Lead-Zinc Exploration in the Gays River District of Nova Scotia

by Patrick Hannon and Fenton Scott

Some occurrences of lead-zinc mineralization in Mississippian carbonates of central Nova Scotia are briefly described. The results of geophysical and geochemical prospecting are presented. Because the deposits do not give a positive response to these indirect techniques it is necessary to site exploratory drilling through the development of geological concepts.

Regional Geology

The Mississippian carbonate rocks of Nova Scotia (Fig. 1) are found in a series of presently isolated basins. They represent a cyclical marine transgression between two periods of essentially continental sedimentation.

The marine sediments (locally named Windsor) comprise red shales, fossiliferous limestone, gypsum, anhydrite, and salt. The limestones are rarely dolomitized, except in the Gays River area and parts of the adjacent Musquodoboit Basin.

The Windsor sediments are locally unconformable on older Mississippian (Horton) "red bed" and grey bed continental sediments, and onlap the pre-Carboniferous basement with angular unconformity.

The Geological Survey of Canada[1] has divided the Windsor at its type area into five subzones. These are, oldest to youngest, A, B, C, D, and E. Each subzone contains limestone units, and is bounded above and below by disconformities. At Gays River, a karst topography exists at the contact between carbonates and overlying evaporites. In general, the cyclic nature of the Windsor sediments represents repeated transgression and regression of the seas.

Pleistocene Geology

Boyle[2] (p. 139) has described the Pleistocene geology of the Walton-Cheverie area. His description applies as well to the entire Minas Basin, as quoted here: "The entire area has been glaciated by an ice sheet whose movement was generally from northwest to southeast. Glacial deposits, mainly till, in places more than 50 feet thick, cover most of the bedrock. Rock exposures are present mainly along the coast or in stream bottoms. Soils of the podsol group are developed on the till throughout the area. These soils exhibit relatively good profiles, are well to poorly drained, and have an acid reaction (pH 4 to 5.8) throughout their profiles".

Structure

On the basis of regional structure, the Minas Basin is divided into two areas, one structually simple, and the other structurally complex. North of a postulated east-northeast hinge line (Fig. 1), the Carboniferous sediments are displaced by a series of northeast, east, and northwest trending faults. Most strata occur in steeply dipping folds that are locally overturned. South of this hinge line the Mississippian sediments are not obviously displaced by faults. Some evidence of northwest pre-Carboniferous faulting is seen on aeromagnetic maps. Down-to-basin faulting may also be present.

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Mineral Deposits

Imperial's explorationists have noted evidence of base metal mineralization (including copper) in carbonate rocks of most of the Windsor subzones.

Pembroke; Galena and minor amounts of sphalerite are associated with fractures in lower Windsor limestones (A and B zones). Gangue minerals include appreciable calcite and minor amounts of barite. The Windsor-Horton contact immediately to the north of the Pembroke occurrence appears to be a fault.

Smithfield: A fault between Windsor limestones (A zone) and Horton shales and sandstones has brecciated the limestone. The fault breccia contains argentiferous galena and sphalerite. Gangue minerals include pyrite, barite, and calcite. The mineralized breccia dips steeply and is 25 to 30 ft wide. It has been traced for a length of 500 ft through underground workings and diamond drilling.

Walton: The structure of the Walton area is extremely complex. It reflects more than one period of tectonic activity, mostly pre-ore. The barite and sulfide deposits are at the intersection of an east-trending fault with a northeast-trending fault (Fig. 2). The fault intersection is at the centre of an S-shaped fold. These deposits occur immediately above an east-dipping conformable Windsor-Horton contact. The barite body overlies the sulfide body, completely masking it (Fig. 3). Roughly half a million tons of ore were mined from the sulfide deposit; this ore averaged 3% lead, 1% zinc, 0.4% copper and 7 oz silver per ton. Over four and one-half million tons have been mined to date from the barite deposit.

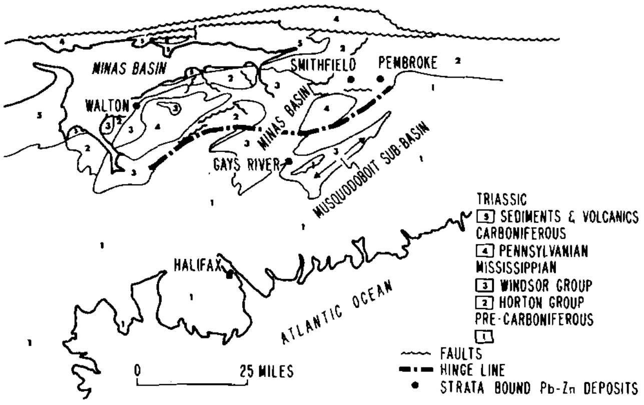

Fig. 1—Geology of the Minas Basin.

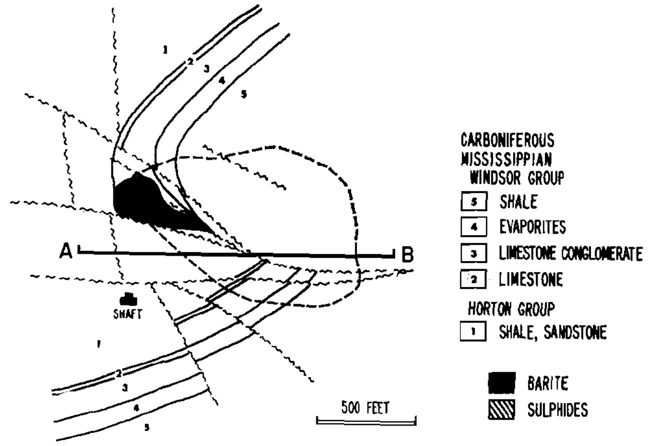

Fig. 2—Surface plan of Magnet Cove mine, Walton, Nova Scotia.

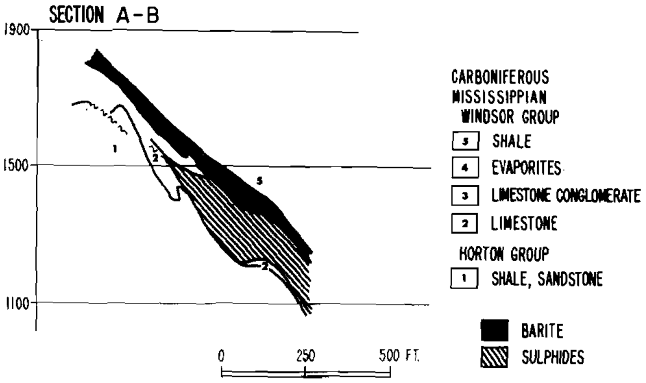

Fig. 3—Section of Magnet Cove mine.

Gays River: The lead-zinc ores at Gays River are located within a dolomitized reef complex of Windsor "B" age. The area drilled shows continuous mineralization for 2¼ miles, averaging ⅛ mile across (Fig. 4). Drill hole intersections indicate thicknesses from 2 ft to 125 ft. These extend from the surface down slope to a depth of 550 ft (Fig. 5).

The reef complex forms part of a barrier between the Minas Basin and the Musquodoboit sub-basin (Fig. 1). The carbonate build up grew on and around a pre-Carboniferous basement island chain in the Windsor sea.

Mineralization at Gays River consists of yellow sphalerite and galena in the ratio of 1.7 to 1. A crude zoning from north to south shows the north part richer in galena. South of the zinc-rich edge is a faint marcasite halo. This is the only evidence of iron sulfides in the carbonate rocks at Gays River.

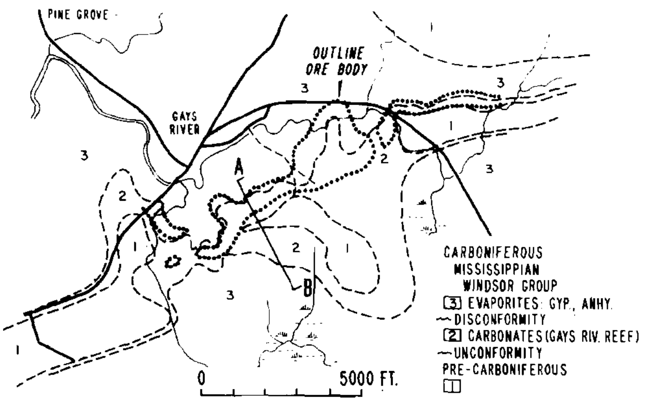

Fig. 4—Geology of Gays River prospect.

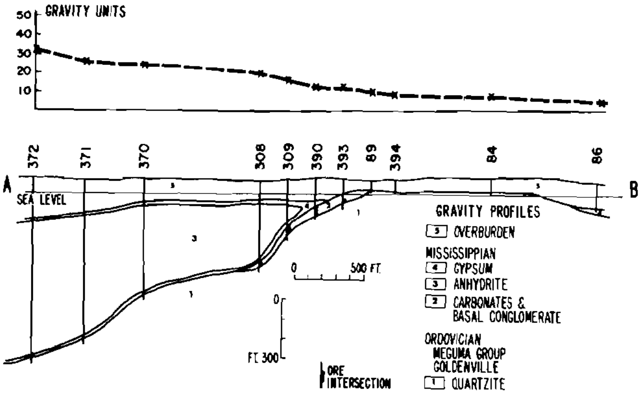

Fig. 5—Section of Gays River prospect.

Ore Genesis and Controls

Boyle[2] considers the lead-zinc-copper-silver sulfide body at Walton as deposited from brines whose movement was structurally controlled.

At Gays River, the authors agree with Jackson and Beales' hypothesis[3] that the lead and zinc were carried to their present site of deposition by brines expelled from Windsor and/or Horton sediments during basin compaction. As Anderson[4] implies, given geological time, the base metal content of these solutions need not have exceeded a few parts per million.

In contrast to the three other known deposits in the Minas Basin, surface drilling results at Gays River have not indicated any structural ore controls. Underground mapping may indicate some structural loci for variation in mineralization.

The four deposits described are all hosted by Lower Carboniferous sediments. All exhibit the association of lead and zinc in a carbonate host. Those sulfide deposits with obvious fault loci, Walton, Pembroke, and Smithfield (as shown in Table 1) differ from Gays River in their silver and/or lead content, plus the association of a barite gangue. These three deposits are near, or within several hundred feet of, a Windsor-Horton contact. At Gays River the nearest known Horton sediments pinch out roughly two miles to the north.

Galena and barite mineralization favour areas of fracture porosity or brecciation. The sphalerite mineralization, on the other hand, is more pervasive. In the fault-controlled deposits to the north, brecciated textures are common. At Gays River there are excellent examples of sphalerite in intimate association with matrix sediment; brecciated textures are also present to a lesser extent.

Geophysical Results

Imperial and others have carried out various geophysical surveys over the Gays River deposit. These included ground and aerial magnetometer surveys, frequency-

Table 1. Data for Walton, Pembroke, Smithfield, and Gays River Deposits

Deposit	Pb/Zn	Cu/Zn	Oz Ag/%Pb	Barite
Walton*	3/1	0.4/1	1.2/1	Plentiful
Pembroke†	34/1	Negligible	0.007/1	Present
Smithfield‡	0.3/1	None	0.50/1	Common
Gays River§	0.6/1	Negligible	0.013/1	Extremely rare

* Ratios from concentrate shipments.
† Average of 2 samples only.
‡ Average of mineralization from drill cores.
§ Ratios from metallurgical tests.

domain induced polarization (IP) surveys, soil resistivity surveys, and a net of gravity stations.

On theoretical grounds it was felt that the lack of chargeable sulfides (i.e. marcasite) associated with the ores, and the average galena content of less than 3% would make detection difficult by induced polarization. IP surveys would be further hindered by the low resistivities of the evaporites which cover roughly half of the mineralized area. This low resistivity observed over the evaporites seems to be the result of solution cavities within the evaporites. Test IP lines over defined drill sections failed to detect the lead-zinc ores. The only increase in chargeability was associated with higher resistance basement topographic features, which also contain minor disseminated pyrite (Fig. 6).

Sensitive magnetometer surveys were run in an attempt to identify, and thus discriminate, basement highs. These indicated a slight increase in magnetic relief, under controlled conditions. The amplitude of this relief, however, was less than the amplitude due to cultural "noise." For this reason, magnetometer surveys have been rejected as a reliable reconnaissance tool. Aeromagnetic surveys, flown high enough to minimize cultural response, were unable to identify topographic highs in the nonmagnetic Ordovician Goldenville formation which underlies the Gays River deposit.

Gravity traverses at Gays River showed the expected positive readings over the thicker evaporite areas (Fig. 5). In the case of a deposit with a barite gangue such as at Walton, a direct positive gravity expression would be expected.

Geochemical Results

As a case history, a reconnaissance stream sediment (−80 mesh) survey was carried out in the vicinity of the Gays River deposit (Fig. 7). As the map indicates, there is no detectable stream sediment zinc anomaly from mineralized outcrops. This lack is probably due to the low mobility of heavy metals in a carbonate environment, coupled with dilution from glacial deposits.

Previous owners of the Gays River deposit geochemically sampled a grid which was centered on the outcrops of subeconomic zinc mineralization. As Fig. 8 shows, in contrast to the stream sediment survey, a definitely anomalous soil zinc content (−80 mesh) occurs in the vicinity of the mineralized outcrops. There is also a narrow "smear" of high zinc content in soils down glacier from the mineralized outcrops for a distance of one mile. As the data show, most of the lead-zinc mineralization is not detectable in geochemical sampling of the thick overlying tills.

Exploration Suggestions

The existence of the four deposits described herein plus a score of other "sights" of base metal mineralization indicate some potential for the existence of a strata-bound lead zinc province in the Nova Scotia Carboniferous.

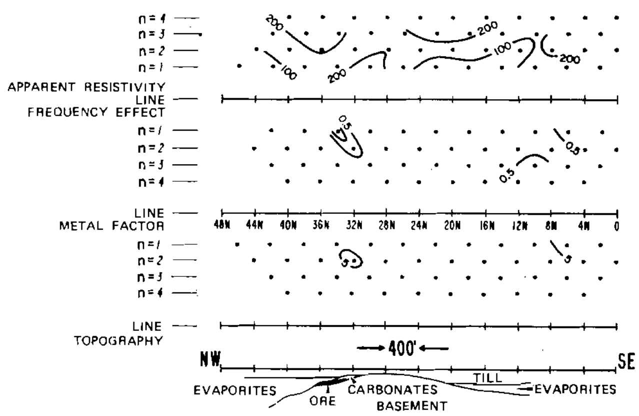

Fig. 6—Induced polarization results, Line 132E, Gays River prospect.

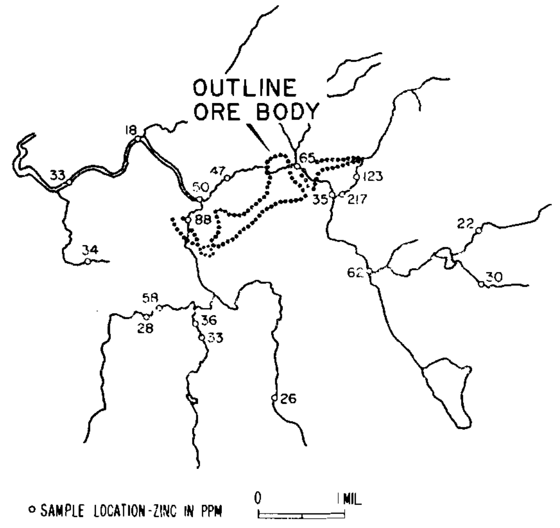

Fig. 7—Zinc reconnaissance stream sediment survey.

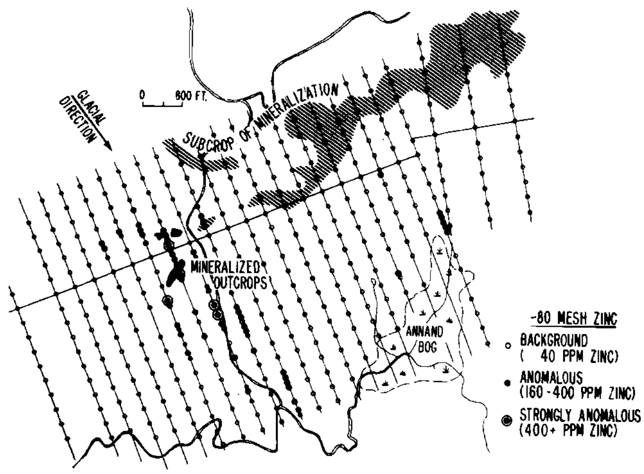

Fig. 8—Soil chemical survey.

The case histories given above suggest that conventional geophysical and geochemical propecting can only have limited application in this area.

The log of one hole drilled for oil in the Windsor section shows that only a small percentage of the section consists of carbonate rocks. Thus any prospecting program must be initially directed toward the location of carbonate areas. This identification can be aided by:

1) The location of basement highs which could act as island loci for reef buildup.

2) Paleontological investigations to aid in determining Mississippian ocean water depths.

3) Studies of published and unpublished data for location of former limestone quarries.

4) Air photo studies for patterns of sink holes. These may be localized at carbonate-evaporite contacts.

5) Studies of the frequency of angular carbonate cobbles in stream gravels.

6) Geological traverses across basement-evaporite contacts.

When a carbonate area has been identified, geochemical sampling of the general area is a first exploration stage. While a geochemical anomaly is a positive feature, the lack of such an anomaly should not lead to the abandonment of a prospect.

The importance of any carbonate accumulation can only be tested through a regular drill pattern. In order to reduce the number of borings (presently costing $8-10 per ft) three environments should be tested initially. These are:

1) The trends of faults or other structural loci.
2) Forereef porous carbonates at an evaporite contact.
3) Proximity to a Windsor-Horton contact.

References

[1] Bell, W.A., "The Horton-Windsor District, Nova Scotia," Memoir 155, 1929, Geological Survey of Canada.

[2] Boyle, R.W., "The Geology, Geochemistry and Origin of the Barite, Manganese, and Lead-Zinc-Copper-Silver Deposits of the Walton-Cheverie Area, Nova Scotia," Bulletin 166, 1972, Geological Survey of Canada.

[3] Jackson, S.A., and Beales, F.W., "An Aspect of Sedimentary Basin Evaluation: The Concentration of Mississippi Valley-Type Ores During Late Stages of Diagenesis," *Bulletin*, Canadian Petroleum Geologists, Vol. 15, 1967, pp. 383-433.

[4] Anderson, G.M., "Hydrothermal Transport and Deposition of Galena and Sphalerite near 100°C," *Economic Geology*, Vol. 68, 1973, pp. 480-492.

Bibliography

Benson, D.S., "Geology of Hopewell Map-Area, Nova Scotia," Memoir 343, 1967, Geological Survey of Canada.

Campbell, C.O., Report submitted to Gays River Lead Mines Ltd., Open Files, Nova Scotia Dept. of Mines, Halifax, Nova Scotia, 1952.

Hannon, P.J.F., and MacEachern, S.B. "The Gays River Discovery—A Mississippi Valley Type Pb, Zn Deposit in Nova Scotia," **Bulletin**, Canadian Institute of Mining and Metallurgy, Vol. 67, No. 750, pp. 61-66.

Newhouse, W.H., "The Composition of Vein Solutions as Shown by Liquid Inclusions of Minerals," *Economic Geology*, Vol. 27, pp. 419-436.

Roedder, E., "Environment of Deposition of Stratiform (Mississippi Valley Type) Ore Deposits, from Studies of Fluid Inclusions," *Genesis of Stratiform Lead-Zinc-Barite-Fluorite Deposits*, J.S. Brown, ed., Economic Geology Monograph No. 3, 1967, pp. 371-379.

Stevenson, I.M., "Truro Map-Area Colchester and Hants Counties, Nova Scotia," Memoir 297, 1958, Geological Survey of Canada.

Stevenson, I.M., "Shubenacadie and Kennetcook Map Areas Colchester Hants, and Halifax Counties, Nova Scotia," Memoir 302, 1959, Geological Survey of Canada.

Zinc in Northeastern Washington–A Review

by A. E. Weissenborn

Current knowledge of the substantial resources of zinc that exist in northwestern Washington is reviewed. These zinc-lead deposits are all associated with the Kootenay Arc, a narrow arcuate belt of folded and faulted rocks that dominates the regional structure of Stevens and Pend Oreille Counties and adjacent parts of British Columbia. The deposits of the Arc are only part of a major lead-zinc silver metallogenic province that includes the deposits of the Coeur d'Alene district and the famed Sullivan ore body of Kimberly, British Columbia. Most, but by no means all the zinc-lead deposits of the Kootenay Arc are in carbonate rocks. They occur in several stratigraphic units, and in different parts of the Arc are quite diverse in character. The deposits appear to have undergone a complex geologic history and have not necessarily all been formed at the same time or by the same geologic processes.

The United States zinc industry began in the early 1860's when plants were built to treat zinc ores from mines in Pennsylvania, New Jersey, and Wisconsin. Until the late 1930's domestic mine production and domestic consumption were virtually in balance. Since then domestic consumption of zinc has doubled, but domestic production has remained nearly constant (Fig. 1).The shortfall has been met mostly by the importation of foreign ores and concentrates. At the same time, world production and consumption have increased greatly. Our failure to mine enough zinc for our needs is by no means due solely to depletion of domestic deposits but is the result of economic factors that have favored the use of foreign materials. In fact, very large domestic deposits of zinc ore have been discovered in the last few years, and this country undoubtedly has large resources of undeveloped zinc ores.

The world price of zinc recently soared to an all-time high (Fig. 2) of over 73¢ per lb. From January 1973 to February 1974 the domestic price was limited to about 21¢ by a government-imposed ceiling. With the removal of the ceiling, the domestic price also increased sharply, although still far below quoted prices on the London Metal Exchange. Both the domestic price and the price quoted on the London Metal Exchange have declined in recent months but as of November 1974 were still well above those prior to 1973. Because of the lack of smelting capacity, which has been adversely affected by the closure of seven domestic zinc smelters, the increased price is not expected to lead to any immediate

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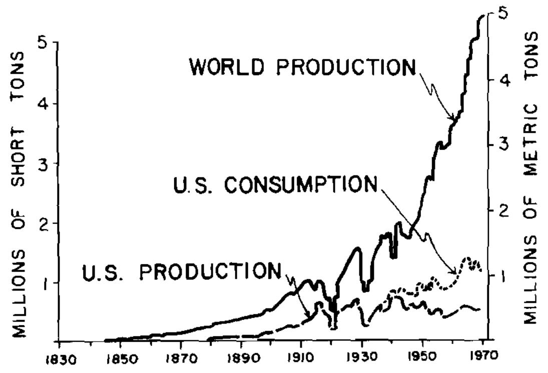

Fig. 1—United States and world production of zinc and United States consumption, 1830-1970. (Adapted from Wedow et al.,[1] Fig. 77.)