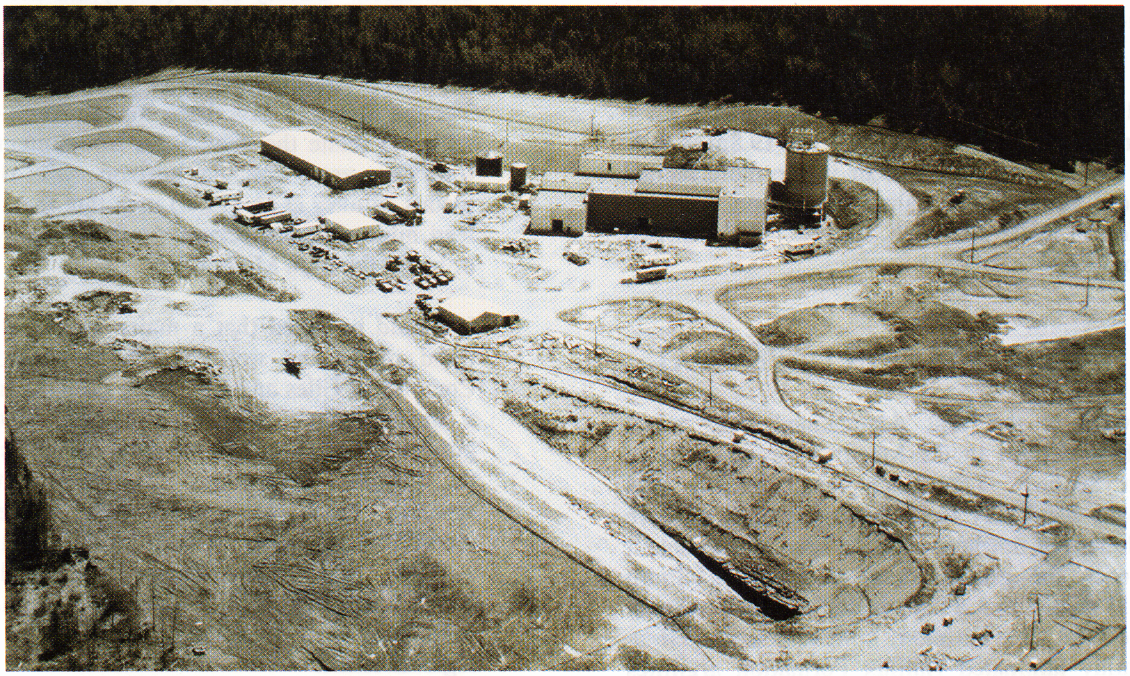
6. CARBONATE-HOSTED DEPOSITS: GAYS RIVER



Aerial view of Gays River mine complex.

6.1 INTRODUCTION

Over the past forty years carbonate-hosted base metal deposits have emerged as a major source of lead/zinc ores, with fluorite, baryte and copper in greater or lesser amounts. The type examples for this deposit class were the SE Missouri, East and Central Tennessee, and Tri-State deposits and the term Mississippi Valley Type (MVT) was applied to all carbonate-hosted base metal deposits. It very quickly became apparent that attempts to squeeze all such deposits in a MVT category were invalid and the term carbonate-hosted is now preferred.

Historically most deposits within this class were to be found in North America but over the past thirty years significant discoveries have been made in Europe, Africa, Asia and Australia. Recent discoveries in Australia have confirmed the tonnage potential of such deposits and recent Irish discoveries indicate that grades can also be greater than previously thought.

Stratigraphically these deposits range from the Ordovician to the Cretaceous and are hosted by carbonates of marine origin which may be limestone or dolomite. The paleotectonic settings for this deposit type include the margins of marine basins within stable cratonic areas, in the failed arms (aulacogens) of rifted continental areas, and on the flanks of embryonic oceans (Evans, 1987).

The carbonate-hosted deposit class characteristically displays a wide variety of deposit types. These include the vein type deposits of the British Pennines, the solution and collapse karstic structures of Baffin Island and the Tri-State, the interconnected small scale solution cavities at Pine Point, and also the massive stratiform orebodies in Ireland and Australia.

Much of this diversity can be displayed within one ore field, as in Ireland, and a similarity of deposit type has been documented from Nova Scotia. Thus the Gays River deposit illustrates a deposit with many characteristics of MVT deposits, while the Jubilee deposit, in Cape Breton Island, shows more of a structural control. The Walton and Lake Enon deposits show the close association between sulphides and sulphates, and these can be compared with the Silvermines deposit in Ireland. The Walton deposit displays more evidence of a structural control and the high silver content is anomalous for a true MVT. However, it does confirm what happens in other carbonate-hosted deposits and is good support for dropping the term MVT.

Though most of the carbonate-hosted deposits in Nova Scotia are contained within sediments of Lower Carboniferous age, the marble-hosted deposits of Cape Breton Island, (described above in Section 4) can also be regarded as associated. The Carboniferous and marble-hosted deposits are essentially Zn ± Pb deposits and as such can be regarded as falling within the class. However, a most important carbonate-hosted deposit occurs within the Silurian rocks at **Lochaber** in Antigonish County. This deposit differs from the others because it is essentially a copper deposit and shows that the target within the carbonates throughout the stratigraphic section in Nova Scotia can also include copper deposits.

The **Lochaber Lake** Cu deposit is hosted within the Silurian /Devonian age Stonehouse Formation which was deposited in a within-plate continental extensional environment (Murphy, 1986). Geological relationships suggest that these faults were active during sedimentation. The local stratigraphy indicates a gradual shallowing of the depositional environment with a final return to subaerial conditions. The limestones in the upper parts of the Silurian section may have been deposited in slightly deeper parts of the shallowing basin. Thus the tectonic environment of shallow sedimentation with local deeper basins giving rise to limestone deposition together with contemporaneous volcanism would support the synsedimentary deposition of metals.

The **Lochaber Lake** section contains approximately 150 m of limestone, mudstone and siltstone enclosed within maroon shale or siltstone. The impure limestone unit strikes northeasterly and dips north at a steep angle. A persistent northwesterly-dipping fault also strikes northeasterly and brecciates the limestone unit for about 10 m out from the structure. Stratabound copper mineralization occurs as disseminations and small blebs of sulphides in the lower 70 m of the limestone. Mineralization comprises mainly chalcopyrite, malachite and pyrite with minor bornite, sphalerite and galena.

Drilling of 16 holes by International Mine Services in 1971-72 outlined drill indicated reserves of 2.29 million tons @ 0.33% Cu, with an additional 3.44 million tons inferred to a depth of 1000 ft. Analyses reported by Northcote et al. (1989) did not indicate any other elements of economic value.

The stratiform nature of the mineralization and the fact that it occurs at the base of a reducing horizon suggests a sedimentary syngenetic or diagenetic origin. Metals may have been deposited during sedimentation or derived from redbeds by dewatering during compaction with deposition in a reducing environment. There is existing potential in the immediate area of the known deposit and the possibility exists of other sub-depressions along the fault zone which might contain limestone horizons with higher grade sulphide mineralization.

The wide geographical distribution, the stratigraphic range, and the diverse variety of carbonate-hosted deposits in Nova Scotia suggest that the search for deposits capable of sustaining commercial production is well founded.

6.2 LOCATION AND ACCESS

The deposit used to illustrate this class is the **Gays River** deposit, which is located in Halifax County approximately 60 km north of Halifax, on NTS map sheet and at 63^{o} 21' 30" W and 45^{o} 01' 55" N. The deposit lies some 19 km from the Halifax International Airport and access is by paved road.

6.3 EXPLORATION HISTORY

From the first reports of mineralization in the area in the early 1800s, exploration activity up to 1950 had consisted of prospect pits, trenches, and sampling which yielded best values of 3% lead. In 1951 Maritime Barytes Ltd. carried out surface exploration and sampling in the showing area and in 1952 Gay's River Lead Mines drilled 74 holes (2876 m) and identified 900,000 tons of 1.1% to 3% Pb+Zn.

In the period 1952-1972, Gunnex, Penarroya Canada Ltd. and Texasgulf carried out geochemistry, mapping and limited drilling in the area. Early drilling was hindered by overburden problems, and many of these holes were abandoned prior to reaching their target. It should be noted that successful completion of some of these early drillholes would have led to the discovery of high grade Zn/Pb mineralization.

In 1972 Cuvier Mines acquired the property, outlined geophysical and geochemical anomalies and, more importantly, discovered high grade sphalerite/galena-bearing boulders. This proved the existence of mineralization of much higher grade than previously discovered. The discovery of these high grade boulders prompted participation by Imperial Oil Ltd., resulting in a joint venture with Imperial holding a 60% interest.

During 1972-1974 Cuvier/Imperial drilled approximately 450 holes, and identified 12,000,000 tons of about 7% combined Zn+Pb, over an area of approximately 3.5 km x 8 km. The discovery hole (#21), drilled 2.5 km northeast of the old Gays River showing, intersected 11 feet of 7% Zn (MacEachern & Hannon, 1974). Some of the better intersections during this drilling program ranged from 60.5 ft @ 4.53% Pb, 7.73% Zn; to 16.5 ft @ 10.26% Pb, 19.02% Zn.

During 1975-1976 Cuvier and Preussag Canada Ltd. formed Preuvier Mines Ltd. to finance Cuvier's 40% interest in the property. Further drilling was carried out and a 760m decline was driven, resulting in a downward revision in ore reserves to 6.0 Mt @ 7% Pb+Zn.

In December 1977 Esso Resources Canada Ltd. (Imperial Oil) bought the interests of Cuvier, Preussag and Preuvier and formed Canada Wide Mines Ltd., to develop and mine the deposit. Canada Wide Mines Ltd. commissioned a 1500 ton/day mill (completed in October 1979) and started underground development. In December 1980 mineable reserves were 5,200,000 tons grading 2.78% Pb and 4.23% Zn. Esso Resources' approach is described by Westminer Canada (1991) as follows:

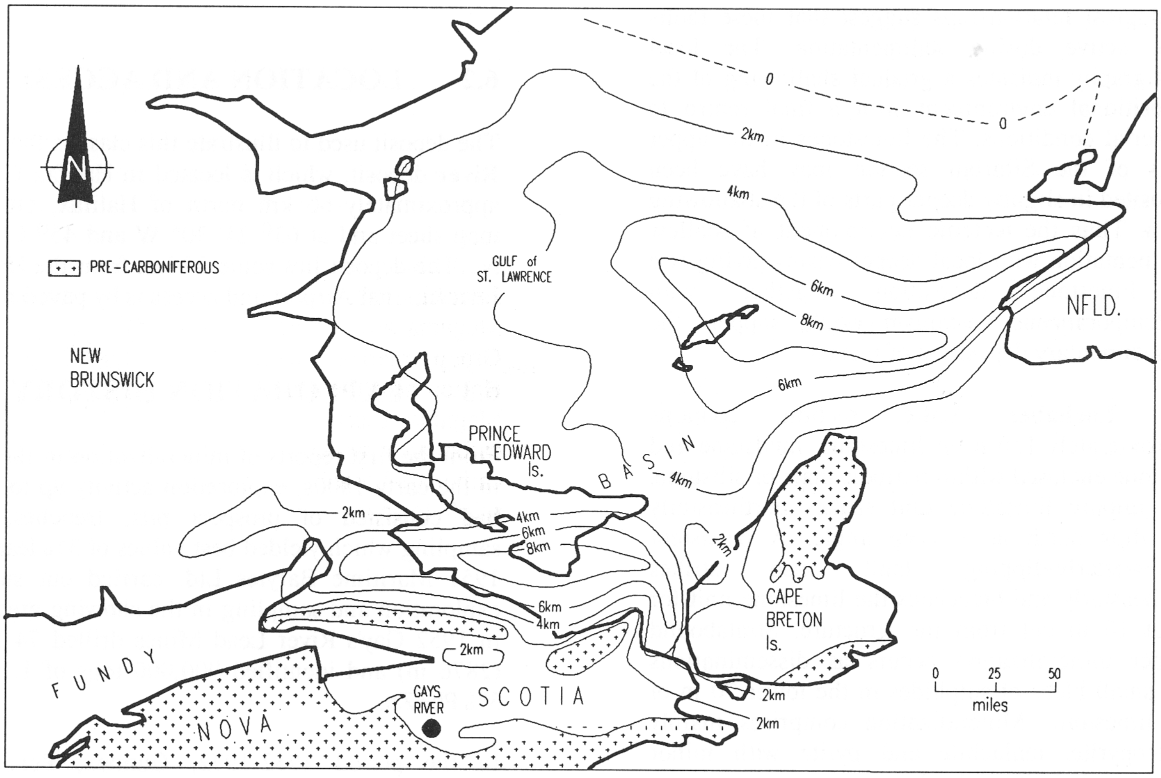


Figure 20. *Fundy (Magdalen) Basin and the location of the Gays River carbonate-hosted deposit (after Ravenhurst, 9187).*

"Esso's approach was to mine relatively low grade ore with high tonnage bulk methods at low cost. Highly mineralized ore zones were not included in the mining plan and were generally left behind."

It should be noted that the highest grade ore at Gays River occurs directly below a poorly consolidated "trench filling" material. It was deemed necessary to leave this high grade material (massive sphalerite) in place as a crown pillar.

In the period 1971-1981 Canada Wide Mines milled approximately 550,000 tons of ore at which stage adverse ground conditions, water problems, lower than expected grade and tonnage, and complex geology caused operations to cease.

In 1985 Seabright Resources Inc. acquired the property and mill for the purpose of milling gold ore. In 1988 Westminer Canada Limited acquired Seabright and, after initial gold milling operations at the Gays River mill, converted the mill back to Zn/Pb processing and began full scale production from the Gays River deposit in March 1990.

In May 1991 hydrogeological difficulties and poor ground conditions prompted Westminer to cease production and in October 1991 buyers were actively sought.

In April 1992 Dundee-Palliser Resources Inc. announced that it had signed a letter of intent with Westminer to acquire the Gays River mine and mill.

6.4 REGIONAL GEOLOGY

The Gays River deposit occurs near the southern margin of the large (> 250,000 sq. km.) and deep (> 12 km) late Paleozoic Fundy (Magdalen) Basin (Fig. 20), bordered on the northwest by the New Brunswick platform, and on the south by the Meguma Platform. During the late Paleozoic the Fundy Basin was divided or segregated through a complex series of grabens into deep linear successor basins or sub-basins, which are now interpreted (Fralic and Schenck, 1981; Bradley, 1984) as pull-apart basins. Subsequent basement subsidence, fragmentation and block faulting produced the irregular pre-Carboniferous topography that was partly infilled by early Carboniferous clastics, and later flooded by middle Carboniferous seas. Carboniferous sediments consisting of terrestrial conglomerates, sandstones, siltstones, and marine limestones and evaporites, were deposited in this Fundy Basin. The complex structural patterns of the Fundy Basin probably remained active during and after the Carboniferous, and may have had a major impact in the ore-forming process. These sub-basins contained thick accumulations of terrestrial and shallow marine sediments, and therefore could provide substantial volumes of basinal fluids (Ravenhurst, 1987).

The Gays River area is underlain by the Cambro-Ordovocian metasediments of the Meguma Group (Fig. 21), which form the pre-Carboniferous basement upon which the Gays River carbonate host rock was deposited. The Meguma rocks were tightly folded during the Acadian orogeny into long NE-SW anticlines and synclines which have been faulted and jointed. Erosion of this basement into irregular knobs and ridges was controlled by these structures prior to deposition of overlying sediments (the Gays River carbonate) (Akande and Zentilli, 1983). Unconformably overlying the Meguma are Horton Group clastics and Windsor Group marine sediments which overstep the Horton near the basin margins and rest directly on Meguma basement. It is these Windsor Group carbonates which have been the host for the carbonate-hosted base metal and associated sulphate deposits in Nova Scotia.

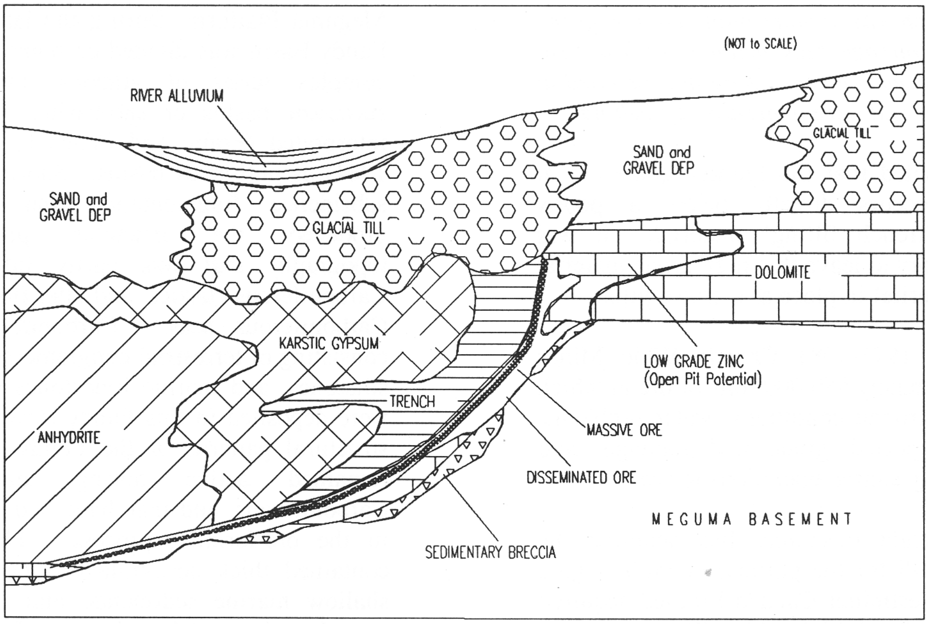


Figure 21. *Gays River deposit - vertical section (after Westminer Canada, 1991).*

6.5 DEPOSIT GEOLOGY

The Gays River deposit occurs in a Windsor Group dolomitic carbonate buildup (reef complex) overlying irregular Meguma basement. A Meguma basement topographic high separates the Shubenacadie and Musquodoboit sub-basins, and produced a favourable environment for carbonate reef development (Fig. 21). The reef complex is now overlain by overburden with thick accumulations of evaporite on each side. However, prior to erosion the total reef complex was covered by evaporite, primarily anhydrite.

Erosion of the protective anhydrite cap over the reef and subsequent solutioning of evaporite at the carbonate-evaporite contact produced a trench area which is now filled by Cretaceous to Recent sediments. It is these sediments that have caused many of the mining difficulties and high water volumes experienced in the mine.

MacEachern and Hannon (1974) identified four main reef facies, namely fore-reef, reef crest, reef proper and back-reef. It is noteworthy that the mineralization shows no preference for any particular horizon within the sequence, nor is it restricted to any one facies. Flanking the reef and slightly disconformable to it are thick beds of gypsum and anhydrite, whereas thick deposits of glacial till overlie the reef. The average depth of overburden is 35 m, with common depths in excess of 60 m.

Hatt (1978) indicated that the carbonate lithologies constitute a wave-resistant organic-framework reef with flank deposits separated from a back-reef lagoon by a carbonate barrier.

Akande and Zentilli (1983) state that detailed underground mapping in the mine indicates that the re-entrant areas, separating the basement knobs and ridges, consist of channel fill conglomerate and grainstone. Bindstone, bafflestone and packstone are the predominant rock types on the basement ridges. These rock types are locally brecciated in areas adjacent to faults. The erratic distribution of carbonate rock types within the deposit and the common occurrence of admixtures, even on a centimetre scale, are indicative of abrupt changes and shifting environments of deposition. It should be noted that Westminer personnel (pers comm.) do not recognise faulting as an ore control within the mine area.

6.6 MINERALIZATION

The mineralization at Gays River grades from massive Pb/Zn ore-grade material to finely disseminated very low grade sub-ore material. The grade and magnitude of sulphide mineralization appear to be directly related to the pre-ore permeability and porosity of the reef host rock.

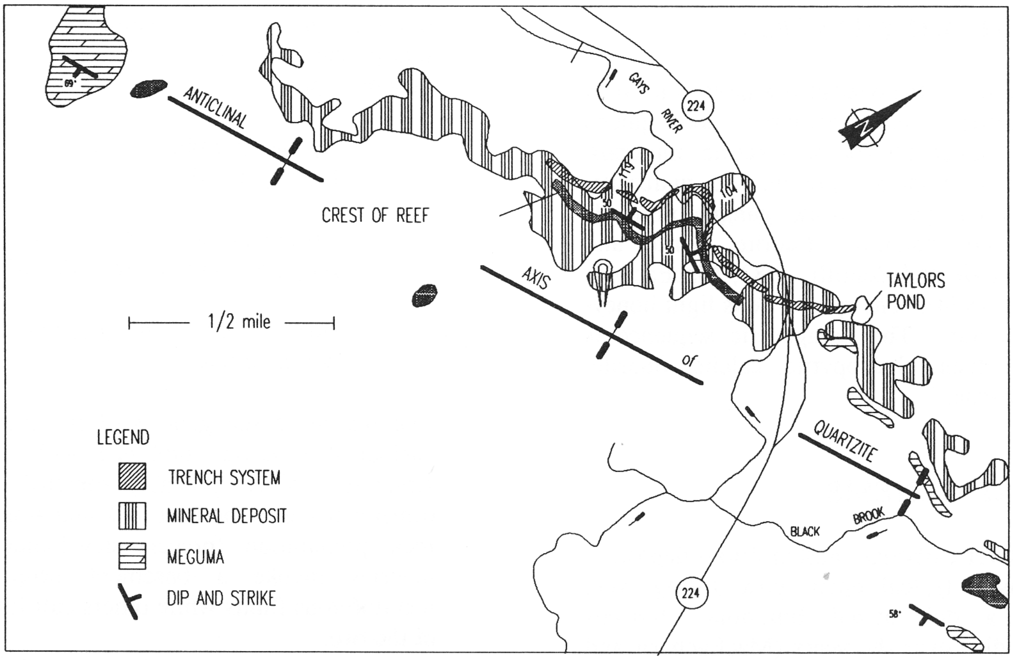


Figure 22. *Plan of Gays River deposit (modified after Esso Minerals Canada).*

The massive Zn/Pb mineralization (Fig. 21) occurs on the top of the dolomite reef at the carbonate/evaporite contact (i.e. the zone of maximum permeability) in a zone primarily in the fore-reef area of the reef proper. In addition it appears that minor concentrations of massive mineralization do occur within the reef proper in areas of fault traces.

The maximum paleo-fluid movements probably occurred along the areas of greatest permeability, which were (a) along the carbonate /evaporite contact in the area of the fore-reef rubble zone and, (b) along fault zones that in all probability were active throughout the time of host rock deposition and subsequent metal deposition.

MacEachern and Hannon, (1974) recognize two main types of mineralization. **Type 1** mineralization is the primary low grade ore which is interpreted as low temperature sulphide infilling of pore space in the host rock. **Type 2** mineralization is the secondary high grade ore which is interpreted as the product of secondary leaching of the primary ore during the karstification process (gypsum solutioning).

Akande and Zentilli (1983) also recognize two main styles of mineralization. The **stratiform** ores are open space fillings and sulphide mineral replacements with an average grade of 5% and increasing to 15-20% along the carbonate/evaporite contact and in areas adjacent to vein ore. **Vein** ores occur as fault-controlled massive base metal sulphide bodies that are distributed in a fault pattern within the carbonate host. The fissure veins constitute approximately 25% of the ore in the deposit and form the highest grades of 60% Zn and 10% Pb.

Westminer Canada (1991) describe the ore grade mineralization at the evaporite contact and interpret this as "replacement" along this contact. The grade of mineralization reduces to sub-ore within 3 m from this contact into the dolomite reef. The "ore deposit" is a massive replacement of the dolomite host, and Westminer do not recognize significant fault related mineralization.

The high grade ore consists of a thin, very high grade, massive sulphide zone in contact with the evaporite or Trench ranging in thickness from 0.1 to 5 metres and grading up to 78% lead and 57% zinc (Fig. 20). On the footwall of the massive sulphide, a zone of disseminated ore grade material (>7% zinc equivalent) is present and locally attains 12 m in thickness. Locally disseminated mineralization (> 2% zinc equivalent) extends up to 20 m into the footwall and Kontak (1992) states that 86% of the ore zone falls within a 60 m vertical interval. The mineralization occurs as a continuous sheet extending for 4 km along strike and mimicking the Carboniferous palaeotopography (Fig. 22).

6.7 ORE MINERALOGY

The mineralogy of the deposit is simple, with only trace impurities, and sphalerite and galena constituting about 99.5% of metallic minerals. Other sulphide minerals present are marcasite, pyrite and chalcopyrite, while gangue minerals include calcite, dolomite, fluorite, barite and selenite (Akande and Zentilli, 1983; MacEachern and Hannon, 1974). The sphalerite is light honey-yellow in colour. The paragenetic sequence is sphalerite, galena, chalcopyrite, calcite, fluorite, calcite and barite.

6.8 ORE GENESIS

The Gays River carbonate-hosted Zn/Pb deposit is classified as a typical open space filling type, hosted in a dolomitized limestone. Various research studies over the years (MacEachern and Hannon (1974), Akande (1982), Ravenhurst (1987), Ravenhurst and Zentillii (1987) and Kontak (1992)) are in general agreement that the Gays River deposit is the result of open space (cavity) filling in a carbonate host rock.

The host rock dolomite developed as a carbonate buildup on an irregular pre-Carboniferous basement topographic high where conditions allowed for growth of reef-building organisms. The Meguma basement highs were originally thought to be the result of irregular folding and erosional features, but analogies with Irish carbonate-hosted deposits suggest that faulting has to some extent controlled the development of this irregular basement and the subsequent development of the host carbonates. This faulting was probably active through geological time and may have provided

(i) the plumbing system to tap metal-bearing solutions,

(ii) the pathway along which the solutions migrated to their site of deposition, and

(iii) assisted in preparation of the dolomite host.

Theories as to the genesis of the metals invoke basinal dewatering combined with active fault structures, which probably directed the metal-bearing brines to the host rock and assisted in host rock preparation (breccia development). Other theories invoke a basement origin for the metalliferous fluids while others call for a mixture of the two.

Kontak (1992) states that the result of his own research and that of other investigators suggest:

(i) mineralization resulted from the dissolution of the dolomite by heated brines of unknown origin,

(ii) the sulphur source was local,

(iii) a chemical front induced metal precipitation from a supersaturated solution, and

(iv) several fluid resevoirs were involved.

Historic Milling Information

	Ore Milled	Mill Head Grades Pb %	Mill Head Grades Zn %	Concentrate Grades Pb %	Concentrate Grades Zn %	Metal Recovery Pb %	Metal Recovery Zn %
Esso 1979-1981	553,688 tonnes	1.36	2.12	73.6	61.5	95.3	89.7
Westminer !989-1991	187,010 tonnes	3.50	7.47	75.6	61.2	90.9	88.9

Table 6.1 (Westminer Canada, 1991)

6.9 PRODUCTION HISTORY AND DATA

Modern mining of the Gays River deposit commenced in 1975 with the excavation of a 760 m long decline by Esso Minerals Canada. Mining difficulties due to water influx and poor roof conditions slowed development, but by mid 1979 some 1800 m of underground drifting and 744 m of underground development had been completed. The deepest workings were at a depth of 100 m.

The Esso mining operation used trackless, large tonnage, low grade methods, leaving in place the high grade Zn/Pb ore along the carbonate/evaporite contact as a hanging wall for the roof support. This operation was to feed a 1500 tpd mill but mining difficulties exacerbated by bad ground conditions and excessive water inflow caused the operation to be suspended in 1981. The head grades did not even approach the planned grades (Table 6.1).

In 1988 Westminer Canada Ltd. acquired the property and initiated mine dewatering in early 1989. A review by Westminer concluded that a more selective narrow vein mining method, which would mine the high grade hanging wall zone, would be more appropriate. Commercial production began in March 1990 but continuing hydrological difficulties caused poor ground conditions. In May 1991, rising water levels due to the spring runoff forced the temporary suspension of mining to permit a comprehensive investigation of the hydrology of the area. The Westminer mining strategy permitted a much higher grade to be mined to feed the 600 tpd operation.

Separate Zn and Pb concentrates were produced from the Westminer operation as follows:

Zinc Concentrate: Assays

Zn	58-62%;
Pb	1.9%;
Fe	0.5-0.9%;
Cd	0.35-0.45%;
Cu	0.13%;
Ag	5-20 g/t;
Ba	0.0002%;
Au	trace.

Lead Concentrate: Assays

Pb	72-76%;
Zn	4-5%;
Cu	0.1%;
Ag	50-70 g/t;
Au	trace;
Ba	0.004%.

The following reserve figures have been generated over the life of the mining activity:

1974	Cuvier-Imperial Oil 12,000,000 tons @ 7% Pb + Zn (drill indicated)
1976	Cuvier-Imperial Oil 6,000,000 tons @ 7% Pb + Zn (mineable)
1977	Canada Wide Mines Ltd. (Esso Minerals Canada) 5,200,000 tons @ 2.78% Pb + 4.23% Zn, (mineable) cutoff; 2.4% Pb+Zn
1991	Westminer Canada Ltd. 2,401,742 tonnes @ 6.3% Pb + 8.7% Zn, (geologic) cutoff; 7% Zn equivalent.
1991	Westminer Canada Ltd. 1,371,000 tonnes @ 5.28% Pb + 9.81% Zn, (mineable) cutoff; 7% Zn equivalent.

It is the smaller tonnage but high grade figures of Westminer that in April 1992 prompted Dundee Palliser Resources Inc. to investigate the purchase of the deposit and facilities with a view to reactivating production.

6.10 EXPLORATION TECHNIQUES

Prospecting and geochemistry have been instrumental in the location of drilling targets in the Lower Carboniferous rocks of Nova Scotia.

At Gays River, prospecting located mineralized float of a grade much higher than that in the known mineralized showing and it was follow-up of this that led to the discovery of the deposit as currently known. Due to the thick overburden cover in the areas of Carboniferous rocks, conventional geochemical techniques are not universally applicable. It should be noted that the sulphides at the Walton baryte mine topped out 82 m below surface and were found only as a result of mining the baryte body.

Many occurrences of carbonate-hosted base metals are know in the Carboniferous basins of Nova Scotia and it is clear that potential for further discovery lies down dip from these known, and other as yet unknown, occurrences. As in the 1970s and 80s it will be diamond-drilling that will be the most successful exploration tool. Fence drilling will be required to determine geological relationships. As in other carbonate-hosted ore fields, grades vary rapidly from massive ore to weak mineralization over short distances so infill drilling will be required to follow up low grade intersections.

Effectiveness of the direct use of geophysics to locate ore is also reduced by thick overburden. Regional geophysics have been used to map irregular Meguma basement topography on which paleo-conditions may have allowed for reef buildups. This technique allowed Amax Exploration Inc. to locate the buried Chib-Dutch Reef in the Dutch Settlement area in 1974 (Isenor, pers. comm.).

6.11 ANALOGIES

The Gays River carbonate-hosted base metal deposit is similar to many such deposits worldwide. Within Nova Scotia the deposit is part of the family of deposits contained within the Lower Carboniferous Windsor Group sediments. Jubilee, Smithfield, Walton and Lake Enon all are part of this deposit class. The deposits exhibit many differences as well as similarities and analogies can readily be drawn with the carbonate-hosted Tynagh and Ballinalack deposits in Ireland and some of the Mississippi Valley deposits in SE Missouri.

Characteristically these deposits are zinc dominant and range from the irregularly distributed replacement deposits within 'reef' limestones to the more stratiform massive ore types. Within the Irish metallogenetic province both types are present, are spatially related to faulted contacts, and can range in tonnage from several hundred thousands of tonnes to in excess of 100 Mt. Grades range from 5% combined Zn + Pb to > 15%.

This deposit class, with its wide variety in grade, tonnage and morphology, is a major contributor to the world's Zn/Pb inventory. In Ireland, Australia and western Canada exploration farther out into the basins has been successful and it is a saluatory lesson to realise that the two major carbonate-hosted deposits discovered in Ireland since 1986 have been down dip from areas where considerable exploration, including diamond-drilling, had been carried out over the previous twenty years. It can be anticipated that similar drill programs in Nova Scotia could meet with similar success.

6.12 EXPLORATION POTENTIAL

The Gays River deposit is but one of the carbonate-hosted mineral deposits known in Nova Scotia. A feature of this deposit, and of many carbonate-hosted deposits in general, is the long and sinuous strike length compared with the relatively narrow dip component (Fig. 22). Other occurrences, including the Getty-Scully and the Chib-Dutch reef deposits are known in the immediate vicinity, while other significant deposits, including the former producers at Walton and Lake Enon, are known on a province-wide scale. As noted above discoveries to date have been either outcrop or sub-outcrop, though it should be noted that the base metals at Walton topped out at approximately 80 m below surface.

The Gays River deposit has a stated geological reserve of 12 Mt at 7% Zn+Pb. However, the peculiar coincidence of a Pleistocene trench and a large river have given rise to difficult mining conditions which have caused termination of mining activity. The evaporites form a competent hanging wall and it can be postulated that carbonate-hosted base metal deposits, as illustrated by the Gays River deposit, will occur under deeper cover further out in the basin and represent attractive exploration targets.