THE STRUCTURAL SETTING AND TECTONIC CONTROL FOR MISSISSIPPI VALLEY-TYPE LEAD-ZINC DEPOSITS

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Mississippi Valley-type (MVT) lead-zinc deposits were recognized as a distinct deposit type nearly 70 years ago (Bastin, 1939). At the time, known deposits were located in flat-lying platform carbonate sequences, often hundreds of kilometers distant from tectonic zones or igneous activity. Therefore, early models for the genesis of MVT lead-zinc deposits assumed that the ore deposits had no connection with tectonic processes. However, in the last 25 years, studies have noted the association of MVT ore genesis with major crustal tectonic events. Perhaps the most significant achievements in understanding the tectonic controls on MVT ore genesis have been from advances in dating MVT ores (Fig.1). The new dating techniques used high precision paleomagnetic dating and radiometric dating of calcite (Re-Os, U-Pb, U-Th), sphalerite (Rb-Sr), and feldspar and clay minerals (Ar-Ar, K-Ar).

TECTONIC SETTING OF MVT DEPOSITS

The most important period for MVT genesis was the Devonian to Permian time that corresponds to a series of intense tectonic events during the assimilation of Pangea. The second most important period was from Cretaceous to Tertiary time when microplate assimilation affected the western margin of the Americas and Africa-Eurasia. Based on the deposits that have been dated, it appears that few MVT deposits were formed during major periods of continental dispersal during the Late Proterozoic to early Paleozoic, and the rapid breakup of Pangea in Triassic through Jurassic time. Thus, the time of most MVT deposits broadly coincides with major contractional events in the Phanerozoic. This interpretation is consistent with a long-recognized connection between many MVT deposits and orogenic forelands (Leach et al., 2001).

Bradley and Leach (2003) examined the tectonic aspects of foreland evolution and concluded that the type of foreland is not a critical control on ore formation. For example, MVT deposits are located in collisional (Ozark MVT province), Andean (deposits in the western Canada basin), and inversion orogens (Cévennes district) (Fig. 2). Also associated with orogens are MVT deposits that occur in fold and thrust belts (Daniels Harbour). Some deposits formed in flat-lying rocks or were later caught up in thrusting (East Tennessee, Austinville). Others formed synchronously with thrusting or formed after burial by the thrusts.

A few MVT deposits, in contrast, clearly formed in large-scale extensional environments. The best examples of MVT formation in an extensional environment are the Lennard Shelf deposits. The age of ore deposition (see references in Leach et al., 2005) coincides with crustal extension of the Fitzroy Trough. There are no compressive tectonic events that affected the region since the time that the host rocks were deposited.

EXTENSIONAL TECTONIC CONTROL

Although most MVT deposits typically formed during contractional events, the single most important tectonic controls at the deposit or district scale are extensional faults (normal, transtensional, and wrench faults) and associated fractures and dilatancy zones. This relationship applies to most MVT districts, including the Ozark MVT province. Bradley and Leach (2003) discussed MVT deposits that formed within extensional domains that developed due to lithospheric flexure (Fig. 3), or in large dilational zones within bounding strike-slip faults during large-scale contractional events. Ordovician normal faults related to the Taconic collision controlled MVT mineralization in the Newfoundland Zinc district. Far-field tectonic effects in the host rocks for MVT deposits commonly reflect reactivation of pre-existing faults and fractures in the basement (e.g., Ozark Province, Irish Midlands, and Cèvennes). Far-field extension inboard of orogenic belts can extend several hundred kilometers into the foreland and may explain districts such as those in the western Canada basin, Upper Mississippi Valley, and the Irish Midlands. Thus, the endowment of orogenic forelands with MVT deposits reflects the link between contractional events in orogenic zones, inboard extensional tectonic domains, and fluid flow. The extensional domains provide fluid drains for large regional aquifers (i.e., Ozark region) or focused pathways for the ascent of fluids in buoyancy driven hydrothermal systems (i.e., Irish Midlands).

EXPLORATION SIGNIFICANCE

Exploration for undiscovered MVT districts must consider the inextricable link between contractional events in orogenic zones, inboard extensional tectonic domains and the fluid flow that produces MVT ores. Extensional faults associated with broad paleotopographic highs and domal structures inboard of orogenic belts that were active during contractional orogenic events are potentially fertile areas for exploration. Highly faulted regions inboard or orogenic belts that also contain extensive paleokarst, regional facies transitions (i.e., shale/carbonate or dolomite/limestone transitions) reef facies, extensive late sparry dolomite, and evidence of evaporative environments are additional favorable factors to consider.

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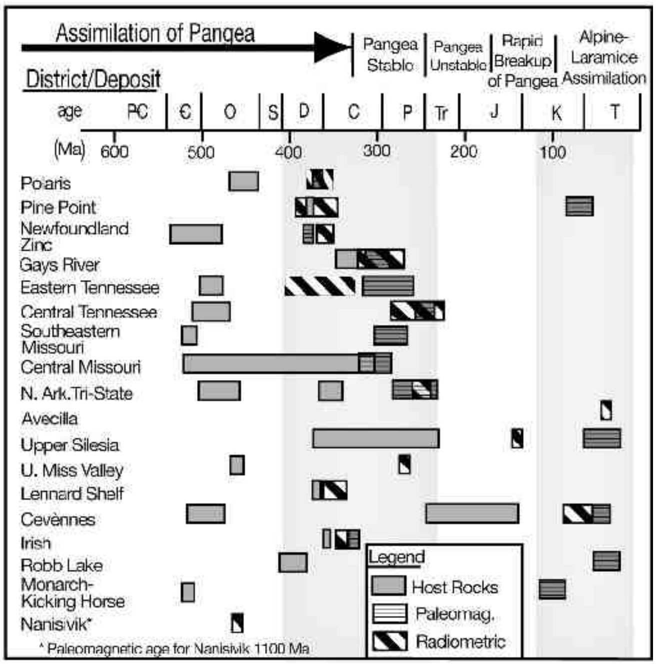

Figure 1. Distribution of isotopic and paleomagnetic ages of MVT deposits and their host rocks in the Phanerozoic. Modified from Leach et al. 2001.

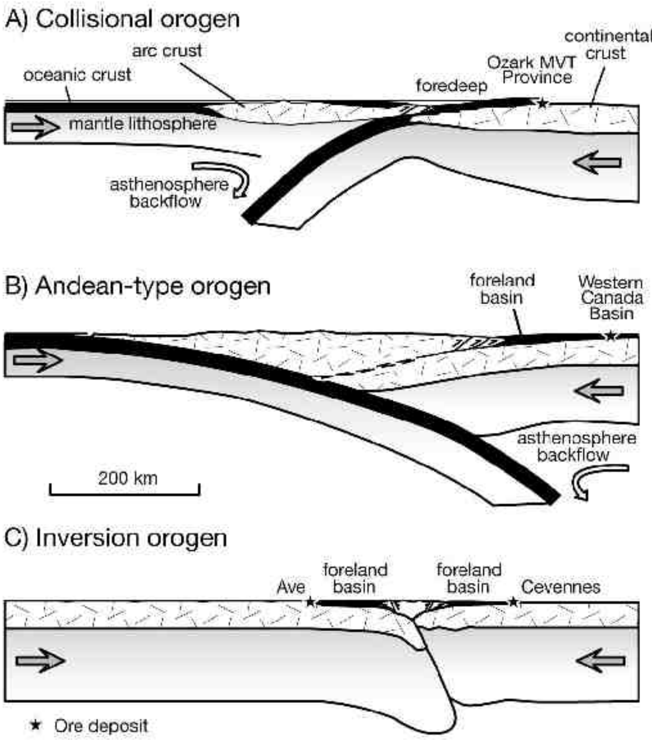

Figure 2. Comparison of collisional, Andean, and inversion orogens. A. Collisional-type orogen. Arc-passive margin collision, based on Neogene examples from Timor, New Guinea, and Taiwan, and various older examples including the Taconic and Ouachita orogenies. B. Andean-type orogen. Based on the present-day Andes and the Late Cretaceous-Paleocene Laramide system of western North America. Convecting asthenosphere contributes to foreland subsidence on a broad, regional scale, which sets this type of foreland system apart from others. C. Inversion-type orogen. Flanking both sides are thrust-loaded foreland basins, based on the Pyrenees. From Bradley and Leach (2003).

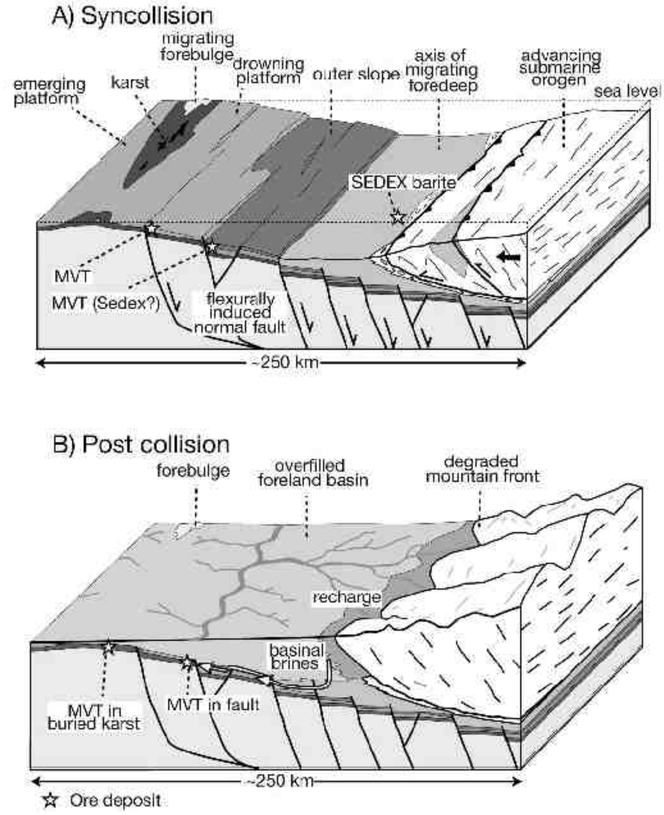

Figure 3. Block diagram showing foreland evolution. A. During plate convergence, a submarine thrust belt loads the passive margin, thereby forming the foreland basin, extensional domain, and forebulge. Plate convergence continually causes these features to migrate across the foreland plate. The foreland basin remains underfilled because the depocenter migrates. Barite mineralization along foredeep axis is based on examples from the Ouachitas. B. Plate convergence has ceased and the foreland basin has filled with sediment, creating hydrologic conditions favorable for MVT mineralization. This is the situation corresponding to mineralization in the Ozark region. From Bradley and Leach, (2003).