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A New Model for the Early Crustal Architecture of the Archean Abitibi Greenstone Belt, Canada: Implications for Gold Mineralization

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The Abitibi greenstone belt (AGB) is host to some of the largest economic mineral deposits of the Archean Superior Province, which are predominantly associated with two major deformation zones, the Porcupine Destor Deformation Zone, and the Larder Lake Cadillac Deformation Zone (LLCDZ). The LLCDZ extends laterally across the AGB for 250 kilometres, exhibits a variable local geometry, defined by segments that vary in both dip and strike orientation, and is defined by a 10- to 300-m-wide alteration and deformation zone, at the contact between older mafic and ultramafic rocks and younger clastic sedimentary rocks. There is a spatial association with world-class gold deposits that lie predominantly in the footwall to this fault, at the intersection with cross faults. Deposits include the Kerr Addison mine, which historically produced over 11 Moz of gold. Gold mineralization is typically associated with fuchsite-altered ultramafic rocks and albite-altered mafic volcanic rocks and to a lesser extent with alkalic intrusions.

To develop an overall understanding of gold endowment for the AGB and its association with major deformation zones the LLCDZ was examined in terms of structure, alteration, and mineralization in the Larder Lake area, combining field mapping, drill hole structural analysis, and new geophysical data. The LLCDZ juxtaposes younger Timiskaming clastic sedimentary rocks (2674-2670 Ma) against older ultramafic and mafic volcanic rocks of the Larder Lake group (ca. 2710-2704 Ma). Previous interpretations for the evolution of this deformation zone proposed i) a crustal -cale extensional fault that formed during lithospheric-scale extension, due to crustal thinning that was coincident with alkaline magmatism (ca. 2680–2670 Ma) and synorogenic deposition of the Timiskaming sediments and gold mineralization, ii) a reactivated thrust fault that formed initially as a result of segment linkage during accretion-related deformation, or iii) a late transcurrent fault system.

New geophysical data for the LLCDZ defines a vertical depth extent of 27 km and variable alteration zone from seismic data, with a corresponding high conductivity in the structural hanging wall. Magnetotelluric data also identifies linear zones of high conductivity that correlate with the plunge and trend of ore deposits, located at the intersection of the LLCDZ and NE-trending cross faults. Furthermore, field observations and drill core provide evidence of a primary gradational nature for the LLCDZ, preserved in a low-strain zone, which has redefined the contact between the Timiskaming sedimentary rocks and the Larder Lake Group volcanic rocks as a strongly modified unconformity.

Contrary to previous interpretations for this deformation zone, this new model presents evidence that the LLCDZ did not originate as a lithospheric-scale extensional fault, reactivated thrust fault, or transcurrent fault but instead formed as a primary stratigraphic contact that was later reactivated. This primary contact acted as a plane of anisotropy that localized the subsequent development of the fault and migration of gold-bearing hydrothermal fluids. These fluids were focused along an inherited basin architecture, as suggested by the apparent control on gold mineralization, by a network of high-angle NE cross faults.