Ore Geology Reviews xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Ore Geology Reviews

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

Mesozoic orogenic gold deposits in Mexico

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ARTICLE INFO

Article history:
Received 27 September 2014
Received in revised form 5 October 2015
Accepted 6 October 2015
Available online xxxx

Keywords:
North American Cordillera
Orogenic gold deposits
Shear zones
Caborca orogenic gold belt
Arteaga metamorphic complex
Oaxacan metamorphic complex

ABSTRACT

Although orogenic gold deposits in Mexico were mostly formed during the Cenozoic, they started forming during the Late Cretaceous, or perhaps even earlier. Mylonitic zones in the Oaxacan metamorphic complex span either Permo-Triassic or Triassic-Jurassic ages, but none of these have been formally associated with the existing orogenic gold occurrences. Given the current scarcity of age data for them, any interpretation concerning the age patterns or distribution of orogenic gold deposits in Mexico other than those in the Sonoran belt is hitherto deemed to be precarious. A few known Mesozoic examples are part of the Quitovac–La Choya deposits in the Caborca Orogenic Gold Belt (COGB) in Sonora, and Los Uvares in the Los Cabos Block (southernmost part of the Baja California Peninsula). The COGB constitutes the most economically important and geologically consistent mineralized area in Mexico with respect to orogenic gold deposits. Also, the COGB arguably correlates with the Mother Lode trend in California and Nevada, whereas the cluster of deposits in the Los Cabos Block may have correspondent similarly mineralized areas in mainland southwestern Mexico (Jalisco Block). Other areas with orogenic gold deposits in Mexico, which have been traditionally overlooked or scantly mentioned, are the northernmost part of the Baja California Peninsula, and the Arteaga and Oaxacan metamorphic complexes, although no geochronological data are available from these. Besides the overly lack of such data, one of the typical problems concerning the characterization and metallogenesis of orogenic deposits in Mexico has been their inaccurate or incorrect ascription to other genetic paradigms or types of deposits, such as epithermal or porphyry Cu–Au deposits, therefore misguiding exploration efforts.

The formation of orogenic gold deposits in Mexico has been commonly associated with the Laramide orogeny, in association with cataclastic or mylonitic deformation and shear zones. Their depth of formation, under lithostatic pressure, has ben estimated at a range between ~3 and ~10 km. Alteration assemblages in them are generally dominated by quartz ± "sericite" ± pyrite, and may be carbonate-rich. The hypogene mineralogy of orogenic gold deposits in Mexico is normally dominated by sulfides like pyrite, galena, sphalerite and whereas gold normally occurs as "electrum", also known as unspecified Ag-rich gold, Au-rich silver, or as free gold. The latter may either be a hypogene or supergene mineral, in which case it is likely to be due mostly to the leaching-off of Ag from "electrum". Te-rich associations are rare and have complex parageneses that consist typically of silver and/or gold tellurides. The mineralizing fluid precipitation into quartz veins occurred at temperatures ~350 °C and are CO_2-rich deeply seated crustal brines from metamorphic sources, with salinities typically ranging between ~2 and ~10 wt.% NaCl equiv. but attaining up to ~33 wt.% NaCl equiv.

1. Introduction

Orogenic gold deposits formed late in the evolution of convergent margin settings during major orogenic events, and their formation requires some form of accretionary setting involving subduction or underplating of oceanic crust (Bierlein et al., 2009), and Mexican examples are no exception to this. The Mexican orogenic gold deposits are clearly linked to the geology of the North American Cordillera originated mostly in compressional conditions (Fig. 1). The majority of the known orogenic gold deposits in Mexico are located in northern Sonora (Fig. 2). This type of ore deposits has become one of the most important in terms of gold production in the country during the last decades, provided that the combined reserves and extraction in these deposits have generated resources of more than 10 Moz Au. The most important deposits in this region (Fig. 2) are La Herradura, El Chanate, San Francisco-Llano, Soledad-Dipolos, Noche Buena, La Choya, and El Boludo, a placer gold deposit most likely from Laramide orogenic veins (Radelli and Pérez-Segura, 1992). The orogenic gold deposits in Sonora cover an elongated area with ~600 km long and ~60–80 km

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http://dx.doi.org/10.1016/j.oregeorev.2015.10.006
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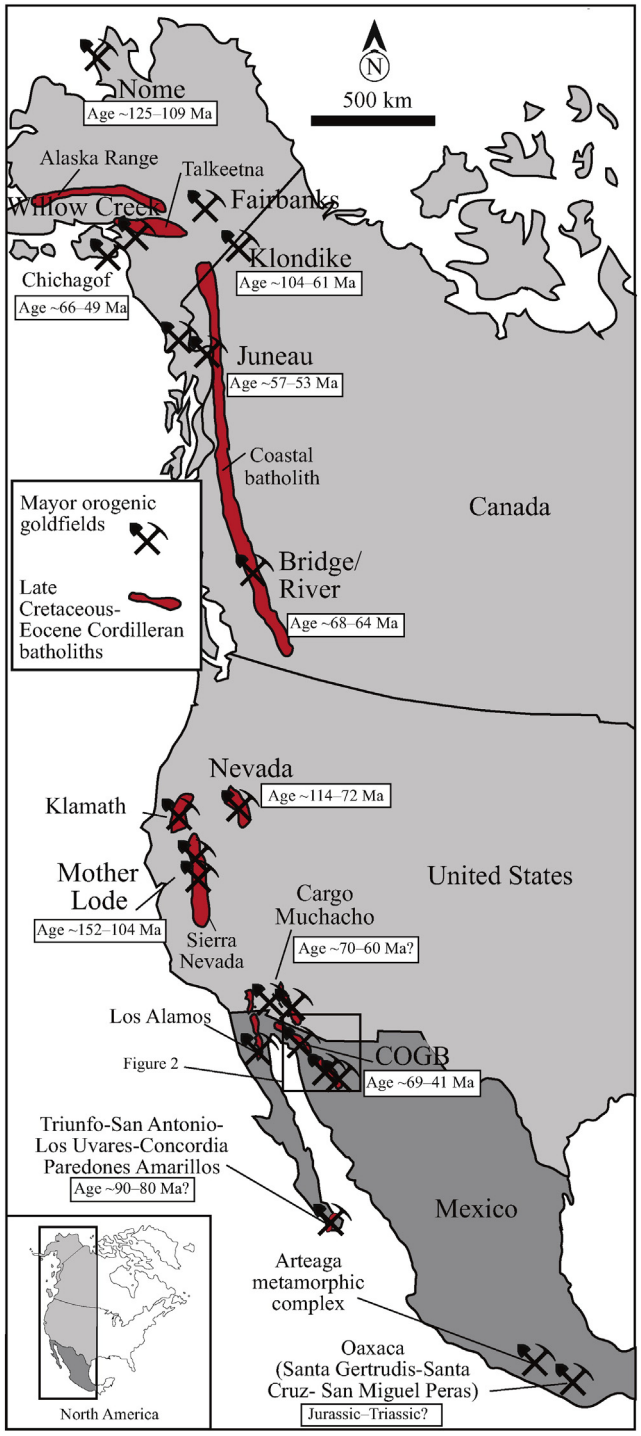

Fig. 1. Map with the distribution of the main mineralized belts that contain orogenic gold deposits in the Cordillera of Western North American (modified from Goldfarb et al., 2008), including the Mesozoic and Cenozoic orogenic gold deposits of Mexico. COGB: Caborca Orogenic Gold Belt.

across with a general NW-SE orientation, and it was labeled recently as the "Caborca Orogenic Gold Belt (COGB)" (Fig. 1) by Izaguirre et al. (2012); however, these deposits were known as the Sonora Gold Belt (Silberman et al., 1988) or Gold Deposits from the Sonoran Desert Province (Pérez-Segura, 1993); nevertheless, previous names included different mineralized areas and involve more type of gold deposits (e. g., epithermal deposits). However, those names are helpful to link previous studies with this publication. The COGB is structurally dissected by the current extensional Basin and Range province, and originated in the active North American margin, as the former Farallon plate was being consumed by subduction underneath the North American plate. Early work (Silberman et al., 1987, 1988) in the Sonoran orogenic gold deposit belt was based on structural geology and vein geochemistry studies, but these included other types of deposits, such as epithermal deposits, which certainly have nothing to do with the orogenic gold model or its associated processes. As a consequence, these studies finally described a favorable area far larger than is known to be nowadays.

Other regions in Mexico where orogenic gold deposits are known to occur are the Baja California Peninsula, the Arteaga metamorphic complex in southwestern Mexico, and the Oaxacan metamorphic complex in southern Mexico (Sánchez-Rojas et al., 1998; Clark and Fitch, 2009; Jiménez-Hernández, 2011; Fig. 1). In the case of Baja California, Concordia-Paredones Amarillos deposits are interpreted as a shear zone and mylonite-hosted deposits with calculated reserves of over 48 Mt at 1.01 g/t Au (Cendejas-Cruz and Aldana-Hernández, 2008) and for Oaxacan deposits reserves are not well documented at the moment.

Host rocks for orogenic gold mineralizations in the Sonoran belt are igneous and metamorphic rocks from the Paleoproterozoic basement, Paleozoic granitic and platform sedimentary rocks, and Mesozoic sedimentary, volcanic, volcaniclastic and granitic (Fig. 2). Iriondo and Premo (2011) suggested that the orogenic gold deposits in Sonora are associated in space with the Paleoproterozoic basement rocks and, most especially, with the province of Yavapai Paleoproterozoic granitc rocks, and therefore the ultimate source for such deposits is due to processes associated with such rock assemblages. Also, the same authors postulate that the Yavapai province represents a crustal weakness area that might have played a role as channelways for buoyant mineralizing fluids. Similarly, in the Oaxacan metamorphic complex host rocks are basically Mesoproterozoic and Neoproterozoic paragneiss and metagranites, as well as Permo-Triassic intrusive rocks (Jiménez-Hernández, 2011).

Hitherto, mineralization ages for the COGB gold belt have been obtained by means of K–Ar and Ar–Ar geochronometry in "sericite" and white micas (Pérez-Segura, 1993; Pérez-Segura et al., 1996; Iriondo and Atkinson, 2000; Araux-Sánchez, 2000; Araux-Sánchez et al., 2001; Iriondo, 2001; see Table 1), and Re–Os model ages in magnetite and pyrite (Quintanar-Ruíz, 2008). However, recently Izaguirre et al. (2013) reported new 59 ages distributed along the COGB with mineralization ages between ~69–36 Ma and an age peak of mineralization activity at ~60 Ma. So the available ages from the COGB deposits suggest a relatively long-lived formation, from the latest Mesozoic (~69 Ma) until the Eocene (~36 Ma, see Table 1). Nevertheless, the available structural models at La Herradura (de la Torre-Carlos, 2004, 2009) suggest that this deposit might be significantly older than the 61 Ma Re–Os model age obtained by Quintanar-Ruíz (2008). The host rocks at the Los Uvares deposit in the state of Baja California Sur were dated between 90 to 80 Ma (K–Ar and fission tracks; Carrillo-Chávez, 1996; Carrillo-Chávez et al., 1999). This deposit is hereby considered to belong to the orogenic gold type, following Clark and Fitch (2009) and our own criteria acquired in a recent fieldwork campaign to the El Triunfo-San Antonio mineralized trend. This case suggests a necessary re-evaluation of the time and space distribution of such type of deposits in northwestern and westernmost Mexico. The nearby Concordia-Paredones Amarillos orogenic gold deposit displays similar ages to Los Uvares, as its age is constrained by those of the underlying and crosscutting intrusive rocks between 91 and 79 Ma (referred by Cendejas-Cruz and Aldana-Hernández, 2008; Clark and Fitch, 2009). The still undated El Triunfo-San Antonio deposit also occurs in the same region and shares many geological similarities with the Los Uvares and Concordia-Paredones Amarillos deposits (Carrillo-Chávez, 1996; Clark and Fitch, 2009). In spite of well constrained Permo-Triassic (Solari, 2001) and Triassic-Jurassic (Alaníz-Álvarez et al., 1996; Alaniz-Álvarez and Nieto-Samaniego, 1997; Solari et al., 2004) ages for mylonites in the Oaxacan metamorphic complex, none of these has been properly associated to the existing orogenic gold deposits, although Jiménez-

Please cite this article as: Izaguirre, A., et al., Mesozoic orogenic gold deposits in Mexico, Ore Geol. Rev. (2015), http://dx.doi.org/10.1016/j.oregeorev.2015.10.006