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Timing and Duration of High-Temperature Gold Mineralization and Spatially Associated Granitoid Magmatism at Chalice, Yilgarn Craton, Western Australia

Louis A. Bucci,†

Centre for Global Metallogeny, School of Earth and Geographical Sciences, The University of Western Australia, Crawley, Western Australia 6009, Australia
SRK Consulting, 1064 Hay St., West Perth, WA, Australia 6005; PO Box 943, West Perth, WA, Australia 6872

Neal J. McNaughton, Ian R. Fletcher, David I. Groves, Natalie Kositcin,

Centre for Global Metallogeny, School of Earth and Geographical Sciences, The University of Western Australia, Crawley, Western Australia 6009, Australia

Holly J. Stein,

AIRIE Program, Department of Earth Resources, Colorado State University, Fort Collins, Colorado 80523

and Steffen G. Hagemann

Centre for Global Metallogeny, School of Earth and Geographical Sciences, The University of Western Australia, Crawley, Western Australia 6009, Australia

Abstract

The Chalice gold deposit, in the Eastern Goldfields province, Yilgarn craton, Western Australia, is located in a middle to upper amphibolite facies metamorphic domain and is hosted by a mafic-ultramafic rock sequence that has been locally intruded by four generations of monzogranite dikes. Two stages of gold mineralization, identified on the basis of crosscutting relationships, formed under broadly synpeak to postpeak metamorphic conditions. Main stage gold mineralization (95% of the resource) comprises foliation-parallel, quartz-albite-diopside-titanite-garnet-gold veins and wall-rock replacement, both within locally developed asymmetric folds in mafic amphibolite. Second stage gold mineralization (5% of the resource) is temporally associated with a second-generation monzogranite dike that crosscuts the folds and hence is younger than the Main event. It is represented by disseminated gold in the dike as well as by foliation-discordant quartz-gold, quartz-diopside-gold, actinolite-gold, and molybdenite-tellurobismuthite-gold veins. Gold is in textural equilibrium with the hydrothermal alteration assemblages in both mineralization stages and also with primary igneous phases (quartz and feldspar) in the monzogranite dike in the Second stage ore.

Magmatic zircons and titanite from second and fourth generation monzogranite dikes and a monzogranite stock, as well as hydrothermal titanite and molybdenite in equilibrium with gold from hydrothermal alteration assemblages, allow dating of the important magmatic and hydrothermal events using the U-Pb and Re-Os isotope systems. Two gold events are identified. Main stage mineralization is coincident with asymmetric fold development at 2644 ± 8 Ma (SHRIMP U-Pb on titanite), and Second stage mineralization (2621 ± 10 Ma; Re-Os on molybdenite) is coeval, within the error of the isotopic ages, with the intrusion of the gold-mineralized second-generation monzogranite dike (2626 ± 9 Ma; SHRIMP U-Pb on zircon). Ages of hydrothermal titanite in monzogranite dikes (2631 ± 10 Ma, 2624 ± 7 Ma, 2623 ± 5 Ma, and 2619 ± 6 Ma; SHRIMP U-Pb ages) indicate contemporaneous hydrothermal alteration, gold mineralization, and evolving magmatism during the Second stage event. A fourth generation, flat-lying pegmatite, which truncates all mine rock units, constrains the minimum age of mine-scale gold-bearing alteration and magmatism to 2622 ± 13 Ma.

The geologically constrained geochronologic data suggest that the Chalice gold deposit is a product of two independent gold events separated by up to 20 m.y., within an extended period of granitoid magmatism also extending over ~20 m.y. It demonstrates, for the first time in the extensively gold-mineralized Yilgarn craton, a clear interdependence and interplay between ongoing granitoid magmatism, deformation, hydrothermal alteration, and gold mineralization in amphibolite-hosted deposits. However, although integrated field and geochemical research establish a clear chronology of events, the controversy of contribution from magmatic and/or metamorphic fluids for the ore remains unresolved, because these events are broadly coeval within the resolution of the isotopic techniques.

† Corresponding author: e-mail, LBucci@srk.com.au