Mississippi Valley-Type Lead-Zinc Deposit Model

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Contents

Table

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Mississippi Valley-type (MVT) lead-zinc deposits are found throughout the world, but the largest and more intensely researched deposits are located in North America, where the deposit type was first recognized about 70 years ago (Bastin, 1939). Mississippi Valley-type deposits owe their commonly accepted name to the fact that several classic districts are located in the drainage basin of the Mississippi River in the central United States.

The median size of MVT deposits is 7.0 million tonnes (Mt) with grades of about 7.9 percent Pb+Zn metal. However, MVT deposits usually occur in extensive districts consisting of several to as many as 400 deposits.

These deposits are characteristically distributed over hundreds of square kilometers that define individual ore districts. Large MVT districts include Southeast Missouri (3,000 km^2), Tri-State (1,800 km^2), Pine Point (1,600 km^2), Alpine (10,000 km^2), Upper Silesia (2,800 km^2), Irish Midlands (8,000 km^2), and the Upper Mississippi Valley (7,800 km^2). Pine Point contains more than 80 deposits and the Upper Mississippi Valley nearly 400 deposits. Individual deposits can be small in some districts. Most deposits in the Pine Point district contain between 0.2 and 2 Mt of ore, and the largest has nearly 18 Mt (Sangster, 1990). Heyl and others (1959) reported that the average deposit size in the Upper Mississippi Valley district was between 0.1 and 0.5 Mt, although a few contained as much as 3 Mt of ore. Some MVT hydrothermal events formed numerous ore districts in a large area that define huge metallogenic provinces. Deposits within ore districts typically have similar deposit attributes and ore controls, whereas individual ore districts can be quite distinct.

Such MVT deposits account for about 24 percent of the global resources for lead (Pb) and zinc (Zn) in sedimentary and volcanic rock-hosted deposits [(MVT + volcanic hosted massive sulphide (VHMS) + sedimentary exhalative (SEDEX) + sandstone lead (ss-Pb)]. Relative to all sedimentary rock-hosted ore deposits (MVT + SEDEX + ss-Pb), MVT deposits account for approximately 38 percent of the total Pb and Zn tonnage.

Zinc and lead are the primary commodities for most MVT deposits which yield about a 10:1 mass ratio of Zn to Pb metal. Some deposits and districts yield only Zn (for example, East Tennessee and Central Tennessee) and others dominantly Pb (for example, Viburnum Trend and Old Lead Belt).

By product commodities include silver (Ag), copper (Cu), and indium (In) for some deposits. Silver is reported for 34 of 113 deposits in table 1, with a median value of 32.5 grams per tonne (g/t) and the 90th percentile value of 88.02 g/t. Total silver production can be substantial; for example, during the period from 1960 to 1990, annual silver production from the Viburnum Trend averaged 45.9 tonnes. Historically, some deposits/districts yielded road gravel, and iron sulfides for sulfuric acid production. Some deposits have recoverable economic levels of germanium (Ge), gallium (Ga), and

cadmium (Cd). Cobalt is present in significant but sub-economic amounts in the Madison Mine, Old Lead Belt, and Missouri deposits.

Environmentally, MVT deposits are less of a concern than other types of mineral deposits. Because of the large grain size of the ores, processing the ores is easier than for most other sedimentary rock-hosted ores. The iron sulfide content of the deposits is an important control on the acid-producing potential of MVT ores (Leach and others, 2005), but is generally low in MVT deposits (typically less than five percent) (Foley, 2002). The oxidation of pyrite and marcasite is responsible for the majority of mine waste acid production. However, the MVT carbonate-host rocks mitigate many environmental issues, thus the iron-sulfide content appears to have little effect on the pH of mine drainage and surface waters in MVT deposits.

The most important characteristics of MVT deposits, modified from Leach and Sangster (1993) and taken from Leach and others (2005), are: (1) they are epigenetic; (2) they are not associated with igneous activity; (3) they are hosted mainly by dolostone and limestone, rarely in sandstone; (4) the dominant minerals are sphalerite, galena, pyrite, marcasite, dolomite, and calcite, whereas barite is typically minor to absent, and fluorite is rare; (5) they occur in platform carbonate sequences, commonly at the flanks of basins or in foreland thrust belts; (6) they are commonly stratabound, but may be locally stratiform; (7) they typically occur in large districts; (8) the ore fluids were basinal brines with around 10 to 30 weight percent salts; (9) they have crustal sources for metals and sulfur; (10) temperatures of ore deposition are typically 75°C to about 200°C; (11) the most important ore controls are faults and fractures, dissolution collapse breccias, and lithological transitions; (12) sulfides are coarsely crystalline to fine-grained, massive to disseminated; (13) the sulfides occur mainly as replacement of carbonate rocks and, to a lesser extent, open-space fill and (14) alteration consists mainly of dolomitization, host-rock dissolution, and brecciation.

As noted by Sangster (1990), and discussed by Leach and others (2001; 2005) and Kesler and Reich (2006), most MVT deposits are hosted in Phanerozoic rocks and are significantly less common in Proterozoic rocks. Only one known deposit occurs in Late Archean rocks. MVT ores are located in platform carbonate sequences in passive margin environments and are commonly related to extensional domains landward of Phanerozoic contractional tectonic belts (Leach and others, 2001; 2005). Exceptions to this general relationship are the deposits in the platform carbonate sequence of the Canning Basin, Australia, where the ore deposition was controlled, in part, by extensional faulting along a late Paleozoic continental extensional basin transitional to a passive margin basin.

Many MVT deposits formed during the Devonian to Permian time that corresponds to a series of intense tectonic events during the assimilation of Pangea. This period accounts for approximately 61 percent of the Pb and Zn in dated MVT deposits. The second most important period for MVT deposit genesis was Cretaceous to Tertiary time, when microplate assimilation affected the western margin of North America and Africa-Eurasia. This lead to deposition of approximately 36 percent of the Pb and Zn in dated deposits. Based on the deposits that have been dated (Leach and others, 2001), few MVT deposits were formed during major plate dispersal from the Late Proterozoic to early Paleozoic period or during the rapid breakup of Pangea in Triassic through Jurassic time.

Numerous subtypes and alternative classifications applied to MVT deposits include, but are not limited to: Viburnum Trend-, Alpine-, Silesia-, Irish-, Appalachian-, and Reocin-type. The subtypes reflect more geographical attributes, rather than geological. A discussion of these subtypes and classification issues are discussed in Leach and others (2005).

Excluding district total metal endowments, the median parameters for MVT deposits are 7.0 Mt ore, 1.9 percent Pb, 6.0 percent Zn, 0.23 percent Cu, and 32.5 g/t Ag. (table 1). Mississippi Valley-type deposits are characteristically distributed over hundreds of square kilometers that define individual ore districts. Because production and reserve data for MVT deposits, particularly in the United States, are commonly presented only as district totals, the size, grade, and metal-ratio parameters for individual deposits are difficult to compile. For example, the Viburnum Trend and Old Lead Belt deposits effectively are production units within a mineralized zone that continues for more than 120 km. Therefore, grade-tonnage models for MVT deposits must take into account the district scale of mineralization. Resource assessments based solely on single deposit data may misrepresent the actual resource defined by many MVT ore districts.

Grade-tonnage data for all known MVT deposits are available from Leach and others (2005). Leach and others (2005) reported grade and tonnage data for 248 known sedimentary rock-hosted deposits, including 110 MVT deposits and eight districts. Included in the data compilations are the amounts of Cu and Ag contained in the deposits, and key references to the geology of the deposits. The data compilations in Leach and others (2005) were based on efforts of D. F. Sangster in the World Minerals Geoscience Database Project (Sinclair and others, 1999). Given the great diversity in MVT deposits, resource assessments can select subsets of deposit data for specific regions and known MVT deposit styles for regional specific grade-tonnage models.

The largest known MVT deposits are Mehdiabad, Iran, with 394 Mt of ore and 22.9 Mt Pb+Zn, followed by Pavlovskoye, Russia, with 128 Mt of ore and 7.0 Mt Pb+Zn, and Admiral Bay, Australia, with 120 Mt ore and 10.4 Mt Pb+Zn. The highest grade ores belong to Schmalgraf, Belgium, with 26.1 percent Pb+Zn and 24 percent Zn, and Touissit-Bou Beker, Morocco, with 13 percent Pb. The Navan, Ireland, deposit (95.3 Mt at 2.1 percent Pb and 8.3 percent Zn) is the largest active mine associated with an MVT deposit, with a metal endowment greater than most districts.   The range of ore and metal tonnage in MVT deposits extend from the maximums mentioned above down to less than 1 Mt. An up-to-date summary of the statistics for selected parameters for the deposits is given in table 1.

Table 1. Summary statistics for select parameters of MVT deposits (modified from Leach and others, 2005).

(Max = maximum value; Min = minimum value; 10th = 10th percentile; 25th = 25th percentile; 75th = 75th percentile; n = number of deposits with data for given parameter; (g/t) = grams per tonne; (Mt) = million tonnes)

	Min	10th	25th	Median	75th	90th	Max	n
MVT deposits (113 deposits)								
Size (Mt)	0.06	0.65	1.90	7.00	18.10	42.40	394.00	113
Pb (Mt)	0.00	0.00	0.02	0.11	0.36	0.98	6.30	108
Zn (Mt)	0.00	0.03	0.10	0.33	0.99	2.45	16.55	107
Pb (%)	0.18	0.75	1.10	1.90	3.60	6.27	13.00	101
Zn (%)	0.11	1.89	3.54	6.00	9.80	12.47	24.00	106
Cu (%)	0.10	0.14	0.17	0.23	0.33	0.44	0.52	8
Ag (g/t)	3.40	10.18	17.83	32.50	54.75	88.02	485.00	34

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