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The genesis of gold-copper-bismuth deposits, Tennant Creek, Northern Territory

by

Roger George Skirrow

A thesis submitted for the degree of Doctor of Philosophy of the Australian National University.

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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma at any other university. To the best of my knowledge and belief this thesis does not contain any material previously published, or written by, any other person, except where it is duly acknowledged and referenced in the text.

[Signature]

Roger George Skirrow
Abstract

The Au-Cu-Bi deposits of the Proterozoic Tennant Creek Inlier share geological and geochemical characteristics that indicate strong links in their genesis, yet the diversity in alteration assemblages, metal ratios and zonation patterns reflect variations in ore forming processes that previously have not been explained in detail.

The West Peko deposit is representative of Cu-rich, pyrrhotite-bearing mineralisation with intermediate gold grades, in magnetite±hematite-rich syntectonic 'ironstones'. By contrast, the high grade Eldorado Au deposit contains minor sulfides and very low Cu grades, similar to several of the larger gold producers in the field (e.g. Juno, White Devil, Nobles Nob), and is also hematite-rich. Au, chalcopyrite and Bi-sulfosalts were introduced into pre-existing ironstone during progressive shearing, either late in the first regional deformation event (D₁) or during a second phase of deformation. The occurrence of some Au zones outside ironstones suggests the ore fluids in part followed different flow paths to those of the ironstone-forming fluids.

Three chemically and isotopically distinct fluids have been characterised. (i) Ironstone-forming fluids at West Peko and Eldorado were Ca-Na-Cl (-Fe?) brines containing 12-20 weight % total dissolved salts, and reached temperatures of 350-400°C during magnetite deposition. Oxygen and hydrogen isotope compositions of minerals formed at the ironstone stage are consistent with an origin of ironstones from formation or metamorphic waters.

(ii) The inferred Au-Bi±Cu transport fluid in the Cu- and sulfide-rich West Peko deposit was of low to moderate salinity (3-10 eq. wt. % NaCl), ~300-350°C and N₂ + CH₄ - rich. Newly represented phase equilibria among the Fe-silicates stilpnomelane and minnesotaite, chlorite, biotite, sulfides, oxides and carbonates as well as fluid inclusion vapour compositions indicate that the Au-Bi±Cu transport fluid was relatively reducing with near-neutral pH and total dissolved sulfur contents of 0.001 m to 0.01 m. In the Eldorado Deeps Au- and hematite-rich deposit the Au-transporting fluid also may have been of low-moderate salinity, with Au deposition occurring at ~300°C. The reducing Au-Bi±Cu transport fluid at West Peko resembles primary magmatic or metamorphic water in oxygen and hydrogen isotopic composition. Carbon isotope ratios of Au-sulfide stage carbonates at West Peko point to involvement of organic carbon, probably sourced outside the host Warramunga Formation.

(iii) A regionally distributed, oxidising Ca-Na-Cl brine with 20-35 weight percent total dissolved salts, was present prior to, after and probably during ore deposition. Mixing with lower salinity reducing Au-Bi±Cu transport fluid is inferred at West Peko and is suggested to have caused effervescence of N₂ + CH₄ by 'salting-out', relatively late in the Au depositional stage.

An hypothesis of metal transport and deposition is proposed for the Tennant Creek deposits in which gold, copper and bismuth were transported in a reducing fluid and were deposited in the Cu- and sulfide-rich deposits dominantly by oxidation, desulfidation and initial pH increase
as the reducing fluid reacted with magnetite−hematite ironstone. Mass transfer modelling indicates that relatively small amounts of ironstone are required to precipitate Au in the observed grades. In deposits with abundant hematite that precipitated with Au + Bi-sulfides, such as Eldorado, the oxidising brine may have played a significant role in ore deposition either by mixing with a reducing Au-Cu-Bi-transporting fluid, or by producing hematite oxidant additional to any already present in the ironstones. The greater extent of oxidation of the ore fluid in such deposits may have generally prevented saturation of copper minerals, resulting in low Cu grades.

Gold is inferred to have been transported dominantly as uncharged bisulfide complexes, although biselenide complexes were potentially important. New thermodynamic data estimated for bismuth complexes are consistent with bismuth transport as uncharged S-H-O-bearing species in the Tennant Creek ore fluids. The existence of high grade Au-Bi deposits outside ironstones is predicted by chemical modelling of mixing between reducing and oxidising fluids, located where structures allowed focussed flow of both fluids.
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