SEDIMENTARY MN DEPOSITS
(MODEL 34b; Cannon and Force, 1986)

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SUMMARY OF RELEVANT GEOLOGIC, GEOENVIRONMENTAL, AND GEOPHYSICAL INFORMATION

Deposit geology

Sedimentary manganese deposits described here are shallow-marine (non-volcanogenic) deposits formed around the rims of anoxic basins during high sea-level stands at locales starved of clastic sediment. These deposits are stratiform marine basin-margin deposits, which may be present in oxide and (or) carbonate facies, in condensed stratigraphic sequences (Cannon and Force, 1986).

Examples

Molango (Jurassic), Mexico (Cannon and Force, 1986); Nikopol (Oligocene), Ukraine (Sapozhnikov, 1970); Groote Eylandt (Cretaceous), Australia (Pracejus and others, 1986); Imini (Cretaceous), Morocco (Force and others, 1986); Kalahari (Precambrian), South Africa.

Spatially and (or) genetically related deposit types

Associated deposit types (Cox and Singer, 1986) include sedimentary phosphorite (Model 34c) and barite deposits (Model 31b); some sedimentary manganese deposits may grade into volcanogenic manganese deposits. In Precambrian sequences, close spatial and stratigraphic relations between iron formation (Model 34a) and sedimentary manganese deposits are common.

Potential environmental considerations

Potential types of geoenvironmental concern associated with these deposits include (1) manganese-rich dust, (2) elevated abundances of manganese (from carbonate-facies deposits in modern low-pH environments or oxide-facies deposits in low Eh and pH environments) in water draining these deposits, and (3) electrochemical properties of mineralized ground associated with battery-active deposits; manganese deposits, from which components used in battery manufacture are produced, can themselves act like batteries in the ground.

Effects related to each of these types of potential impact may be manifested by unmined and mined deposits and thus may be as widespread as the deposits themselves. Potential for environmental impact of the first two types is enhanced by mining; these impacts pose possible health concerns. Barium and lead abundances in these deposits may be greater than a percent; sulfide-bearing carbonate-facies deposits may contain elevated abundances of other base metals.

Examples of potential environmental impacts described above are as follows:

(1) All oxide deposits, including exposed parts of unmined deposits, are potential sources of manganese-rich dust, which is also produced by sintering (high-temperature oxidation) plants associated with some carbonate-facies deposits (for example, Molango).

(2) Some water draining Molango and other carbonate-facies deposits contains elevated abundances of dissolved manganese.

(3) Groote Eylandt and other battery-active deposits that contain the oxide minerals nsutite and (or) vernadite are associated with distinctive electrochemical potential fields.

(4) Imini and possibly other diagenetic oxide-facies deposits are characterized by elevated barium and lead abundances.

(5) Molango and other carbonate-facies, sulfide-mineral-bearing deposits have elevated abundances of other base metals.

Exploration geophysics

Few geophysical investigations of this deposit type are known; however, deposits with similar geologic relations provide analogies. Battery-active deposits are electrochemically active, as described above; the associated self-potential field is distinctive. Aeromagnetic surveys can be used to define broad terranes permissive for the presence of this deposit type because of an association between some sedimentary manganese deposits and iron formation; most iron formation has a distinct, positive magnetic contrast with surrounding rock (U.S. Geological Survey and Corporaciaon Venezolana, 1993; Sangmor and others, 1982). Manganese ore minerals, including manganite, "psilomelane" (see section below entitled "Ore and gangue mineralogy and zonation"), and pyrolusite, are dense (3.3-7.9 g/cc). Resulting dense ore and moderate deposit size (up 10 m thick, and covering 10 km^2) indicates that detailed gravity surveys may help identify these deposits (Rowston, 1965). However, many sedimentary manganese deposits are either carbonate-facies, poorly consolidated, vuggy, and (or) extremely thin, any one of which may limit the utility of gravity surveys in exploration for this deposit type (Dorr and others, 1973). In cases where strata are minimally deformed and their seismic characteristics are well known, seismic refraction or refraction can help delineate orebodies. All manganese minerals except psilomelane are conductive (Keller, 1989); psilomelane ranges from conductive to resistive. Thus, massive manganese deposits may have low associated resistivity that can be detected by electromagnetic or direct current resistivity methods; these deposits also may be identified by induced polarization surveys. The presence of elemental carbon in surrounding rocks enhances resistivity lows (Dorr and others, 1973), but also renders direct detection more ambiguous. Electrical surveys over manganese deposits have not been documented.

References

Geology: Roy (1981), Cannon and Force (1986), and Force and Cannon (1988).
Environmental geochemistry: Matrone and others (1977).

GEOLOGIC FACTORS THAT INFLUENCE POTENTIAL ENVIRONMENTAL EFFECTS

Deposit size

The 10th, 50th, and 90th percentiles of tonnage for these deposits are 280, 7.3, and 0.19 million tonnes, respectively (Mosier, 1986). Deposits are typically less than 10 m thick; large deposits can cover more than 10 km^2.

Host rocks

Host rocks include shallow marine sedimentary rocks, most commonly carbonate rocks, clay, and glauconitic sand, commonly with shellbeds, in high-stand sequences associated with anoxic basins. Most deposits include carbonate rocks in the host sequence. Barium-, phosphorous-, and copper-enriched rocks may be spatially or stratigraphically adjacent to manganese-enriched rock. Reduced deposits such as black shale may be similarly associated with manganese-enriched rock and may contain enrichments of a variety of base metals.

Surrounding geologic terrane

Sedimentary manganese deposits are along the margins of stable cratons or in basins contained therein. Starved sedimentary basins, in which barium and phosphorous abundances in reduced facies rocks have been enriched (see section above entitled "Host rocks"), are characteristic of these deposits.

Wall-rock alteration

Alteration associated with these deposits is minor and diagenetic rather than hydrothermal in origin.

Nature of ore

Ore consists of thin beds of manganese oxide and (or) carbonate minerals, only incidentally influenced by structural features. Vertical zonation may record depositional regression at high sea-level stand. Lateral zonation may involve oxide-facies to carbonate-facies transitions.

Deposit trace element geochemistry

The geochemistry of these deposits is variable; barium, lead, and phosphorous may be major constituents, whereas any base metal capable of adsorption on manganese oxide minerals may be present in trace amounts.

Ore and gangue mineralogy and zonation

Oxide-facies deposits: Ore- Cryptomelane-group minerals and pyrolusite are common in the most oxic deposits. Less-oxic deposits contain manganite, braunite, and kutnahorite. "Psilomelane" and "wad" (primary and supergene iron and manganese oxide mineral intergrowths) commonly are listed in older literature. Over forty oxide minerals are potential ore constituents; additional mineralogic description here is restricted to potentially environmentally problematic minerals. Among these are coronadite and hollandite, because of their elevated lead and barium contents, respectively, and nsutite and vernadite, because of their electrochemical activity. Gangue- Clay minerals (commonly montmorillonite), carbonate minerals, glauconite, quartz, chert, and biogenic silica.

Carbonate-facies deposits: Ore- Rhodochrosite, kutnahorite, siderite, mixed manganese and iron carbonate minerals, pyrite, and wad. Gangue- Clay, calcium and calcium-magnesium carbonate minerals, glauconite, organic matter, pyrite, quartz, and biogenic silica.

Mineral characteristics

Rocks that host these deposits can include various textural features, including sedimentary laminae, sedimentary oolites and pisolites, and diagenetic botryoidal and vuggy textures, that probably do not affect the environmental signature of these deposits. Grain-size variation among deposits is extreme.

Secondary mineralogy

Secondary minerals include lithiophorite, nsutite, and wad. Nsutite and vernadite may be associated with electrochemical activity.

Topography, physiography

The topography and physiography of these deposits are variable, nondiagnostic, and have limited relation to geoenvironmental signatures. Nsutite deposits tend to be perched on ridges and plateaus.

Hydrology

These deposits exert little, if any, influence on the local hydrologic regime. Locally, manganese carbonate minerals are present only below the water table.

Mining and milling methods

These deposits are mined by both open-pit and underground methods. Mining and milling sedimentary manganese ore generate manganese-rich dust, which may be the major health risk associated with sedimentary manganese deposits (Matrone and others, 1977).

ENVIRONMENTAL SIGNATURES

Drainage signatures

The geochemistry of water draining sedimentary manganese deposits is directly related to and mimics the characteristics of individual deposits.

Metal mobility from solid mine wastes

Manganese is weakly to moderately mobile except under acidic (oxide- and carbonate-facies deposits) or reducing (oxide-facies deposits) conditions. Base metals (for example, lead) are less mobile when contained in oxide minerals.

Soil, sediment signatures prior to mining

Manganese commonly is concentrated in soil, to form supergene deposits, by secondary manganese mineral growth. High manganese-iron ratios are characteristic of soil associated with these deposits. Abundances of other elements, except those of aluminum and potassium (in lithiophorite), are depleted by these processes.

Potential environmental concerns associated with mineral processing

Processing ore from deposits of this type can yield manganese-rich dust and enhance dissolved manganese abundances. Manganese mineral dissolution is enhanced by acidification of carbonate-facies deposits and (or) reduction and acidification of oxide-facies deposit.

Smelter signatures

Manganese ore is not commonly smelted near mine sites.

Climate effects on environmental signatures

Varying climatic conditions probably have minimal influence on the environmental signature related to these deposits unless they cause the chemistry of natural water to have lower pH (as with acid rain) or Eh.

Geoenvironmental geophysics

Detailed gravity, seismic (Sklash and Jiwani, 1983), and electrical surveys aid tonnage estimates and delineation of deposit geometry prior to mining; accordingly, estimates concerning the potential magnitude of air and water pollution that may be associated with ore extraction can be made. Magnetic surveys augment these techniques by enabling definition of hydrologic features, including cavities, faults, and aquitards, within and surrounding deposits. In favorable circumstances, resistivity, seismic velocity, and seismic reflectivity surveys may enable estimates of depth to the water table.

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