Ore Geology Reviews 35 (2009) 4–46

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

Subaqueous calderas in the Archean Abitibi greenstone belt: An overview and new ideas

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ARTICLE INFO

Article history:
Received 10 July 2008
Received in revised form 21 December 2008
Accepted 21 December 2008
Available online 6 January 2009

Keywords:
Archean calderas
VMS deposits
Abitibi belt
Volcanology
Carbonate alteration
Exploration model

ABSTRACT

The 300×700 km Abitibi greenstone belt in Canada contains numerous world class Archean volcanogenic massive sulfide (VMS) deposits, yet documentation of Archean subaqueous calderas hosting such deposits is lacking. The modern Sunrise deposit in the Myojin Knoll caldera of the Izu–Bonin arc shows that submarine calderas are first order sites for VMS. The Hunter Mine and Normetal calderas, as well as the Blake River megacaldera complex are reviewed with respect to geometry, regional geology, physical volcanology, dyke emplacement, and hydrothermal carbonate alteration. These subaqueous calderas are placed into the geodynamic context of the Abitibi greenstone belt. The Abitibi belt displays a complex history of oceanic arc formation, evolution, collision and fragmentation with numerous types of volcanic edifices and sedimentary basins controlled by oblique subduction and mantle plumes.

Analogue models yielding new insights into the sequence of caldera-forming events and their synvolcanic fault patterns are applied to explain Archean examples. Underpressure experiments develop a consistent sequence of fault patterns that compare favourably with natural caldera events. During subsidence, two sets of faults propagate from the magma chamber margin: (1) early reverse (outward dipping) faults, and (2) normal (inward dipping) faults. The largest massive sulfide deposits form preferentially at the caldera margin. Based on experimental studies and detailed facies mapping, the Hunter Mine caldera is of the segmented, piecemeal variety, and the Normetal caldera is akin to a piston structure. The Blake River megacaldera contains (1) the E–W trending Misema, (2) the NW-trending New Senator, and (3) the NE-trending Noranda calderas with the latter two being nested graben-type calderas, consistent with oblique Archean subduction.

The poorly-documented hydrothermal carbonate alteration is discussed and a new exploration model for calderas is presented. The alteration study was evaluated at three levels: microprobe analysis, geochemical staining of drill core, and whole rock analyses. There were two principal stages of alteration related to VMS formation. An early silicification phase developed either at depth and/or at the seawater interface, whereby silicification was bedding parallel in fine-grained volcaniclastic deposits near the water surface. A pervasive and extensive semi-conformable carbonate alteration zone with a discordant focused root zone along faults evolved subsequently. Three distinct carbonate pairings were observed: (1) proximal siderite (sideroplesite) — Fe-ankerite next to the VMS-deposit, (2) an intermediate ankerite-Fe-dolomite zone and (3) a distal calcite-dolomite zone. The carbonate phase is associated with the mineralizing event. Transitions between carbonate species are subtle and changes are indicated by mineral assemblage overlap. The silica-carbonate hydrothermal alteration pattern is a replacement product and is far more widespread than has been documented. This alteration can be easily confused with primary carbonates and chemical precipitation deposits (e.g. banded iron-formation) if detailed volcano-sedimentary facies mapping with alteration has not been conducted and if outcrop is insufficient.

1. Introduction

Paleoproterozoic and Archean greenstone belts are supracrustal sequences that host abundant volcanogenic massive sulfide (VMS) deposits. Of these belts, the 300×700 km Archean, Abitibi greenstone belt (Fig. 1) is one of the most prolific metallotects in the world. This supracrustal sequence contains numerous VMS deposits totalling >600 m.t. of Cu–Zn–Pb as well as orogenic (lode) gold deposits producing >3680 t of Au (Chartrand and Cattalani, 1990; Robert and Poulsen, 1997; Hannington et al., 1999). Because of the abundance of metals, the Abitibi greenstone belt has been intensively studied with respect to volcano-sedimentary history and stratigraphy (e.g., Dimroth et al., 1982, 1983a,b), structure (e.g., Camiré, and Burg, 1993; Sawyer and

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doi:10.1016/j.oregeorev.2008.12.003