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Mesozoic volcanogenic massive sulfide (VMS) deposits in Mexico

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ABSTRACT

Volcanogenic massive sulfide (VMS) deposits are the most conspicuous type of deposits that formed during the Mesozoic in Mexico. Many Mexican VMS deposits display "classical" Kuroko-type mineral zonation and structure, and some of them, as Cuale and La Minita formed in shallow submarine environments. The most prospective time window for the formation of VMS deposits in Mexico comprises the Late Jurassic and the Early Cretaceous. VMS stopped forming during the progressive continentalization of Mexico, since its metallotectonic processes (dominated by extensive tectonics) changed giving way to compression during the late Early Cretaceous; new VMS deposits did not form until after the opening of the Gulf of California.

Mesozoic VMS deposits in Mexico occur in submarine volcano-sedimentary sequences that deposited essentially in association with back-arc basins (now found roughly along the boundaries between tectonostratigraphic terranes) or within juvenile and slightly evolved arcs (at the internal parts of the terranes), while few others occur on the epicontinental seafloor and hinterlands of eastern Mexico. VMS deposits are especially abundant in the Guerrero composite terrane, and are also present in the Alisitos and Parral terranes. However, new evidence referred in this paper indicate the western continental edge of the cratonic block of Oaxaquia as a promising, new prospective region for VMS deposits. Interestingly, no VMS deposits are found in the northern part of the Guerrero composite terrane despite the occurrence of marine volcano-sedimentary sequences similar to those in the south; such absence can be related to differential extensional unroofing, much larger in the southern part of the Guerrero composite terrane than in the northern part. Many VMS deposits occur along or close to terrane boundaries, especially around the Guerrero composite terrane. This distribution reflects the association between VMS deposits and back-arc basins, which represented the frontal part of terranes or sub-terranes that were ultimately accreted to the Oaxaquia cratonic block. As a consequence, VMS deposits usually display strong deformation and thrusting, and their mineral and compositional zonation can be found overturned. Due to such common association between these deposits and terrane boundaries that reactivated during the Cenozoic, VMS deposits are especially susceptible to overprinting by later metallogenic processes, unrelated to VMS-producing environments. This susceptibility may be held accountable for the complex mineral associations found in the Francisco I. Madero deposit.

The inclusion fluids in the Cuale, La Minita, El Rubí, Tizapa and Campo Morado deposits have salinities that range from 2.5 to 20.0 wt.% NaCl equiv. and temperatures of homogenization from 110° to 420 °C, although a particular fluid inclusion assemblage (with daughter halite and sylvite) from a stockwork at the Tizapa deposit ranged salinities from 39.7 to 64.7 wt.% NaCl and from 35.9 to 43.5 wt.% KCl, and temperatures of homogenization from 440° to 550 °C. The general characteristics listed above may account for mineralizing fluids from magmatic, marine, and modified marine sources. The entrainment of cool and oxidizing seawater within upwelling fluids increased as the paleohydrothermal systems waned. The waning stages are normally represented by barite-rich mineralizations and, in the case of the La Minita deposit, this notoriously outlasted by Mn oxide mineralization that reflects even more oxidizing conditions. A similar evolution is deduced in Cuale, which is the only known Mesozoic VMS deposit in Mexico that formed in a shallow-submarine environment together with La Minita. The shallower the formation of VMS deposits is, the more quickly mineralizing fluids evolve into highly oxidized end-members, once the paleohydrothermal systems cooled down. The extremely high-salinity and hot inclusion

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fluids in Tizapa, despite the unavailability of further geochemical data, are likely to represent magmatic brines that did not undergo significant mixing with seawater.
As for the temporal evolution of the studied deposits, they generally exhibit (1) an increasing magmatic contribution from early to middle stages for both fluids (as mineralizing fluids grew hotter and more saline) and sulfur, and (2) the waning of hydrothermal activity towards the last stages on mineralization, which is characterized by the prevalence of seawater (as fluids grew cooler, and more diluted and oxidizing), thus reflecting quite a typical evolution for most VMS deposits elsewhere. New $\delta^{34}S$ values for the same VMS deposits reflect multiple sources of sulfur in the mineralizing fluids: magmatic, sedimentary/metasedimentary, and marine. Different degrees of dominance of either source for sulfur in these deposits and in their stages of mineralization have been inferred, in a way that also responds to a schematic evolution from magmatic- to seawater-dominated paleohydrothermal systems.

1. Introduction

Volcanogenic massive sulfide deposits (VMS) constitute the most abundant type of Mesozoic ore deposits in Mexico, especially regarding pre-Cenomanian deposits. They occur along the Pacific margin, from Baja California to the Guerrero State, and in Chihuahua (Fig. 1). The overwhelming majority of VMS deposits in Mexico are classified as Kuroko-type deposits (*e.g.*, Charoy and González-Partida, 1984). The vast majority of VMS deposits in Mexico belong to the Zn–Pb–Cu or Zn–Cu metal associations of Large (1992) (Fig. 2). They formed in association with either calc–alkaline, tholeiitic or alkaline volcanic rocks (González-Partida, 1993), although the time and space distribution of

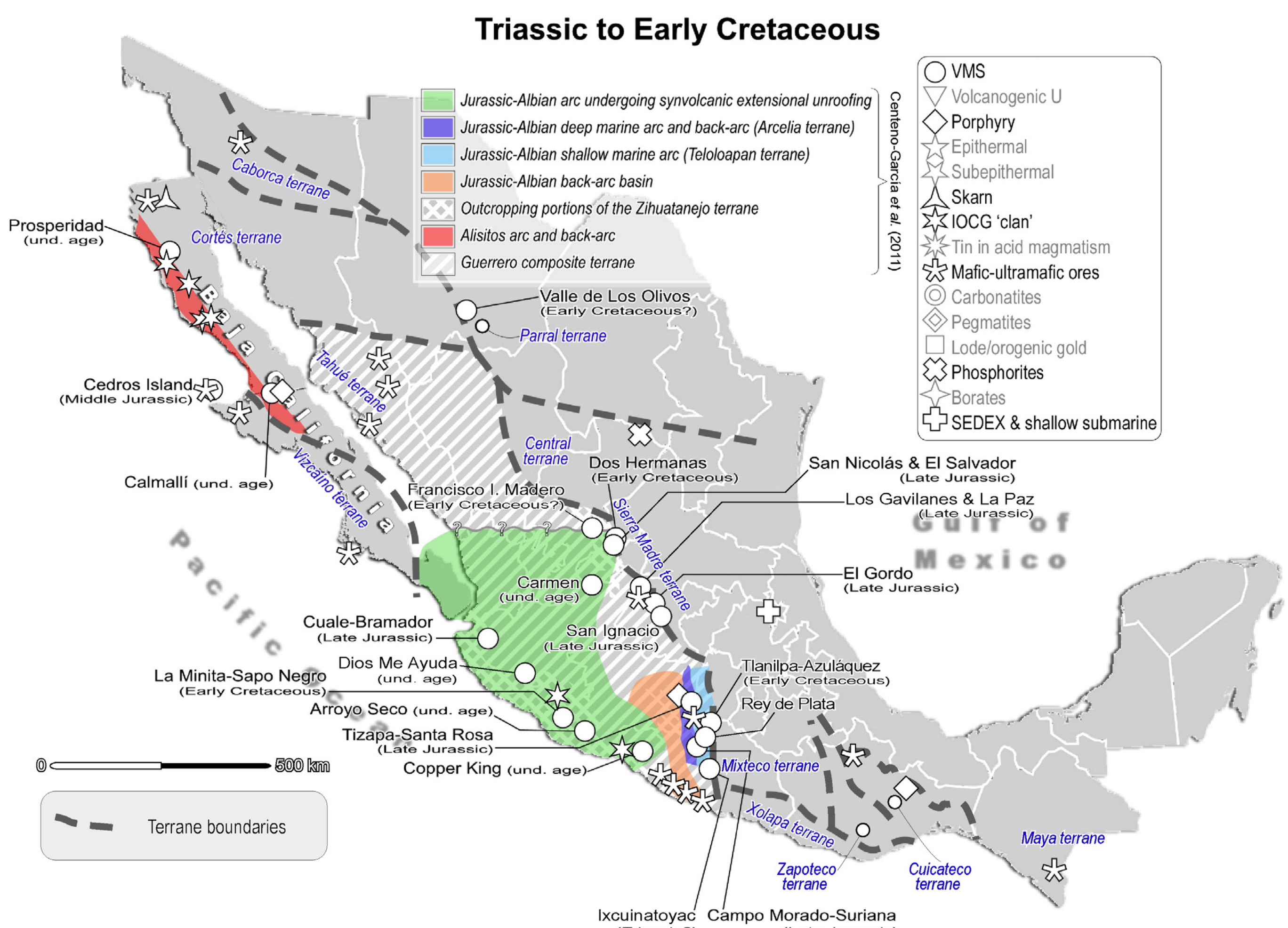

Fig. 1. Distribution of ore deposits formed from the Triassic to the Early Cretaceous in the Pacific convergent margin of Mexico, showing terrane names and other significant geological features. Modified from Camprubí (2009). See available ages in Camprubí (2013). The deposit names that carry the "und. age" label stand for those deposits whose age is undetermined but reasonably inferred from their stratigraphic position or bearing according to various sources, mostly found in Miranda-Gasca (2000) and in Ortiz-Hernández et al. (2006). The position of the Baja California Peninsula is reconstructed to its approximate pre-rifting position. Paleotectonic reconstructions from this period were taken from Centeno-García et al. (2011). Following these, the area of Jurassic–Albian arc undergoing synvolcanic extensional unroofing (green) is extended northwards into known similar areas, and the Jurassic–Albian back-arc basin is extended southwards into the Petatlán–Papanoa region, as data from the Loma Baya deposit (this paper, see sections below) confirm that it formed in suprasubduction-zone back-arc ophiolites. Thick gray dashed lines denote terrane boundaries. Symbols for ore deposit types are the same as in Camprubí (2009, 2013), and gray symbols and the labels for types of ore deposits in the legend stand for those absent in this period. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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