Geology and U-Pb geochronology of high-grade gold mineralization: the example of the Goldcorp Red Lake mine, Canada

Benoit Dubé[1], K. Williamson[1], V. McNicoll[2], M. Malo[1], T. Skulski[2], T. Twomey[3], and M. Sanborn-Barrie[2]

1. INRS-ETE, 490 de la Couronne, Quebec, QC, G1K 9A9 ¶ 2. Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, K1A 0E8; ¶ 3. Goldcorp Inc, Red Lake mine, Balmertown, Ontario, P0V 1C0

The giant Campbell-Red Lake deposit, actively mined by Placer Dome Inc. (Campbell mine) and Goldcorp Inc. (Red Lake mine), represents one of the largest and richest Archean gold deposits. The total deposit size (past production + reserve) is approximately 840 t of gold and an average grade of 21 g/t Au. The Goldcorp High-grade Zone at the Red Lake mine has produced more than 2 M oz at an impressive average grade of 88 g/t Au since the beginning of its extraction in 2001. Reserves (proven and probable) are established at 1.775 million metric tonnes at an average grade of 80.6 g/t Au. Such high-grade mineralization provides an opportunity to define fundamental geological parameters controlling the formation of high-grade ore and to assist in developing exploration guidelines for similar prime targets.

The Campbell-Red Lake gold deposit is hosted mainly by tholeiitic basalt of the Mesoarchean Balmer assemblage. Peridotite komatiite, variolitic basalt, rhyolite and associated mafic intrusions of the ca. 2.99–2.96 Ga Balmer assemblage, and felsic pyroclastic rocks with clastic and chemical sedimentary rocks of the ca. 2.984 Ga Bruce Channel assemblage

Copyright © 2015 Atlantic Geology

complete the sequence in the mine. The deposit is stratigraphically below a folded regional unconformity marking the contact between locally overturned Balmer assemblage volcanic rocks and overlying volcanics of the ca. 2.75–2.73 Ga Confederation assemblage. Gold mineralization in the Goldcorp High-grade Zone is related to silicification and brecciation of pre-existing cm- to m-wide foliation-parallel and oblique extensional, barren to low grade iron-carbonate±quartz colloform-crustiform veins and cockade breccias that are extensively developed in basalt. High-grade replacement mineralization is also present in the arsenopyrite-rich selvages hosting the silicified veins. Gold mineralization in the High-grade Zone is syn-D_2 deformation, a protracted event that resulted in NE-SW directed shortening in the vicinity of the Campbell-Red Lake deposit.

New U-Pb geochronological data combined with detailed mapping and cross-cutting relationships between high-grade ore and intrusive dykes provides timing constraints and new insights into the formation of the exceptionally-rich High-grade Zone in relation to the geological evolution of the Red Lake district and the Superior Province. The results show that the main stage of the high-grade mineralization is pre-2712 Ma, and that a second stage of gold mineralization, much smaller in terms of total gold content but extremely spectacular in terms of grade, is post-2702 Ma. It is proposed that the main stage of high-grade mineralization formed between ca. 2723–2712 Ma, possibly synchronous with emplacement of the Dome and McKenzie Island stocks, the Abino granodiorite and Hammell Lake batholith, as well as with penetrative D_2 tectono-metamorphism. The second stage is attributed to gold remobilization. Lamprophyre dykes spatially associated with the deposit postdate main-stage mineralization by at least 10 Ma. The presence of the lamprophyre dykes indicates that the structural corridor hosting the Campbell-Red Lake deposit has deep roots that facilitated the emplacement of lamprophyric magmas to higher crustal levels.

A folded and metamorphosed polymictic conglomerate located above the Campbell-Red Lake deposit, deposited after ca. 2747 Ma, is correlated with the Huston clastic assemblage. Cross-cutting relationships between the conglomerate and the alteration indicate protracted multistage aluminous and iron-carbonate ± quartz veining/alteration event(s) pre- and post-conglomerate deposition. The conglomerate confirms that the Campbell-Red Lake deposit is proximal to a folded regional unconformity supporting the empirical relationship between gold deposits and unconformities elsewhere in greenstone belts. Proximity to such paleosurface represents a key first order exploration target for world-class gold deposit.