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Paleohydrothermal evolution of the 3.24 Ga Panorama Zn-Cu volcanic-hosted massive ide system, Pilbara craton, Western Australia

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The 3.24 Ga Panorama VMS District, located in the Pilbara craton of Western Australia contains discrete volcanogenic zinc-copper deposits over a strike length of about 30 km with ide mineralization exhibiting a typical upward and outward zonation from copper-rich to zinc (lead)-rich (Vearncombe et al., 1995). Indicated and inferred resource estimates for the Sulphur Springs deposit are 2.8 Mt at 10.7% zinc and 0.6% copper and 2.5 Mt at 4.0% copper and 1.1% zinc (Morant, 1998). Base metal mineralization at Sulphur Springs occurs as Zn-rich mineralization within the Marker Chert, as a much larger Zn- and Cu-rich accumulation in the dacite immediately beneath the Marker Chert, and as a stringer-style Cu-bearing zone at the base of the massive ide lens (Vearncombe et al., 1995).

The Panorama VMS District is exposed as a cross-section through subvolcanic granite intrusions and a coeval submarine volcanic sequence that hosts Zn-Cu mineralization. The near-complete exposure across the district, the very low metamorphic grade, and the remarkable preservation of primary igneous and volcanic textures provides an unparalleled opportunity to examine the P-T-X-source evolution of an ancient VMS ore-forming system and to assess the role of the subvolcanic intrusions as heat sources and/or metal contributors to the overlying VMS hydrothermal system.

Detailed mapping of the Panorama VMS District has revealed seven major vein types related to the VMS hydrothermal system or to the subvolcanic intrusions. (1) Quartz-chalcopyrite veins, hosted in granophyric granite immediately beneath the granite-volcanic contact, formed prior to main stage VMS hydrothermal convection, and were precipitated from mixed H_2O-CO_2-NaCl-KCl fluids with variable salinities (2.5 to 8.5 eq mass% NaCl); (2) quartz-sericite veins, ubiquitous across the top 50m of the volcanic sequence, were formed from an Archean seawater with a salinity of 9.7 to 11.2 eq mass% NaCl at temperatures of 90° to 135°C. These veins formed synchronous with the regional feldspar-sericite-quartz-ankerite alteration during seawater recharge into the main stage VMS hydrothermal convection cells; (3) quartz-pyrite veins hosted in granophyric granite; (4) quartz-carbonate-pyrite veins hosted in andesite-basalt, also formed from relatively unevolved Archean seawater (5.5 to 10.1 eq mass% NaCl; 150° to 225°C), but during the collapse of the VMS hydrothermal system when cool, unmodified seawater invaded the top of the subvolcanic intrusions; (5) quartz-topaz-muscovite greisens; (6) quartz-chlorite-chalcopyrite vein greisens; and (7) hydrothermal Cu-Zn-Sn veins are hosted in the subvolcanic intrusions. Primary H_2O-NaCl-$CaCl_2$ fluid inclusions in the vein greisens were complex high temperature hypersaline inclusions (up to 590°C and up to 56 eq mass% NaCl). The H_2O-CO_2-NaCl fluid inclusions in the Cu-Zn-Sn veins have variable salinities, ranging from 4.9 to 14.1 eq mass% NaCl, and homogenization temperatures ranging from 160° to 325°C. The hydrothermal quartz veins and magmatic metasomatic phases in the subvolcanic intrusions were formed from a magmatic-hydrothermal fluid that had evolved through wallrock reactions, cooling, and finally mixing with seawater-derived VMS hydrothermal fluids.

Interpretation of the physico-chemical conditions of the Panorama fluids has led to a model of continuous interaction between seawater and volcanic rocks within a thermally waxing and waning system. Four end-member fluids precipitated the veins mapped in the Panorama VMS District: Archean seawater, VMS hydrothermal, magmatic-hydrothermal, and magmatic brine. These end-member fluids have been variably modified by fluid-rock reaction, phase separation, and fluid mixing. Volcanic-hosted veins and veins hosted in altered granophyric granite were formed from slightly modified Archean seawater. The granite-hosted veins were formed from magmatic-hydrothermal fluids exsolved from the crystallizing inner phase granite. Due to temperature and density contrasts, the magmatic brine phase exsolved from the granophyric granite remained stratified and isolated from the overlying lower temperature seawater-hydrothermal convection cells in the volcanic sequence. Therefore, this metal-bearing magmatic brine played no role in the formation of the overlying VMS deposits. The VMS deposits were precipitated from hot (>300°C) highly evolved seawater that had undergone significant low- and high-temperature reaction with the volcanic rocks to modify its chemical composition and leach metals from the volcanic strata and underwent phase separation to increase its volatile content and decrease its salinity relative to unmodified Archean seawater. The chemistry and isotopic compositions of the VMS hydrothermal fluids can be adequately explained as evolved and phase separated seawater, and no magmatic fluid component is required.

REFERENCES

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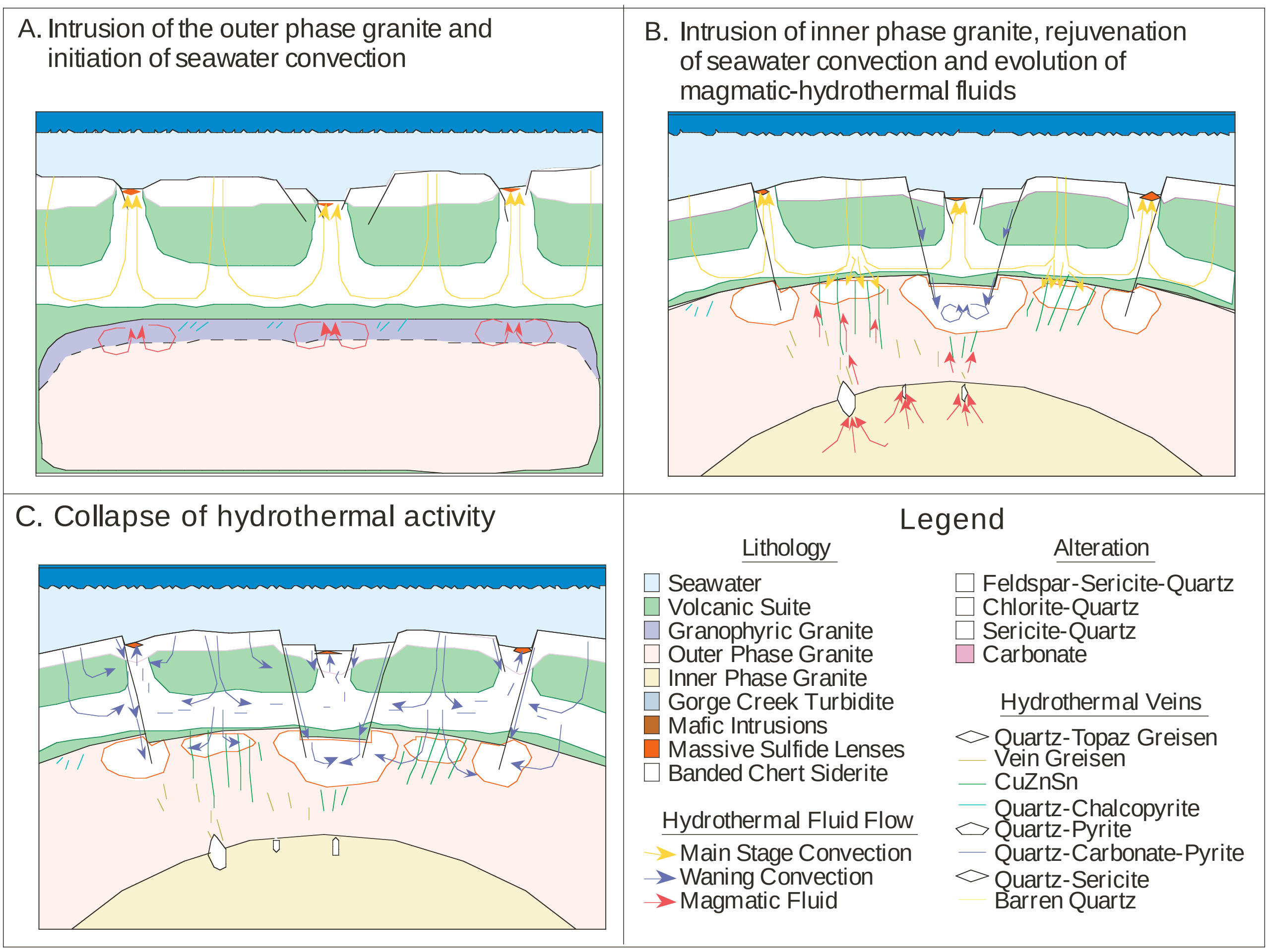

Fig. 1 Inferred hydrothermal evolution in the northern part of the Panorama volcanic hosted massive ide hydrothermal system: (A) Intrusion of outer phase of Strelley Monzogranite and initiation of seawater convection, (B) Intrusion of inner phase of Strelley Monzogranite, rejuvenation of seawater convection, and evolution of magmatic-hydrothermal fluids, and (C) Collapse of hydrothermal activity.