1. INTRODUCTION

1.1 OBJECTIVE OF THIS STUDY

The primary objective of this study is to increase the awareness among the mining and exploration industry of the variety of geological environments in which base metals have been discovered in Nova Scotia. By identifying the main base metal environments in the province and by illustrating each class by a representative deposit it is hoped that company personnel will be encouraged to delve a little deeper into the potential of this province. The deposits selected as representative of each class are, where possible, former producers so that a good database is available from which to expand and develop an exploration model and program. By drawing analogies with better known deposits, both nationally and internationally, it is intended to demonstrate the potential for further discoveries of associated deposits within the province.

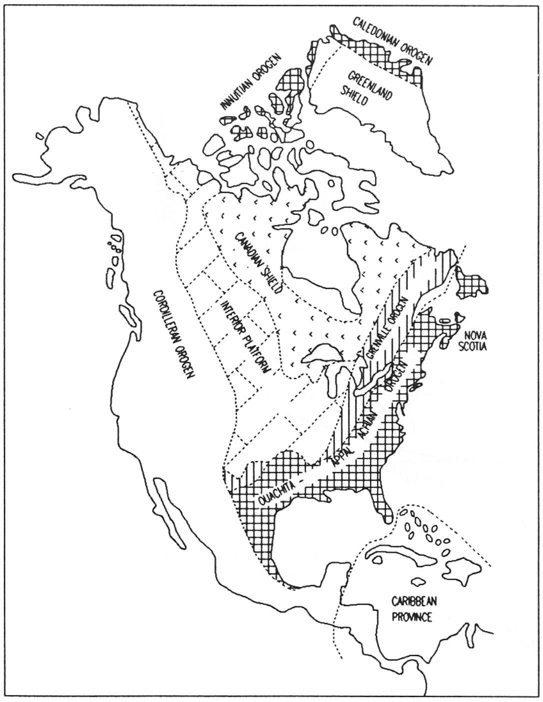


Figure 1. *North American orogenic and mineral production provinces.*

1.2 REGIONAL GEOLOGICAL SETTING

Situated on the eastern seaboard of North America, and with a land area of some 55,000 square kilometres, Nova Scotia lies within the Acadia Composite Terrane (Keppie, 1985) in the northern part of the Appalachian Orogen.

The Appalachian Orogen is a Paleozoic megastructure (Fig. 1) that stretches more than 3000 km from Alabama in the southwest to Newfoundland in the northeast. The chain is bounded to the northwest by the Laurentian craton of Precambrian rocks or by their platform cover. Within the Appalachian Orogen lie strips of post-orogenic early Mesozoic sedimentary and volcanic rocks, deposited in grabens or half grabens. Williams (1978) has attempted to trace tectonostratigraphic belts within the megastructure and interprets these as representing specific geotectonic, fossilized environments reflecting original Ordovician paleogeographic elements which have been tectonically assembled as an orogenic belt.

Bird and Dewey (1970) first proposed the concept of tectonic assembly by suggesting that the northern Appalachians were formed as a result of a collision between Laurentia and the Avalon platform. An oceanic domain comprising continental shelves, island arcs, back-arc basins and associated sedimentary and igneous rocks was postulated between the two. Upon collision this mixed rock assemblage was thrust (obducted) onto the continental edge. Ophiolite sequences (interpreted as remnants of oceanic lithosphere) within the obducted masses mark the suture lines between the collided plates.

Keppie (1992) states that the long lived , though geographically restricted, deformation events which appear to characterize the early Paleozoic evolution of the Appalachians may be related to terrane accretionary events. He suggests that these events were followed by a terminal, diachronous, long-lived event which affected the entire width of the Canadian Appalachians and which may be related to continental collision.

Keppie notes that the Precambrian deformational events in the Appalachians in general and in Nova Scotia in particular are represented by:

(i) Middle Proterozoic polyphase structures associated with high grade metamorphism within Grenvillian inliers in northwest Cape Breton Island and eastern Cobequid Highlands, and

(ii) by Late Proterozoic-Cambrian single phase to polyphase structures accompanied by low to high grades of metamorphism in the Avalon Zone.

The Paleozoic deformational events in the Canadian Appalachians are described by Keppie as corresponding to narrow diachronous events in the Ordovician, Silurian and early to middle Devonian, whereas the late Devonian, Carboniferous and Permian deformational events are widespread and broadly synchronous. It is these Paleozoic events which have combined to form the Appalachian Orogeny. Keppie notes that in plan view the shape of this orogen is inherited from the original irregular edge of the North American craton. In general the major structures also follow this sinuous trend in the orogen and Keppie suggests that their surface traces are more a function of the initial geometry of the North American margin rather than of kinematics.

Keppie (1985) introduced the term "composite terrane" to describe the collage of smaller terranes of the Avalon belt and in 1987 proposed a sequence of five terrane categories, from northwest to southeast, for the northern Appalachians. Keppie's terranes 4 and 5 are well represented in Nova Scotia by the diverse Precambrian terranes which comprise the Avalon Composite Terrane and the Cambro-Ordovician metasediments of the Meguma Terrane, the most outboard of the northern Appalachian terranes.

The Avalon Composite Terrane shows signs of several stages of deformation and assembly with docking of individual parts occurring at different times. Thus the Carolina terrane in the south docked in the Ordovician while the Avalon terrane, in southeastern New England, docked in Devono-Carboniferous times.

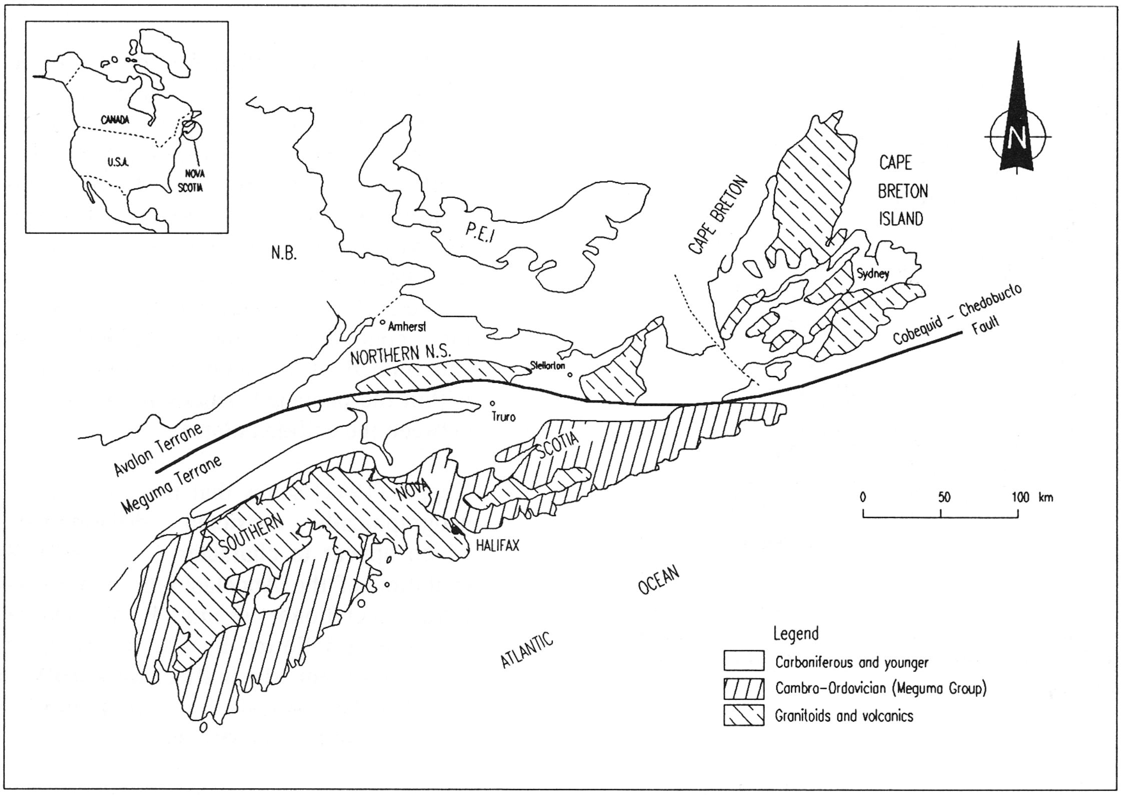


Figure 2. *Simplified geological map of Nova Scotia.*

The Meguma terrane, an important part of Nova Scotia, is bounded on its northern side by a major east-west dextral shear/fault zone - the Cobequid/Chedabucto Fault. The earliest docking was in Devonian times while the boundary between the Meguma and Avalon terranes is overstepped by the earliest Carboniferous unconformity. Other evidence indicates a prolonged period of convergence, ranging from Devonian to early Permian, after initial accretion.

It should be noted that Keppie (1992) has redefined some of these deformational events and has introduced a revised nomenclature for the orogenic phases. However, for the purposes of this paper, the longer established names are retained for the main orogenic events in Nova Scotia.

1.3 GEOLOGICAL FRAMEWORK OF NOVA SCOTIA

A simplified geological map of Nova Scotia (Fig. 2) shows a broad division into three main geological areas. Southern Nova Scotia is separated from Northern Nova Scotia and Cape Breton Island by the prominent Cobequid-Chedabucto Fault System.

This southern section conforms to the Meguma Terrane of Keppie, which comprises argillites and greywackes of Cambro - Ordovician age. These rocks were folded during the Acadian Orogeny of Devonian age into northeast- to north-trending upright folds. During Devonian and Carboniferous times these rocks were intruded by granites. Throughout the Carboniferous, non-marine and minor (in extent but important economically) marine sedimentation occurred upon the older rocks in downfaulted and warped areas.

The area to the north of the Cobequid-Chedabucto Fault System is geologically more complex and difficult to generalize. On mainland Nova Scotia, lower to middle Paleozoic with minor Proterozoic rocks occur in two areas known as the Cobequid and the Antigonish Highlands. Adjacent to these blocks, thick successions of Permo-Carboniferous non-marine and minor marine sediments occur in faulted and folded rift basins and/or synclinoria of various sizes.

Hadrynian or older Proterozoic sedimentary and volcanic rocks crop out in much of northern Cape Breton Highlands and along SE Cape Breton Island. Smaller basement horsts occur scattered throughout the remaining area. In SE Cape Breton Island these rocks are overlain by a lower Paleozoic sequence of Precambrian to Cambrian sedimentary and volcanic rocks. Granitic and minor basic plutons of Carboniferous, Devonian and possibly Ordovician or older age intrude the older deformed rocks. As on mainland Nova Scotia, a very thick succession of non-marine and minor marine sediments occur in faulted and folded basins and synclinoria that developed adjacent to and on top of the older rocks.

Glaciation has played a major role in moulding the present day topography and Pleistocene glacial deposits, both till and glaciofluvial deposits, mask much of the bedrock.

1.4 STRATIGRAPHIC RANGE OF METALLIC MINERAL DEPOSITS

Nova Scotia has had a long mining history with the first recorded coal export being a shipment from Cape Breton to Boston in 1724. Coal, hosted by Upper Carboniferous silicilastic rocks, and gypsum and salt, hosted by Lower Carboniferous rocks contribute significantly to the provincial mining industry.

Metallic mineral deposits have played an important role in the Nova Scotian economy, and deposits from a wide range of the stratigraphic column have been mined (Fig. 3).

The purpose of this paper is to identify the main geological environments or deposit classes which hold potential for base metal production in the province. The following classification of the main environments is proposed and the deposits representative of each class are shown on Map 1:

(i) The Precambrian **volcano-sedimentary massive sulphide** environment is exemplified by the **Stirling** deposit in SE Cape Breton Island, the Coxheath Hills Cu (Zn) deposit adjacent to Sydney, Cape Breton Island and the massive sulphide deposits (primarily pyrite) in the southern Antigonish Highlands of northern Nova Scotia. It should be noted that the volcanogenic-hosted deposits in the Cheticamp area of northwestern Cape

Breton Island, which formerely were considered to be hosted by volcanics of Precambrian age , have been shown by Lynch and Tremblay (1992) to be of Silurian age.

At Stirling, intermittent mining operations since the late 1920s have milled 1.06 million tonnes of ore grading 6.3% Zn, 1.5% Pb, 0.8% Cu, 74 g/t Ag and 1.1 g/t Au. Total metal production over the life of the mine was 48,684 tons zinc, 10,348 tons lead, 4,920 tons copper, 1,302,776 ounces silver and 16,492 ounces gold (Roscoe, 1986). Exploration is currently underway on the property.

(ii) The **shale-hosted** mineralization in the Precambrian sedimentary rocks of the Antigonish Highlands in northern Nova Scotia is considered to be representative of this class of deposit. Elsewhere in

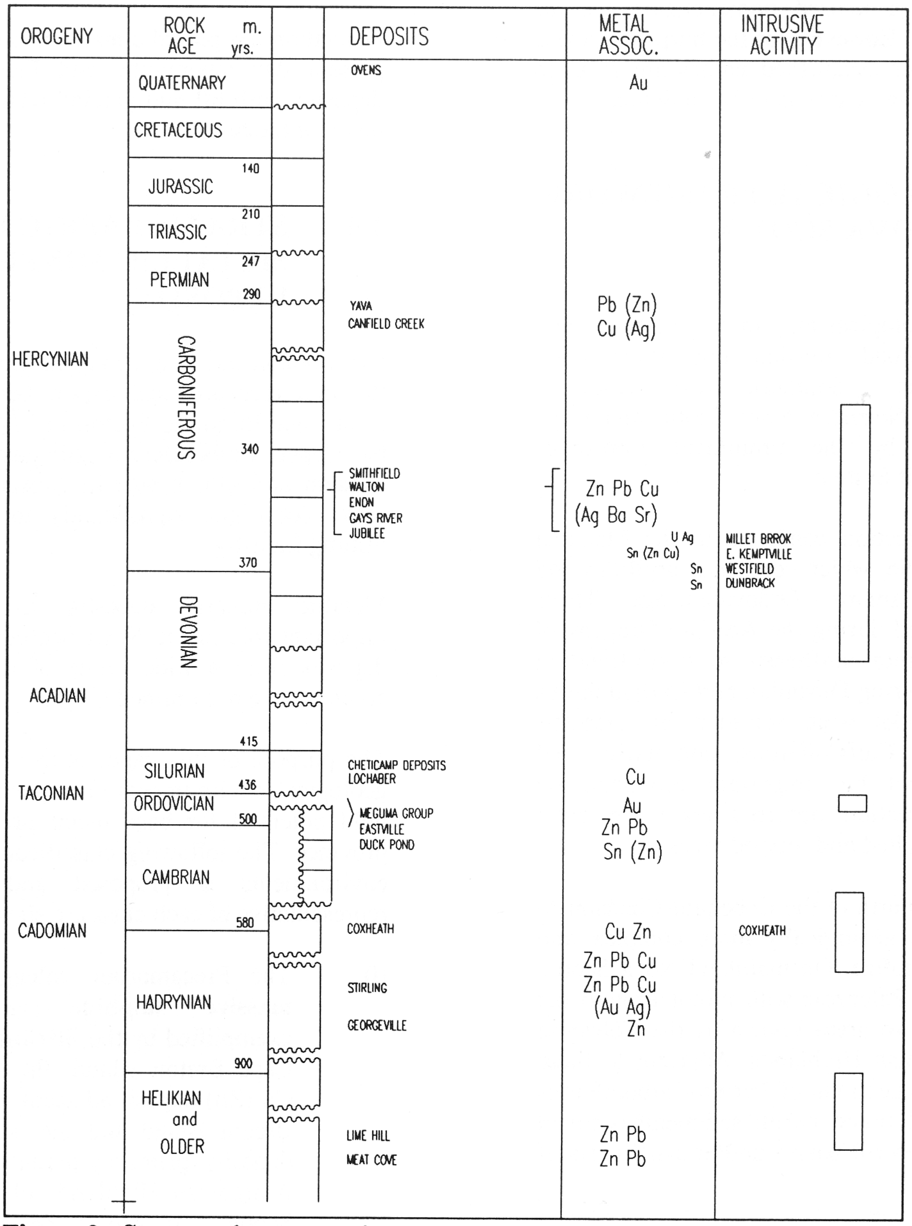


Figure 3. *Stratigraphic range of main metallic deposits in Nova Scotia.*

Canada shale-hosted deposits have contributed greatly to the base metal inventory.

The type deposit for this class is the **Georgeville** property where exploration has identified low grade (1%) zinc mineralization over intersection lengths of 17 m with greater lengths (52 m) of lower grade (0.69% Zn). The mineralized horizon has been tested by nine drillholes over a strike length of 5 km and the description of mineralization in fractures may suggest remobiliation of syngenetic mineralization or introduction at a later time.

The **Kirkmount** (Kirkmont) property, in the western part of the Antigonish Highlands, represents a shale-hosted deposit where zinc mineralization is present in silicate form and core assays averaged 1.66% Zn over 21 m in one drillhole. Shorter and higher grade sections occur.

(iii) The **marble-hosted** (George River Group) metallic deposits in the pre-Carboniferous rocks of Cape Breton Island comprise two major categories. **Polymetallic skarn** mineralization is related to a discrete contact metamorphic or metasomatic event and may be hosted both in the carbonates and the intrusives. **Stratabound** mineralization is generally restricted to a discrete carbonate unit, is not related to a definable contact metamorphic event, and the associated calc-silicate assemblages are interpreted as reflecting regional rather than local contact metamorphism.

Two deposits, **Meat Cove** and **Lime Hill**, illustrate the stratabound marble-hosted deposit type. Both have undergone substantial drilling and Meat Cove has been investigated by underground workings. Zn-Pb sulphides are present in both; Meat Cove has associated Ge and Cd values, and wollastonite is associated with the Lime Hill deposit.

(iv) A significant base metal deposit, hosted in metasediments of the **Meguma Group** (Cambro-Ordovician), was discovered at **Eastville** in 1977. Limited drilling along a 10 km strike length intersected Zn-Pb mineralization over 2 to 10 m sections and grading between 1% to 3% combined Zn-Pb at various stratigraphic positions within a 100 m interval. Best intersections were 3.34% Zn-Pb over 6.1 m and 4.09% Zn-Pb over 9.33 m. The deposit is classified as a distal type sediment-hosted stratiform deposit remobilized by subsequent tectonic activity. Minor base metals have been identified in the Meguma-hosted gold deposits, which abound in southern Nova Scotia, and there may be some association between these two types of deposits.

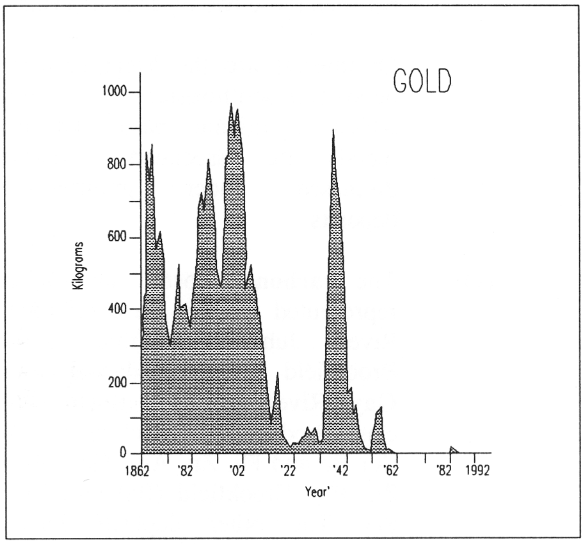
Of interest are the Meguma-hosted Sn deposits in southwestern Nova Scotia with which significant base and precious metals are associated. These are discussed under granite-associated deposits.

(v) The **carbonate-hosted** environment is represented by the Carboniferous Gays River, Jubilee, Walton, Smithfield, Brookfield and Enon deposits, and the **Gays River** deposit is illustrative of the class. Production was achieved at Walton (for Ba and Pb, Zn, Ag), Gays River (for Zn, Pb), Brookfield (Ba) and Enon (for Sr). The other deposits have been subjected to fairly intensive exploration including detailed diamond-drilling and underground exploration (Smithfield). A carbonate-hosted Cu deposit of probable Silurian age occurs at Lochaber Lake in Antigonish County and potential exists along the bounding fault.

(vi) In 1962, exploration programs initiated as a result of exploitation of the argentiferous base metals at Walton, led to the discovery of the Upper Carboniferous **sandstone-hosted Yava Pb** deposit in the Salmon River Basin of Cape Breton Island. In the period 1962 - 1978, various drilling programs showed stratiform lead mineralization at the base of the Upper Carboniferous sandstone over a strike of nearly 3 km and for a distance down-dip of 450 m.

Total ore reserves for the three zones identified amount to 12 million tons @ 4.0% Pb (3.5% cut-off), or 19.1 million tons at 3.4% Pb (2.5% cut-off). Mining was carried out on one zone from 1979 - 1981 and 428,000 tons @ 4.75% Pb were milled.

The Terra Nova deposit, also within the Salmon River Basin and immediately north of the Lake Enon deposit, is similar, though it does carry significantly higher Zn values than at Yava. Analogies may also be drawn with the sandstone-hosted Cu deposits in the Cumberland Basin of northern Nova Scotia where the Upper Carboniferous, sandstone-hosted, Canfield Creek deposit contains drill-indicated reserves of 300,000 tons @ 1.2% Cu with minor Ag values. In addition, the shale-hosted Cu deposits in the Cumberland Basin show similarities with the Kupferschiefer deposits of Poland and this potential is currently under investigation.



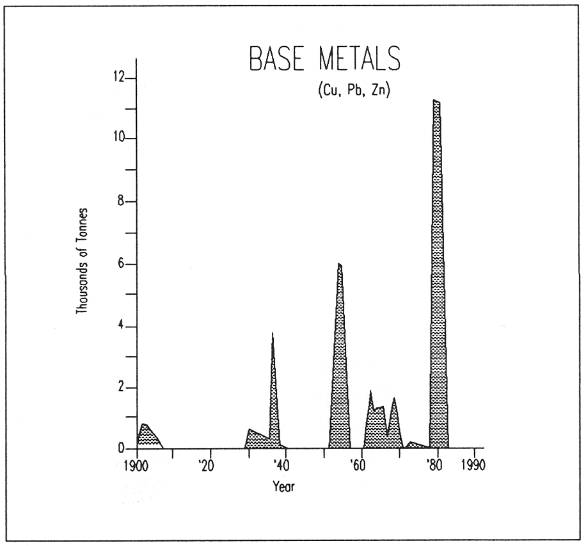


Figure 4. *Nova Scotian historic metallic mineral production (NSDNR Annual Report for 1990).*

(vii) The **granite-associated** class of deposits includes both granite- and metasediment-hosted bodies. The **East Kemptville** Sn Mine, which ceased production in January 1992, was the only primary Sn mine in North America and illustrates the granite-hosted sub-class. During the five years of operations some 19 million tonnes were milled at 10,000 tpd and by-product Cu, Zn and Ag were also recovered. This greisen-type granite-hosted deposit was brought into production on published reserves (Moyle, 1985) of 56 million tons @ 0.165% Sn.

Mineralization within the southwestern Nova Scotia tin domain consists of both granite- and metasediment-hosted types, which are spatially (and probably also genetically) related to the regional East Kemptville shear zone. The **Duck Pond** deposit, some 2 km west of the East Kemptville open pit, represents the metasediment-hosted sub-class.

Additional granite - associated mineralization is known at the Coxheath and Deep Cove deposits, both in Cape Breton Island.

(viii) Recent work by Lynch and Tremblay (1992) has shown that the Cheticamp volcanics are of Silurian age. Recent drilling by the Nova Scotia Department of Natural Resources has identified "sulphide-rich black shales" in upper Silurian rocks (Smith, 1992 in press) and the reference to the possible Silurian age of the host limestone the Lochaber lake Cu deposit all point to the existence in Nova Scotia of an important, but poorly documented, exploration target in the Lower Paleozoic rocks.

1.5 NOVA SCOTIA MINERAL PRODUCTION

Since the mid 17th century the mining industry has contributed significantly to the economic and social life of Nova Scotia. Production over the years has included coal, salt, gypsum, anhydrite, barite, celestite, iron, manganese, copper, lead, zinc, silver, gold, antimony and tin. Though uranium deposits are known, a government moratorium does not permit continued exploration or development of these deposits.

Among the metallic minerals, gold was very significant during the 1800s and, though intense exploration and underground development in the mid to late 1980s confirmed the depth potential of these deposits, no viable commercial production was sustained. It should be noted, however, that in the period 1862 - 1942 gold production from the Goldenville District amounted to 210,000 oz. (5,800,000 g) (Donohoe, 1984). Figure 4 shows that the majority of this production came in the period 1862-1912.

Commercial production of base metals began in the early 1900s and the intermittent production, (Fig. 4) reflects mining activity at Smithfield, Stirling, Walton, Gays River, Yava and East Kemptville. The Gays River Mine was reopened briefly in late 1990 but by early 1992 all base metal production had ceased in the province. The major tin production came from the East Kemptville operation, which also produced by-product copper and zinc. Production at this mine ceased in January 1992.

Base metal production came from deposits hosted in a variety of geological environments and stretching the length of the province. The combination of this diversity of proven geological environments with the fact that thick glacial deposits mask much of the favourable geology suggests that continuing exploration of these environments will be rewarding.

The value of total mineral production in the province has shown a steady increase since the early 1980s (Fig. 5). However, metallic mineral production has accounted for less than 10% of the total and the recent closure of both the Gays River and East Kemptville mines will further reduce the value of metallic minerals production. However, the possibility of recommencement of production at Gays River, together with continuing base metal exploration programs, hold promise for the industry.

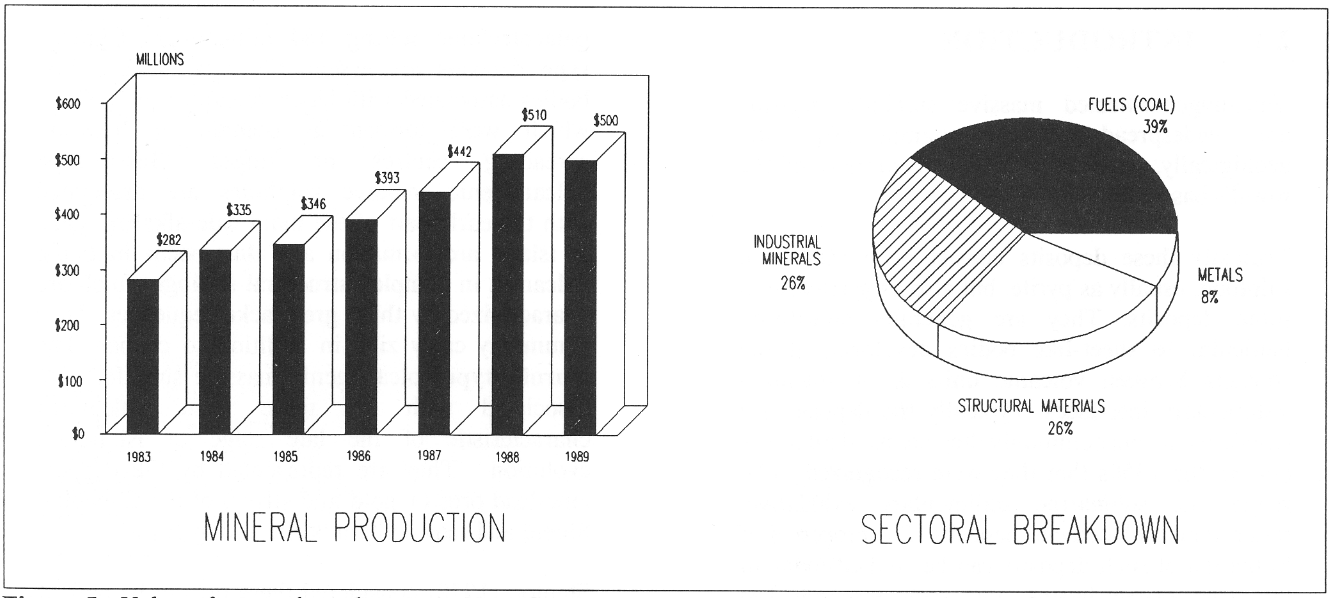


Figure 5. *Value of mineral production in Nova Scotia and sectoral allocation (NSDNR Annual Report for 1990).*