosted major shear systems of southern Makhonjwa Mountains, collectively preserve subduction signatures resembling modern style intraoceanic arc-back arc systems and records of crustal growth by horizontal tectonics controlled by subduction-accretion processes as observed in Phanerozoic convergent margin settings. In this article, the authors corroborate subduction-driven plate tectonic genes in Paleoproterozoic Earth and suggest that plate convergence and plate tectonic processes were operative by 3.6–3.2 Ga. The inferences and ideas emerging from this comprehensive study reinforce the consensus for plate tectonics in early Archean. In the next paper, [Agangi et al. \(2018\)](#) evaluate Paleoproterozoic felsic magmatism and crustal evolution of Kaapval Craton, South Africa. Bulk chemical analyses, zircon U–Pb ages and Hf-in-zircon systematics of igneous clasts from a conglomerate of the 3.2 Ga Moodies Group of the Barberton Greenstone Belt attest to the presence of a differentiated felsic continental crust at >3.5 Ga that imply mantle processes and melt extraction episode dating back to Eoarchean. The authors propose a unified model for plutonic and volcanic magmatic suites suggesting coeval, multiple pulses of sodic and potassic magmatism during 3.5–3.2 Ga that resulted into gradual progression from tonalite-trondhjemite-granodiorite (TTG) to granite-monzogranite-syenogranite (GMS) lithologies.

Archean ultramafic-mafic complexes, as attributed either to extrusive magmatism of mantle origin or to layered intrusions of subvolcanic magma chamber crystallization, are associated with a

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wide variety of tectonic settings ranging from intraoceanic (oceanic crust or oceanic plateau) to oceanic ridge, forearc basin, marginal back arc basin and active continental rift environments and provide significant clues for understanding dynamic mantle processes during early stages of the earth. These magmatic bodies are important source for several types of ores like chromite (source of Cr), magnetite (source for Fe, V, Ti), gold (Au), Ni–Cu sulphides, base metal sulphides (BMS; Cu–Pb–Zn) and platinum group of elements (PGE). In accordance with these, the third paper by [Szilas et al. \(2018\)](#) elucidate the geochemical characteristics and petrogenetic evolution of layered dunite-peridotite and stratiform chromitites of 2.97 Ga Seqi Ultramafic Complex from southwest Greenland. Highly forsteritic olivine compositions and Platinum Group Element (PGE) fractionations indicate in situ olivine-spinel dominated cumulus crystallization of melts derived by >40% partial melting of a highly magnesian, anhydrous, refractory mantle. The authors infer that the peridotite-dunite cumulates of Seqi ultramafic complex represents an ultra-depleted cratonic keel beneath Archean North Atlantic Craton and provide insights into the melt generation processes and geodynamic conditions of primitive Archean mantle that served as precursor to continent generation and subcontinental lithospheric mantle (SCLM) evolution in early earth. Furthermore, this type of chromitite-bearing ultramafic layered intrusive complexes provide potential evidence for Ni–Cu ores, PGE, Fe, Ti, V and chromite mineralization.

The Neoarchean period (2.8–2.7 Ga), marked by a peak in crustal growth, enhanced crustal thinning and extension, development of thick komatiite-basalt and felsic volcanic sequences, large scale deposition of banded iron formations (BIFs), cratonization, regional deformation and metamorphism, and development of shear zone systems represents an important timeframe in greenstone metallogenesis. [Mishra et al. \(2018\)](#) provide a detailed account of the nature and source of ore-forming fluids contributing to the genesis of Neoarchean orogenic gold deposits associated with the granite-greenstone belts of Dharwar Craton, southern peninsular India. Orogenic gold mineralization associated with Archean granite-greenstone terranes is primarily controlled by structural style, tectonic setting, metamorphism of host and associated rocks, shear zones, hydrothermal system involving physico-chemical processes and flow of hydrothermal fluids for mobilization, transportation and deposition of gold. The authors interpret geochemistry of sulphide, tourmaline and other minerals, and also evaluate fluid inclusion microthermometric and Raman spectroscopic data to address the source of ore fluid, nature of gold transport and mechanism of gold ore formation in the Dharwar Craton. This study corroborates uniform ore fluid compositions in orogenic gold deposits of Dharwar Craton and suggests their origin from low salinity, reduced aqueous-gaseous fluids derived by hydrothermal alteration and metamorphic devolatilization of mafic rocks and interlayered sediments of Dharwar greenstone belts. The authors suggest that gold precipitation occurred by fluid-rock sulfidation reactions in narrow P–T regime and fluid phase separation driven by fluid pressure fluctuation.

The next paper by [Yakymchuk and Szilas \(2018\)](#) highlights the prospects of kyanite and sillimanite hosted corundum (ruby-sapphire) mineralization in high-grade Archean granite-greenstones terranes of southwest Greenland comprising aluminous gneisses of sedimentary origin and amphibolite facies meta-peridotites. The authors deduce a phase equilibria model to evaluate the geochemical, metamorphic and tectonic parameters that principally govern genesis and mineralization of corundum in Archean greenstone belts and thereby suggest amphibolite- to granulite-facies metamorphic conditions, desilicification inducing breakdown of sillimanite and kyanite at elevated temperatures and ruby formation, juxtaposition of low-silica ultramafic rocks

and high-silica aluminous metapelite triggering a chemical potential gradient to stabilize corundum in metapelites, addition of alumina by mica-rich metasomatic reactions as the essential vectors for corundum exploration.

The arc-style and non-arc style magmatic records of Archean greenstone belts have propounded bottom-up mantle upwellings through plume ascent and top-down oceanic slab subduction processes as principal mechanisms that initiated continent generation, lithospheric evolution and crustal growth in early Earth. Petrological, geochemical and geochronological studies of Archean greenstone belts over the last three decades from all major cratons of the world have documented two major types of volcanic rock associations: (i) an oceanic plateau association composed of compositionally relatively uniform komatiites and Mg- to Fe-rich tholeiitic basalts erupted from mantle plumes and (ii) a compositionally diverse intra-oceanic island arc association, dominated by 'normal' tholeiitic to calc-alkaline basalts, andesites, dacites, and rhyolites (BADR). These diverse magmatic suites are juxtaposed in most of the greenstone terranes through plume-arc interaction and subduction-accretion processes. In their paper, [Tang and Santosh \(2018\)](#) present a comprehensive overview of crustal growth and cratonization of the North China Craton (NCC) linked with amalgamation of microblocks welded by 2.75–2.6 Ga and ~2.5 Ga mineralized granite-greenstone belts. The authors integrate lithological characteristics, petrological, geochemical and geochronological data to address two distinct episodes of granite-greenstone generation and associated gold, BIF-hosted iron, VMS type Cu–Zn mineralization in NCC. [Tang and Santosh \(2018\)](#) infer plume-arc interaction processes generating the early Neoarchean (2.75–2.6 Ga) greenstone belts and associated mineralization and propose subduction-accretion-collision processes for the generation of their late Neoarchean (~2.5 Ga) counterparts and their mineralization. This paper deciphers the transitional geodynamic conditions for the Neoarchean greenstone belt evolution and crustal growth in NCC substantiated by plume-arc interaction to oceanic slab subduction tectonics and accretionary processes that provide insights into the tectonic control on spatial and temporal diversity of greenstone-hosted mineralization in NCC.

The last paper in this issue is by [Singh et al. \(2018\)](#) who present the geochemical systematics of the Mauranipur-Babina greenstone belt from Bundelkhand Craton, Central India and identify a komatiitic basalt-island arc tholeiitic BADR association that corroborates plume-back arc-arc accretion tectonics for Neoarchean crustal evolution in Bundelkhand Craton.

We hope that the contents of this issue will generate interest among our readers in the Earth Science community, and will provide impetus for further scientific probe on this topic. We sincerely thank all the authors for their insightful contributions to this volume and all the referees for providing timely constructive peer reviews. We are grateful to Prof. M. Santosh, Editorial Advisor, *Geoscience Frontiers* for all the motivation and guidance. We also thank the editorial staff of *Geoscience Frontiers* and in particular Dr. Lily Wang for their assistance and support towards this special issue.

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