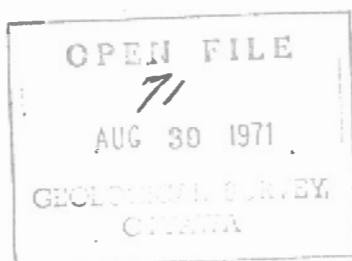


W. H. P. G. L.

A REPORT ON THE
FIRST PHASE OF THE
CAPE BRETON MINERAL RESOURCES PROJECT

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1. SUMMARY

The first phase of the Cape Breton Mineral Resources Project was an examination of the known mineral occurrences in relation to the geology. The data was abstracted, statistically analysed, mapped and considered within the framework of various metallogenic concepts. The study confirmed what many geologists have suspected - that there is a strong preference of the known mineral occurrences for certain geologic environments. The vicinity of the 740 miles of Carboniferous - Pre-Carboniferous contact is the common denominator for 54% of all known occurrences, thus strongly suggesting a genetic relationship between mineralization and the Carboniferous basin margins which appear to be a complex combination of faulting and unconformity. Less marked but significant associations were noted between mineral occurrences and (a) the Horton and Grantmire - Windsor contact (b) the George River Group and (c) certain intrusives.

2. INTRODUCTION

2.1 HISTORY

The Cape Breton Mineral Resources Project was first conceived in response to a request from Mr. Fern Doucet of Devco, for ideas on industrial development. A brief describing a proposed mineral exploration program with an annual budget of \$204,000 was forwarded to Devco on April 18, 1968. Following several discussions it was decided to proceed with a preliminary study of the geology and mineral occurrences of Cape Breton Island and to prepare a long term plan and budget for a more intensive study. This preliminary study is referred to as First Phase - Cape Breton Mineral Resources Project. Confirmation of the project was received by letter on April 28, 1969, and a contract with St. Francis Xavier University was completed about mid-May 1969.

2.2 PURPOSE

The prime purpose of government sponsored mineral exploration in Cape Breton is to stimulate private mineral exploration in the hope that ore bodies will be found and developed and thereby contribute to economic renewal. The immediate goal of this first phase of the Mineral Resources Project was to examine the geology and mineral occurrences data on an island-wide basis in an effort to detect systematic relationships between mineral occurrences and geologic settings. The discovery of such relationships would provide the basis for designing and proposing an exploration program which would utilize the most effective combination of geological, geophysical and geochemical techniques available at a reasonable cost.

2.3 SCOPE AND METHOD

A comprehensive study of the mineral resources of Cape Breton should eventually cover all minerals. To obtain the greatest value from the First Phase of the project it was decided to exclude coal, limestone, dolomite, gypsum, anhydrite and clays. The occurrence of limestone and dolomite in Cape Breton has already been well documented by the Department of Mines in a recently published memoir. The coal reserves are being studied by the coal division of Devco. Adequate supplies of gypsum and anhydrite are proven. This study encompasses mainly the metallic minerals plus such others as barite, fluorspar, magnesite and celestite.

The basic approach consisted of assembling all accessible information on the geology and mineral occurrences in Cape Breton in forms that would highlight systematic associations of ore minerals, rock types, structure and other geologic conditions.

Base maps on scale of 1" = 2m. were constructed from film negatives of standard geologic maps (Scale 1" = 1 mile) provided by the Geological Survey of Canada. The geologic units were co-ordinated across the island and in some instances regrouped and revised to suit our purposes. At the same time an exhaustive search of mineral occurrence data was begun. The information was compiled on large charts which closely followed the recommendations of the National Advisory Committee for Storage and Retrieval of Geologic Data. The mineral occurrence information thus organized can be easily transferred to cards or magnetic tape for the computer processing anticipated in later stages of this program.

A preliminary statistical analysis of mineral occurrences was carried out manually by summarizing the more important factors on charts (see Appendix A) and then running counts on selected relationships. The counts were then assembled in tables (see Tables A, B, C, D in section 4.1). These brought out rather striking relationships which, with qualifications, were an important influence in the design of our proposed exploration program.

Considerable attention was given to developing ideas on metallogenesis. A map (Metallogenic Map) was prepared to illustrate (a) the various ore mineral suites (b) the age of the host-rock (c) the Carboniferous-Pre-Carboniferous contact (d) the Horton (and Grantmire)-Windsor contact, and (e) the area underlain by Pre-Carboniferous rocks.

2.4. PERSONNEL

Professional services were drawn from a variety of sources and specialities. The principal contributors to the study and to this report are:

Dr. William S. Shaw, St. Francis Xavier University	- Geologist & Project Director
Dr. Don Bidgood, N.S. Research Found.	- Geophysicist
Dr. R.F. Cormier, St. Francis Xavier University	- Geologist & Geochemist
Dr. B.J. Keating, St. Francis Xavier University	- Geologist
Mr. H.R. Oldale, N.S.E. Institute of Tech.	- Geologist
Dr. U.J. Vagners, Acadia University	- Geologist
Dr. A.J. Wintermans, St. Francis Xavier University	- Economist

Considerable help and advice were generously given by:

Dr. D.G. Kelley, Geological Survey of Canada.

Mr. Frank Shea, Department of Mines

Dr. J.P. Nowlan, Deputy Minister of Mines

Dr. William Poole, Geological Survey of Canada

Dr. J.E. Blanchard, President, Nova Scotia Research Foundation

Dr. E. Schuegraf, St. Francis Xavier University - Data Processing Specialist

3 GEOLOGY

3.1 GENERAL

The accompanying geological map is a synthesis of a number of separate compilations of various rock divisions. These divisions were made on the basis of genetic, lithologic and stratigraphic relationships that in the early stages of the project appeared to merit individual analysis. In each case the prints used carried the plotted known mineral occurrences so that the relationship of the separate division could be viewed and assessed within the economic geological framework.

Accordingly the following geological rock division maps are available on file but do not constitute a part of this submission:

1. George River Group
2. Fourchu Group and Early Paleozoic Formations, including the Bourinot
3. The Carboniferous Formations
4. The Intrusive Rocks

In addition, the traces of faults as shown on the most recent geological maps were traced on an overlay.

The following is a summary of significant lithologic and stratigraphic features of these major rock divisions.

3.2 PRECAMBRIAN - GEORGE RIVER AND FOURCHU GROUPS

3.2.1 George River Group - Archean

General: Metasediments, with minor metavolcanics, shists and gneisses described as a Pre-Carboniferous complex comprise this group. No fossils are known to occur in these rocks. The group is overlain by volcanic and sedimentary rocks of the Bourinot Group (Middle Cambrian). Various inferences suggest that the George River rocks are Archean in age. The presence of crystalline limestone and dolomite in association with other metasedimentary rocks and various schists and gneisses of uncertain derivation has in the past formed the basis for assignment to this group. However, except in such areas as George River, Whycocomagh, Marble Mountain, Dunakin, etc. areal extent of the crystalline carbonate rocks is restricted. Where the crystalline carbonates constitute only a minor component they are grouped in some cases with schistose and gneissic rocks and in other cases with assemblages of George River "aspect" classed as "undivided".

Since 1962, G.C. Milligan has worked intermittently on a Nova Scotia Department of Mines program of investigation of the George River Group. A compilation and report are presently in progress. Advance copies of the mapping in the Craginsh Hills, Boisdale Hills, Middle River, Crowdis Mountain and Christopher MacLeod Brook areas were made available for this project and reductions have been incorporated in the accompanying geological map.

The literature records a number of attempts to establish succession within the George River Group. For instance Fletcher (1877 and 1881) described the crystalline carbonates as unconformably overlying the "felsites". As noted by Kelley (1967) some of these felsites have since been included by Weeks (1954) in the Fourchu Group (Proterozoic) and the Cambrian Bourinot Group. Nevertheless, it does seem reasonable to assume that different units of the George River are related unconformably and that in some instances impressions of unconformable relationships may be attributable to overthrusting (Milligan 1969). If relationships like this exist to any considerable extent, they may have an important bearing on control of ore-bearing solutions. This is particularly applicable to situations involving the crystalline carbonate unit which presently appears to be the most promising host rock in the George River Group.

Volcanic Rocks (Map Unit 1): Volcanic rocks are associated spatially with other units of the George River Group. In many instances their inclusion in the George River is questionable because at present writing the George River succession has not been established. However in some instances they appear to form an integral part of the succession. Milligan and Parsons (1964) and Parsons (1964) in describing the volcanics of the Craginish Hills note the occurrence of andesite interbeds in the upper layers of the slates beneath the main volcanic assemblage and in the lower part of the limestone above. Other volcanic assemblages of assumed Precambrian age may be correlative with the Fourchu Group.

Many of the basic rocks are classified as lavas on the basis of obscure criteria. In some cases vague pillow structure, amygdules and flow banding can be discerned. In other cases it is not certain whether these rocks are sills or dikes. For instance, in the Crowdis Mountain and Middle River area, Milligan et al. (1966 & 1967) have recorded areas of considerable extent underlain by: "Amphibolite. Probably mainly volcanic rocks, but much is of uncertain origin; includes minor gabbro and diorite. Some tuff."

Acidic type lavas such as rhyolite and trachyte and tuffs are sparingly distributed.

Slates, Schists, Gneiss (Map Unit 2):

Slates: Black slates are common. Included in this category are grey to greenish grey phyllites. Banding is prevalent but its origin is largely doubtful. Generally, it is parallel or nearly parallel to the cleavage and much of it is believed to be pressure induced. In some instances it has the characteristics of bedding. Where it is interbedded with the quartzites and limestones the contacts are believed to be more reliable indicators of bedding attitude. In the slates and phyllites themselves wide discordancies between cleavage and bedding such as exists in axial plane cleavage - bedding relationships have not been observed.

Schists and Gneisses: In some instances these are micaceous, chloritic, hornblendic, garnetiferous, staurolitic, etc. They are interpreted as more highly metamorphosed equivalents of George River-type metasediments and metavolcanics. Neale (1963) effects a separation of types into:

1. acidic, in which are included minor quartzite and crystalline limestone
- and: 2; basic, in which are included minor basic metavolcanic rocks.

In addition, composite gneisses and hybrid rocks connected with granitic intrusives of Devonian or earlier age may be included here but where mapping has rendered it feasible they have been included with the intrusives (Mixed Rocks - Map Unit J).

Quartzite, Felspathic Quartzite (Map Unit 3): These have their greatest development in the Cragin Hills where felspathic quartzites and associated, dense, massive, greenish quartzites are separated by Milligan and Parsons from what they term the upper quartzites which are white to buff in color containing well rounded quartz grains cemented by quartz. The felspathic quartzites have a brownish cast due to the presence of feldspar and minor biotite and are generally softer. In the North Mountain area a similar distinction is tenable although the development of felspathic quartzite is restricted.

Crystalline Limestone and/or Dolomite (Map Unit 4): Although the crystalline carbonate rocks vary considerably in appearance and composition they are very distinctive and, as previously mentioned, they serve as a basis for assignment of associated units to the George River Group. Types include pure white marble, cream colored coarse granular marble and grey banded crystalline limestone. Finely crystalline limestones veined by calcite stringers appear to favor transition zones with the black slates. Interbeds of arenaceous material promote differential weathering which provides the most reliable data for structural determinations. In some instances, "sandy" interbeds are fragmented and stretched in the mobile carbonate rock.

In proximity to some intrusives, as near the alaskite at Lime Hill (McCuish Brook), magnesian limestones have been extensively contact metamorphosed with the development of bands of diopside rock and serpentine rich rocks (ophicalcites).

Interbeds rich in biotite are intercalated locally. At present writing there is a suspicion that these mica-rich sections may have been sites of preferential replacement at Lime Hill.

Buff to brown coloured ferruginous siliceous carbonate rocks occur rather extensively in the central North Mountain area. There is a suggestion that these form a capping on other units of the George River Group although substantiating field evidence is not clear-cut. Some of the carbonate content in these rocks appears to be ankeritic. Weathering has promoted the formation of gossan areas locally and "limonite" skins on some boulders and outcrops.

Undivided (Map Unit 5): Substantial areas underlain by George River rocks fall within this category. In them, crystalline limestone is a minor component and has not been separated during recent mapping. In many cases limestone localities are indicated by symbol on the old series (Fletcher) geological maps, but it was not feasible to carry this information through to the present compilation.

3.2.2. Fourchu Group - Proterzoic (Map Unit 6)

According to Weeks (1954) the Fourchu group "... consists of a succession of mainly acid volcanic rocks, commonly pyroclastic, associated with some sedimentary beds."

Along the coastal type area the rocks consist of a gradational

series of acid volcanic types commonly pyroclastic ranging from coarse volcanic breccias to fine tuffs. Lavas, shales and siltstones are also present but not abundant.

Alteration varies from relatively minor to schists and gneissoid rocks of doubtful derivation. This metamorphism is believed to be largely dynamic due to lack of high temperature mineral assemblages.

The upper part of the Fourchu group is often marked by a breccia with red matrix containing light colored, angular lithic and crystal fragments up to an inch or so across. The lower boundary is nowhere observed.

The age of the Fourchu rocks has been assigned through correlation of overlying fossiliferous Cambrian strata and by comparison with similar Proterozoic and Cambrian assemblages in Newfoundland.

Layering is generally not observed but attitudes can be determined on a few narrow bands of bedded sedimentary rocks or water-lain tuffs. The Fourchu group appears to be localized along major northeast-trending anticlinal axes. Most of the fragmental rocks display a distinct schistosity parallel to large fragments.

On the northern end of Sporting mountain, the Fourchu group is composed mainly of chloritic volcanic rocks, which include some recognizable sedimentary beds. Although correlated by Weeks with the Fourchu group, they may be actually assignable to the George River Group.

3.3 EARLY PALEOZOIC SEDIMENTS AND VOLCANICS

General

Rocks of Cambrian, Ordovician, Silurian (?) and Devonian age are represented in the early Paleozoic rocks of Cape Breton Island. Strata positively identified as early Paleozoic are confined mainly to southeastern Cape Breton with the Cambrian showing the most complete development.

These early Paleozoic sedimentary and volcanic rocks are structurally related to the Appalachian geosyncline and represent both tectonic and non-tectonic phases of geosynclinal development. The rocks have undergone several periods of intense folding and deformation and prior to the Carboniferous at least two periods of extensive igneous intrusion.

Cambrian

Cambrian Rocks include Morrison River, Canoe Brook and MacCodrum Formations of Lower Cambrian age, the Bourinot group, the Trout Brook, MacLean Brook, MacMullin and Kelvin Glen Formations of Middle Cambrian age and the MacNeil formation of Upper Cambrian age. All are confined to southeastern Cape Breton. The breakdown of the Cambrian is that of Hutchinson (1952) and Weeks (1954).

Lower Cambrian

Morrison River Formation: This is a series of predominantly non-fossiliferous clastics with shale and white quartzite members at the top. The clastics comprise red sandstone and conglomerate underlain by volcanic breccia of the Fourchu group and succeeded by the MacCodrum formation. The Morrison River formation forms an excellent

marker horizon facilitating the definition of the rather complicated fault and fold patterns of the area. Where exposed the formation varies from a minimum of approximately 150 feet to a maximum of 2,400 feet. Its age has been determined by its conformable relationship with overlying fossiliferous beds of the MacCodrum formation.

MacCodrum and Canoe Brook Formations: The MacCodrum formation comprises a sequence of fossiliferous green shales some 550-780 feet thick. It is in turn conformably overlain by non-fossiliferous red to green claystone, some 300 feet thick, of the Canoe Brook formation.

Middle Cambrian

The Middle Cambrian includes the Bourinot group and the MacMullin, Kelvin Glen, Trout Brook and MacLean Brook Formations disconformably overlying Lower Cambrian Rocks.

Bourinot Group: Hutchinson subdivides the Bourinot into 3 formations called the Eskasoni, Dugald, and Gregwa formations. The Eskasoni and Gregwa formations are predominantly volcanic in origin and the Dugald is predominantly sedimentary.

Weeks subdivides the rocks of the Bourinot group into 3 lithological classes which have no stratigraphic significance. They conform to a single environment and indicate a time interval of tectonic activity. The most common class comprises intermediate to basic amygdaloidal lavas and associated pyroclastics. Of equal importance are thick successions of more or less graded sequences of clastic material, most of which are reworked volcanic debris. The sandstone members are true greywackes (appreciable amounts of clay material in the matrix)

and the coarser and finer members, although true conglomerate and shale, nevertheless have many of the characteristics of greywacke, and all are believed to have had a similar origin. Rocks of the third class are normal clastic beds, usually orthoquartzites which are most common in the Bourinot group northwest of East Bay.

MacMullin, Trout Brook, MacLean Brook, Kelvin Glen Formations: The Trout Brook and MacLean Brook formations, composed of fossiliferous grey to black shale and interbedded siltstone and shale some 1500 feet thick, outcrop north and east of Victoria Bridge. West of Mira River, conglomerates, sandstones, siltstones and mudstones of the Kelvin Glen formation apparently overlie the Bourinot. These fossiliferous rocks are probably equivalent to the middle to upper portions of the Trout Brook formation to the east. In the Boisdale Hills to the west are found locally fossiliferous grey quartzite and shale probably equivalent to the Kelvin Glen.

Upper Cambrian

MacNeil Formation: Disconformably overlying middle Cambrian rocks along MacNeil Brook at Marion Bridge are fossiliferous black shales and limestones. Hutchinson also shows rocks equivalent to the MacNeil formation on both the east and west sides of the Boisdale Hills.

Ordovician and Cambrian

Bell and Goranson (1938) mapped a sequence of fossiliferous marine sediments ranging in age from Middle Cambrian to Middle Ordovician. Much of this sequence has been subdivided by Hutchinson and correlated with the Middle and Upper Cambrian, but it is shown as an undivided

sequence on the geological map accompanying this report. With the exception of the Lower Ordovician, MacLeod Brook formation, extending from Rear Boisdale to Barachois Harbour, all other exposures classified as Cambro-Ordovician are placed in the Middle and Upper Cambrian by Hutchinson.

The Middle Cambrian sediments are mainly sandstone, grit, sandy shale and some conglomerate. The upper Cambrian and early Ordovician rocks are mainly black and grey shales. Questionable Middle Ordovician black shales and conglomerates which lie $1\frac{1}{2}$ miles south-southwest of MacAdam lake, are placed in the middle and upper Cambrian by Hutchinson. These Cambro-Ordovician sediments are tightly folded and strike north-east. No igneous rocks are found cutting them.

Silurian or Devonian (?)

Middle River Group: Rocks of the Middle River group occur in four isolated basins west of the Mira River. They include non-fossiliferous coarse to fine conglomerates, locally indurated to quartzite and quartzite conglomerate, that unconformably overlies Lower and Middle Cambrian strata. No younger beds are found in contact with these rocks.

Devonian

MacAdam Lake Formation: The MacAdam Lake formation, exposed along the west side of the Coxheath Hills, consists of grey, fresh-water arkoses and conglomerates that are generally highly inclined. Near MacAdam Lake there is a bed of carbonaceous shale, at one time prospected for oil shale, and a mile to the north an interbedded volcanic fragmental rock is poorly exposed.

3.4 CARBONIFEROUS SEDIMENTS AND VOLCANICS

General

Approximately 40 percent of Cape Breton Island is underlain by rocks of Carboniferous age. These include essentially continental deposits of the Horton group deposited in a fluvio-lacustrine-flood plain environment accompanied by relatively continuous uplift.

Volcanism at the base of the Horton group is indicated by the volcanic-sedimentary Fisset Brook formation. The Windsor group was deposited in a cyclic transgressive-regressive marine environment with at least local high relief suggested by the presence of the red conglomerate Grantmirefacies of eastern Cape Breton. The Pennsylvanian represents a return to a continental environment with deposition taking place in a gradually subsiding basin under fluvio-lacustrine conditions.

Mississippian

Fisset Brook Formation: The Fisset Brook formation is described by D.G. Kelley and W.O. MacKasey (G.S.C. paper 64-34, 1965). This name has been proposed to define a rock-stratigraphic unit at the base of the Horton group in western Cape Breton Island. It is a volcanic-sedimentary unit that unconformably overlies older rocks and is in turn conformably overlain by the Craignish formation of the Horton group. The Fisset Brook formation includes a basal, predominantly sedimentary unit, a middle predominantly andesitic unit, and an upper dominantly rhyolitic unit. The type section, some 950 feet thick occurs along Fisset Brook, 2 miles southeast of the town of Cheticamp. Other

equivalent occurrences have been mapped in the Pleasant Bay - Bay St. Lawrence area; north of Mabou, northwest of Port Hawkesbury and east of Lake Ainslie.

In the type section the basal unit comprises about 50 feet of greenish-red mixed conglomerate, red and grey siltstone and andesite. The andesitic unit some 800 feet thick contains intercalated beds of red hematitic siltstone. The andesite is typically structureless in outcrop and massive to amygdaloidal in texture. The siltstone beds suggest a thickness of approximately 10 feet for the individual flows. The rhyolitic unit is composed of a basal rhyolite and andesite agglomerate, overlain by red siltstone, conglomerate and red and green ripple-marked siltstone and andesite respectively.

Horton Group: The name Horton Group is derived from Horton Bluffs north of Windsor N.S. by Bell (1929). He divided the group into the lower Horton Bluff formation and the upper Cheverie formation. The undivided Horton has been traced throughout mainland Nova Scotia to Cape Breton Island. Fossils in the Horton are poorly preserved and rare, but various plant species, fish scales, teeth and bones, and plant spores have been identified on Cape Breton Island.

The Horton group flanks much of the Pre-Carboniferous upland area over the western half of the Island, but is virtually absent over the eastern portion. In this area strata of the Windsor group overlap unconformably on the pre-Carboniferous. Murray (1960) divided the Horton group into 3 formations, the Craignish below and the Strathlorne and Ainslie above. Kelley (1958) extended this breakdown throughout

the entire Baddeck and Whycocomagh map areas.

The Craguish formation, some 5000 feet thick in the type area, consists of medium to coarse-grained grey arkosic sandstone and conglomerate with interbeds of red sandstone and siltstone. The formation rests unconformably on pre-Carboniferous rocks and is conformably overlain by the Strathlorne formation.

The Strathlorne formation is approximately 1000 feet thick in the type area and is composed of thinly laminated grey siltstone, fissile shale, medium bedded sandstone, and thin impure limestones. Thin beds of red siltstone, sandstone, and rarely conglomerate, are also present. The lower contact with the Strathlorne is readily recognized due to a sharp lithologic and color change. The upper contact with the Ainslie formation is often difficult to establish and in such cases the Strathlorne and overlying Ainslie formations are together referred to as the Strathlorne-Ainslie formation.

The Ainslie formation is 1,860 feet thick in the type section and consists mainly of alternating beds of red and grey sandstone and siltstone. In some areas conglomerate forms an important component of the Ainslie formation. Thin beds of intra-formational limestone conglomerate are also common. The Ainslie formation is conformably to disconformably overlain by the basal Windsor laminated limestone commonly referred to as the A₁ limestone.

Neale (1963) divides the Horton group in the Aspy Bay area of northern Cape Breton into three conformable units that roughly correspond to the Craguish, Strathlorne and Ainslie formations. In the Lake Ainslie area of Western Cape Breton, Norman (1935) describes

two Horton "groups", a lower group which is essentially the Craignish formation and an upper group which includes the Strathlorne and Ainslie formation. Over the remainder of the Island the Horton remains undivided.

The Grantmire Facies: Bell (1938) applies the term Grantmire to designate a basal member of the Windsor group flanking the Coxheath Hills west of Sydney. Bell used the term "where thick deposits of conglomerate lie below marine limestone or sandstone of Lower Windsor age and form the base of the series". Weeks (1954, p. 73) has modified Bell's definition to "a formation comprising all Windsor conglomerate members that form the base of the group, regardless of whether they are Lower or Upper Windsor in age". Kelley (1967) shows Horton group rocks in the Washabuck area striking directly into rocks of the Iona area ascribed to the Grantmire by Weeks. Consequently, considerable confusion exists in the precise definition of the term Grantmire.

The Grantmire facies is described as a separate unit in this report because of its potential economic significance. The contact of the Grantmire formation with the typically marine Windsor sequence contains disseminated copper sulfide mineralization throughout. Drilling by Mariner Mines has also indicated significant sulfide mineralization in grey beds near the base of the Grantmire at Beechmont in the Coxheath Hills. There is also drilling evidence to suggest that the granitic rocks of the Coxheath Hills are thrust over the Grantmire in this area.

Lithologically the Grantmire is characterized by a thick deposit

(3,500+ in the type area) of chocolate red coarse rubble conglomerate with interbeds of red sandstone and shale of deltaic or piedmontane origin. Grey beds are also present.

Windsor Group: The Windsor group derives its name from the type locality near Windsor, Nova Scotia. Bell (1929) divided the group in the type area into 5 sub-zones A, B, C, D and E with sub-zones A and B forming the lower Windsor and sub-zones C, D and E forming the upper Windsor.

The applicability of these sub-zones over all of Nova Scotia including Cape Breton Island has been substantiated by numerous authors.

Lithologically, the Windsor group in Cape Breton Island consists of thick members of massive red siltstone and shale, some red and grey sandstone, grey siltstone and shale, thin beds of limestone and dolomite, and locally thick deposits of gypsum, anhydrite and salt. The basal member (A_1 limestone) is a thinly laminated, fine-grained limestone, medium to dark grey in colour. It serves as an excellent horizon marker in differentiating the marine Windsor rocks from rocks of the Horton Group.

The Windsor strata occur in lowland areas and because of their susceptibility to erosion, outcrops are scarce. The overall thickness of the Windsor group in western Cape Breton Island is estimated at 2,200 to 2,700 feet (Kelley 1958, p. 179). However, as a result of flowage during folding and faulting, abnormal thicknesses of gypsum and salt have been encountered in anticlinal structures.

Pennsylvanian

Canso Group: The Canso group, defined by Bell (1944) in the type locality along the eastern shore of the Strait of Canso was assigned by Bell to the basal Pennsylvanian on the basis of contained fossil flora and fauna. The Canso group includes the Point Edward formation of the Sydney area and the Mabou formation of the Lake Ainslie map area. Some doubt exists as to whether the Canso group is actually Mississippian or Pennsylvanian. It is quite possible that it represents a transitional phase between the two. However, for the purposes of this report the original Pennsylvanian designation has been retained.

The thickness of the Canso varies considerably from a minimum of 750-1250 feet in the Sydney area to a maximum of 7000 feet in the south central part of the Whycocomagh map area of Kelley (1958, p. 179). Lithologically the group includes laminated grey shale and fine to medium-grained sandstone. Locally conglomerate is also present.

Post-Canso: Pennsylvanian rocks younger than the Canso group include strata of the Riversdale and Pictou groups. Pennsylvanian rocks equivalent to these groups on Cape Breton Island include the Port Hood formation (Riversdale) and the Inverness (Pictou) of Western Cape Breton; and the Morien series (predominantly Pictou) of eastern Cape Breton. The Broad Cove formation, a red bed sequence in the Margaree area overlies the Pennsylvanian. There is doubt as to whether the Broad Cove formation is actually Pennsylvanian or Permian in age.

Rocks equivalent to the Riversdale include grey and red sandstone, conglomerate, grey arkosic sandstone, and thin coal seams. The Pictou group includes mainly grey sandstone, grey and red shale and coal seams. The upper part of the Pictou group contains thin beds of freshwater limestone and the workable coal seams of the Sydney and Inverness areas. The lower part of the Morien series in the Sydney area, comprising grey arkosic grit and sandstone, some conglomerate and shale, a few red beds and thin coal seams may be in part equivalent to the Riversdale Group.

3.5 INTRUSIVE IGNEOUS ROCKS

The intrusive igneous rocks of Cape Breton Island are characterized by the great variety of lithologies which have been recognised in the field. The rocks range in composition, with practically all intermediate grades represented, from syenite at the acid end of the spectrum to gabbro and anorthosite at the basic end.

Plutons composed of syenite (Unit A) have been mapped in the northernmost portions of Cape Breton in a zone extending from Pleasant Bay to Cape North. The largest of these bodies measures roughly four square miles in area and is adjacent to rocks containing extensive zinc mineralization at Meat Cove.

Several large masses of granite (Unit B) have been mapped in northern Cape Breton. For the most part, these appear to be situated on the northwestern and southeastern margins of the igneous-metamorphic complex comprising the bulk of the bed-rock in northern Cape Breton. In southeastern Cape Breton, Weeks (1954) considers rhyolite associated with granitic intrusives in the Loch Lomond district to be of intrusive origin. These have been shown on the map accompanying this report as Unit D.

Unfortunately, practically all of the intrusive rocks of southeastern Cape Breton (those situated to the south of the Bras d'Or Lakes) have not been subdivided and are mapped simply as undivided, granitic rocks (unit E). For the most part, these areas are underlain by granite, granodiorite and diorite. Other varieties are no doubt present, but are much less abundant. In those areas

which are north of the Bras d'Or Lakes, subdivision of the granitic rocks into specific varieties has been attempted. Fortunately, these areas of Cape Breton contain at least 75% of the area underlain by intrusive igneous rocks.

Among the rocks which have been mapped as granite, one unit is particularly conspicuous. This is the porphyritic or porphyroblastic granite (Unit C) which occurs in northern Cape Breton. This rock is a granite characterized by the presence of extremely large (up to $3\frac{1}{2}$ inches long) phenocrysts or porphyryoblasts of perthitic feldspar. One mass of this rock-type has been traced over a length of nearly twenty five miles with an average width of about two miles.

Intrusive rocks of intermediate composition (Unit G) include granodiorite, diorite, monzonite, quartz monzonite and quartz diorite. These rock-types have, in general, not been differentiated from one another by the various geologists who have mapped in Cape Breton. An exception is the quartz diorite in the Coxheath area; it is presented separately on the accompanying map (Unit F) because of its possible importance in connection with the mineral deposits at Coxheath. It is interesting to note that practically all of the intrusive rocks in the northwestern and central portions of Cape Breton Island are of intermediate composition. In contrast, the intrusives in northeastern Cape Breton are distinctly more acidic in character. As mentioned earlier, the intrusive rocks in the southeastern portions of the island have not been subdivided.

Meta-anorthosite (Unit I) occurs in two separate but co-linear, tabular bodies to the west of Pleasant Bay in the northeastern part of the island. No other anorthosite masses have as yet been

recognized elsewhere on the island.

The gabbroic rocks (Unit H) appear to exhibit two modes of occurrence in Cape Breton. In the northeastern highlands, fairly large masses of gabbro such as the body to the west of Ingonish are encountered. These may well be genetically related to the acid intrusives which are so abundant in this part of Cape Breton Island. In southern Cape Breton, on the other hand, swarms of small, gabbroic plutons occur which have no apparent connection with the other, more acid, intrusive rocks and which are quite obviously younger in age (post-Windsor).

Large areas in northeastern Cape Breton are underlain by intimately mixed intrusive granitic material, gneisses, metavolcanics and metasediments (Unit J). Indeed, more than half of the northeastern highlands of Cape Breton are underlain by such mixed rocks.

Age of the Intrusive Rocks

Until recently, it had been more or less tacitly assumed that practically all of the intrusive rocks of Cape Breton Island were of Devonian (Acadian) age. This conclusion was based upon both stratigraphic and radiometric data. Thus, intrusives of acidic and intermediate composition have been found to cut all rocks up to the Horton Group (Lower Mississippian). Moreover, a few radiometric ages (Black Brook, MacKenzie River, Framboise) by Fairburn et al (1960) indicated a Devonian age. More recently, radiometric measurements by Wanless at the Geological Survey and by Cormier at St. Francis Xavier University indicate that there were at least two periods of granitic intrusions on Cape Breton Island. While some of the

intrusives are Devonian in age, others are considerably older at Late Cambrian.

At the present time, the older ages have been obtained for granite rocks in the Craguish Hills, North Mountain, the Boisdale Hills, the Coxheath Hills and the granitic intrusives south of Loch Lomond. Devonian ages for the intrusive rocks have been obtained in northeastern Cape Breton and south of Framboise in southeastern Cape Breton.

3.6 STRUCTURAL GEOLOGY

Cape Breton Island forms part of the Appalachian geosyncline extending from the southeastern United States to Newfoundland. Neale (et al, 1961) describe three tectonic phases for the Canadian Appalachian area, based on age of folding. Phase one is the Taconic orogeny that took place in Middle and/or Late Ordovician time and was accompanied by intrusion of ultrabasic rocks. Phase two, the Acadian orogeny climaxing in the Middle Devonian, was accompanied by widespread granitic intrusion. Late Paleozoic folding, the third phase, was restricted to a narrow belt which extends from the Bay of Fundy through Cape Breton Island northeast to Cape Anguille and beyond to White Bay Newfoundland. Folding of the Carboniferous rocks varied in time and intensity from place to place within this belt. It was chiefly controlled by movements of rigid blocks of Pre-Carboniferous rocks. Late Pennsylvanian (Pictou) sediments and block-faulted Triassic red beds and basic volcanics cover strata of this late Paleozoic folded belt.

On Cape Breton Island, the Taconic orogeny may be only weakly developed. No ultra basic intrusives are known. However, Cambrian dioritic intrusives have been dated in the Coxheath Hills. The Acadian orogeny apparently affected all of Cape Breton while the late Paleozoic orogeny appears to be confined to western Cape Breton and the Salmon River Valley of eastern Cape Breton. Mississippian rocks of western Cape Breton Island are commonly strongly folded whereas those of eastern Cape Breton are gently folded.

The most prominent structural features of the island are north-

easterly trending belts of Carboniferous rocks interspersed by uplifted and upfaulted blocks of the older Pre-Carboniferous rocks.

Weeks (1954 p. 82) recognizes four periods of folding in southeastern Cape Breton. The earliest period or periods of folding deformed the beds of the George River group before deposition of the Fourchu group. A Taconic fold axis affecting rocks of the Fourchu group, extends along the southeastern coast from Framboise Cove through Gabarus and Louisberg.

The Acadian orogeny is represented by a north-south trending fold axis between Grand Mira and Gabarus Bay. Extensive shearing accompanied the Acadian orogeny along a belt extending from Stirling to Catalone River in the new Boston area. Late Paleozoic faulting is evident in a belt extending from St. Peters through the Salmon River Valley. Here the fault zones occur along the Carboniferous-Pre-Carboniferous contact zones.

The structural geology of Central Cape Breton is described by Kelley (1967, p. 52-54). Folding is apparently linked genetically with movement in the Pre-Carboniferous basement rocks, commonly faulted along at least one of their boundaries. Late Paleozoic uplift has caused doming in the overlying Mississippian rocks.

Post-Paleozoic faulting is prevalent in central Cape Breton striking either northeast to north or northwest to west. "Where overturned folds are present near boundary faults between Pre-Carboniferous and Carboniferous strata, the faults are probably high angle reverse faults. In other boundary faults they are probably normal block

faults. Westerly trending faults are interpreted as adjustments that resulted from stress set up by the northerly trending faults." Kelley 1967).

In northern Cape Breton (Neale, 1963) defines three periods of folding; one in the PreCambrian and the other two conforming to the Acadian and late Paleozoic tectonic phases. The Devonian folding, accompanied by widespread granitic intrusion trends northeast with these structures appearing to have influenced the trend of the Mississippian basin of deposition. During the late Paleozoic tectonic phase "it is probable that the crystalline rocks acted as resistant buttresses during this final folding, and deformation of the Mississippian rocks varied from place to place with the type and amount of movement of the adjacent crystalline rocks. Thus, dips are moderate to gentle in the Aspy Valley and moderate in the northern part of the area, whereas steep dips and overturned and breached west limbs of north-northeast-trending anticlinal structures are common along the west coast High angle faulting accompanied and followed post-Mississippian folding and in many places the Mississippian rocks are truncated by normal and reverse faults of large displacement."

The southerly extension of the Aspy fault has been subject to considerable conjecture. Since localization of ore bodies along this structure would appear to be a distinct possibility, then the extent and character of this fault become of prime interest in mineral exploration.

Some interesting possibilities are:

1. That the Aspy fault, or a branch of the fault, extends in an arcuate trend from Aspy Bay through the central highlands to St. Ann's Gut. This trend is suggested on Airborne Magnetic Map 7034 C, Canse Nova Scotia.
2. That the Aspy fault, or a branch of this fault, continues south-southwestward crossing the Cheticamp River and on through the north Margaree Valley to Mabou Harbour and into Northumberland Strait. (Gaps, however, occur in this trend that are not too well supported by existing geological and aerial magnetic data.)
3. That the Aspy is substantially offset to the west along a line extending between the Cheticamp River and Clyburn brook. This possibility has been suggested by a disruption of continuity of George River group units. It is supported somewhat by evidence of faulting along the Cheticamp River and Clyburn Brook indicated in recent geological mapping. If such a postulate is valid, it might serve to affect the displacement of the southern extension of the Aspy fault to the west beyond the island.

4. MINERAL OCCURRENCES, METALLOGENIC PATTERNS AND MINERAL DISCOVERY POSSIBILITIES

4.1 STATISTICALLY DERIVED ASSOCIATIONS

Tables A, B, C and D were prepared in an attempt to determine whether or not there existed well defined relationships between mineral occurrences and certain selected geological factors. The basic data used in assembling Tables A, B, C and D were obtained from the mineral occurrence summaries which are included in this report as Appendix A. These summary sheets were prepared from much more comprehensive detailed data sheets which are available for inspection at St. Francis Xavier University. In the statistical study, only bed-rock occurrences were considered; several occurrences for which available information was insufficient were not included in the study. The geological factors considered were:

1. host-rock age (Carboniferous vs. Pre-Carboniferous)
2. association with the Carboniferous-Pre-Carboniferous contact
3. association with the Windsor-Horton (including Grantmire) contact.

In Table A, the host-rock in each of 127 deposits for which information was available has been tabulated. The following observations are considered noteworthy.

- a) The George River Group is host-rock in early 30% of the occurrences. It appears to be the single, most productive rock unit in terms of the number of mineral occurrences.
- b) Both the Windsor and Horton Groups, with 20% and 17% respectively of the total mineral occurrences, are definitely among the more productive rock units and merit close attention.

Table A - Host Rock by Age and Rock Group

Type of Deposit	Precarboniferous				Carboniferous				Totals
	George River Group	Fourchu Group	Cambr-Ordovician	Intrusives	Mississippian			Pennsylvanian	
					Horton Grantm.	Windsor	Canso		
Cu	14 (29%)	5 (10%)	2 (4%)	15 (31%)	8 (17%)	2 (4%)	1 (2%)	1 (2%)	48
Pb	5 (20%)	0	0	1(4%)	5 (20%)	7 (29%)	0	6 (25%)	24
Zn or Pb-Zn	5 (50%)	0	0	1 (10%)	1 (10%)	3 (30%)	0	0	10
Zn-Pb-Cu	5 (62%)	0	3 (38%)	0	0	0	0	0	8
Ba-F-Sr-Mg	2 (13%)	0	1 (7%)	0	6 (40%)	6 (40%)	0	0	15
Fe-Mn	4 (26%)	1 (7%)	1 (7%)	0	1 (7%)	8 (53%)	0	0	15
Mo±Cu	2 (29%)	2 (29%)	0	3 (42%)	0	0	0	0	7
Totals	37 (29%)	8 (6%)	7 (6%)	20 (15%)	21 (17%)	26(20%)	1 (1%)	7 (6%)	127
	72				55				

Table B - Relationship of Mineral Occurrences to the Carboniferous - Pre-Carboniferous

Contact and to the Horton (+ Grantmire) - Windsor Contact:

Type of Deposit	Located within one mile of Carboniferous - Precarboniferous Contact	Located within one mile of Windsor-Horton (Grantmire) Contact	Apparently unrelated to either contact	Totals
Cu	35 (73%)	5 (10%)	8 (17%)	48
Pb	8 (33%)	5 (21%)	11 (46%)	24
Zn or Pb-Zn	5 (50%)	2 (20%)	3 (30%)	10
Zn-Pb-Cu	0	0	8 (100%)	8
Ba-F-Sr-Mg	8 (53%)	4 (27%)	3 (20%)	15
Fe-Mn	10 (67%)	0	5 (33%)	15
Mo±Cu	3 (43%)	0	4 (57%)	7
Totals	69 (54%)	16 (13%)	42 (33%)	127

Table C - Host-rocks of Deposits Associated with Carboniferous - Precarboniferous Contact.

Type of Deposit	Precarboniferous				Carboniferous				Totals
	George River Group	Fourchu Group	Cambro- Ordovician	Intrusives	Mississippian.			Pennsylvanian	
					Horton Grantm.	Windsor	Canso		
Cu	11	4	0	15	3	2	0	0	35
Pb	2	0	0	0	1	3	0	2	8
Zn or Pb-Zn	4	0	0	0	1	0	0	0	5
Zn-Pb-Cu	0	0	0	0	0	0	0	0	0
Ba-F-Sr-Mg	2	0	0	0	3	3	0	0	8
Fe-Mn	3	1	0	0	1	5	0	0	10
Mo±Cu	0	0	0	3	0	0	0	0	3
Totals	22	5	0	18	9	13	0	2	69
	45				24				

Table D - Host-Rocks of Deposits Apparently Unrelated to Carb. - Pre-Carb. and Horton-Windsor Contacts

Type of Deposit	Precarboniferous				Carboniferous				Totals
	George River Group	Fourchu Group	Cambro- Ordovician	Intrusives	Mississippian			Pennsylvanian	
					Horton Grantm.	Windsor	Canso		
Cu	2	1	2	1	0	0	1	1	8
Pb	3	0	0	1	2	1	0	4	11
Zn or Pb-Zn	1	0	0	1	0	1	0	0	3
Zn-Pb-Cu	5	0	3	0	0	0	0	0	8
Ba-F-Sr-Mg	0	0	1	0	0	2	0	0	3
Fe-Mn	1	0	1	0	0	3	0	0	5
Mo±Cu	2	2	0	0	0	0	0	0	4
Totals	14	3	7	3	2	7	1	5	42
	27				15				

- c) Among the intrusive rocks, practically all occurrences (18 out of 20) are of copper (15 occurrences) or molybdenum-copper (three occurrences). This would indicate that as far as base-metals are concerned, areas of intrusive rock with acidic tendencies should be prospected for copper. The association of molybdenum with copper is encouraging in that the possibility of finding large-tonnage deposits of the 'porphyry copper' type is enhanced.
- d) The above four rock units account for more than 80% of the mineral occurrences studied. The remaining four rock units (Fourchu Group, Cambro-Ordovician sediments and volcanics, Canso Group and Pennsylvanian Groups) account for less than 20% of the occurrences.

In Table B, the relationship of each mineral occurrence to the Carboniferous-Pre-Carboniferous boundary and to the Windsor-Horton (Grantmire) boundary is examined. Certain relationships present themselves in Table B.

- a) The most striking observation is the marked association of mineral occurrences with the contact between rocks of Carboniferous and Pre-Carboniferous age. Of the 127 mineral occurrences considered, 69 or 54% are located on or within one mile of this boundary. Looked at in another way, 54% of the Cape Breton mineral occurrences considered are located in only 30% of the area of Cape Breton Island (the 69 occurrences related to the Carboniferous-Pre-Carboniferous contact fall within an area of 1500 square miles while the area of the entire island is about 5000 square miles).

- b) The correlation between mineral occurrences and the Windsor-Horton contact is much less marked. Only 16 of 127 occurrences (13%) appear to be related to this boundary.
- c) At this point, it might be wise to inject a word of caution. The correlation between mineral occurrences and the Carboniferous-Pre-Carboniferous boundary may be more apparent than real. Other factors (outcrop distribution, accessibility, etc.) may have contributed to more fruitful prospecting along this contact than elsewhere. With the evidence available now, however, it would appear that this contact merits a good deal of attention in the search for mineral deposits on Cape Breton Island.

When occurrences of specific elements are studied, additional correlations are found.

- d) Among copper showings, 35 out of 48 occurrences (73%) are located on or close to Carboniferous-Pre-Carboniferous boundaries.
- e) None of the zinc-lead-copper occurrences appear to be related to either the Carboniferous-Pre-Carboniferous contacts or the Windsor-Horton contacts. Moreover, all eight occurrences of this type are found in host-rocks of Pre-Carboniferous age (see Tables A and D). These observations may indicate that this type of mineralization (rather more complex than the other types considered) is older (Pre-Carboniferous).
- f) All seven of the molybdenum occurrences are in host-rocks of Pre-Carboniferous age; this could be taken to indicate a Pre-Carboniferous age for molybdenum mineralization. In this

case, however, three showings are situated close to Carboniferous-Pre-Carboniferous boundaries.

- g) In the case of barite-fluorite mineralization, 80% of the occurrences are in host-rocks of Carboniferous age. In addition, 80% of the showings occur in association with either the Carboniferous-Pre-Carboniferous boundary or the Windsor-Horton boundary.

Tables C and D are a further break-down of the host-rock types associated with those deposits lying on or within one mile of the Carboniferous-Pre-Carboniferous boundary (Table C) and those which are apparently unrelated to either the Carboniferous-Pre-Carboniferous or the Windsor-Horton boundaries (Table D). In both cases, the George River Group is quite clearly the most productive host-rock with the combined Horton-Windsor groups running a close second.

4.2 METALLOGENY AND DISCOVERY POSSIBILITIES

At some stage in an investigation of this nature, it becomes appropriate to examine data in the light of theoretical background. The application of general principles should be attempted in the event that this could aid in charting the most promising courses of ore search. This involves an entry into the realm of conjecture considerably at variance with the statistical approach of the preceding section. The following is offered in the light of these preliminary remarks.

Many metalliferous deposits are co-extensive with particular groups of sedimentary, volcanic or igneous rocks. Although thermal zoning of mineral deposits based on ascending magmatic fluids has been well established, a more useful classification perhaps from a prospecting and exploration point of view would be one based on metalliferous provinces, i.e. "native copper in basalts," red bed coppers, asbestos in serpentine." Metallogenic trends such as this "convey a practical meaning which corresponds with well known field facts." (Sullivan 1957).

This leads to the question; what base metal metalliferous provinces do we have in Cape Breton Island? With regard to actual mineral deposits three deposits stand out.

- (1) The Stirling Mine (now abandoned) containing massive Zn-Pb-Cu mineralization. This deposit occurs in schists and carbonates of the Bourinot group of the Middle Cambrian.
- (2) The Meat Cove zinc deposit in George River limestones enclosed in syenitic intrusive rocks. This deposit is estimated to

contain about $3\frac{1}{2}$ million tons grading 2-3 percent zinc.

(Keating 1960).

- (3) Disseminated galena in Pennsylvanian sandstones at Salmon River, where upwards of 40 million tons of lead grading $2\frac{1}{2}$ - 3 percent are estimated.

Deposits 1 and 2 above would correspond to Sullivan's thermal reconcentration from sediments through intrusion (normally of limestone) by granite. Deposit 3 appears to be a modification of Sullivan's syngenetic sedimentary and thermal reconcentration from sediments classifications.

At this time it might be desirable to draw attention to base metal mineralization in the Carboniferous sedimentary rocks of the island. With the exception of the Salmon River valley and a few other isolated situations no systematic exploration of these Carboniferous sedimentary rocks has been carried out. A generally heavy overburden cover is typical of much of these rocks making exploration difficult.

The association of base metal mineralization in Nova Scotia with the Windsor limestone belt is well known, i.e. Walton, Smithfield and numerous occurrences over the rest of the mainland and Cape Breton .

Three other situations not directly associated with the Windsor limestone are worthy of note.

1. The already mentioned galena in sandstone at Salmon River.
2. Copper (chalcopyrite-malachite) mineralization along the Grantmire-marine Windsor contact at Coxheath. Drilling by Mariner Mines in 1966 defined continuous copper mineralization over a

5 mile strike length. The zone ranged from 2 to 8 feet thick grading less than .50% copper. Similar occurrences have been noted elsewhere along this contact.

3. Lead in sandstone of Pennsylvanian age at Leitches Creek (similar to that of Salmon River, but of much lower tenor and grade).

Common to these three occurrences is the fact that similar metallic mineralization is known in the adjacent Pre-Carboniferous rocks. Galena occurs in rhyolite immediately to the east of the Salmon River deposit. Extensive copper mineralization is present in the monzonite-diorite rocks of the Coxheath Hills; and lead mineralization has been recorded in the George River group at Leitches Creek. This is suggestive that the mineralization may be at least in part derived from erosion of the Pre-Carboniferous. Consequently under the right environmental conditions a syngenetic sulfide ore body may occur. However, the chances for an ore body would be greatly enhanced with remobilization and reconcentration of these syngenetic sulfides. This, in accord with Sullivan's scheme, may be brought about in different ways: (1) accumulation by circulating meteoric water and; (2) accumulation through thermal reconcentration with or without the introduction of new mineralization along new or existing channelways (faults, folds, joints, unconformities, etc.).

In applying this concept as an exploration tool one would be also directed to those other Carboniferous sedimentary basins with known

evidence of folding and faulting, lying adjacent to known mineralization in the Pre-Carboniferous. Four such basins are :

1. The Carboniferous rocks (mainly Horton group) of the Aspy region.
2. The Mississippian rocks of the St. Anne's Bay area.
3. Mississippian rocks of the Middle River-Baddeck area.
4. Carboniferous rocks of the Margaree-Cheticamp area.

It is noteworthy that this particular concept involves exploration in selected areas along the Carboniferous-Pre-Carboniferous contact where 54% of the known mineral occurrences are found. It does not imply, however, that these are the only areas along this contact where ore deposits may be located. Other modes of ore formation may exist in the areas already cited and elsewhere within the Carboniferous rocks along this contact.

Alternative to the foregoing, in which attention is directed mainly to the Carboniferous sedimentary basins, is an approach based on a concept of mineralized "belts" along which additional conditions and processes are invoked. Visualized are loci where convergence of all these promote optimum conditions for introduction of ores along the Horton (or Grantmire)-Windsor contact and on either side of the Carboniferous-Pre-Carboniferous contact.

In this approach to discovery possibilities it becomes important to scrutinize the statistics relating to the Carboniferous-Pre-Carboniferous contact for relationships that would focus attention on favorable sections of the contact. In other words, although this contact constitutes a very favorable access channel its potential

would of necessity be limited. It would, of course, be untenable and impractical to imply that over 1200 miles of contact possess an evenly distributed potential. It seems imperative then to examine other factors that may have entered into conjunction with the contact structure to create favorable loci for ore deposition.

The most obvious accessory factor is faulting. Here again, however, one is overwhelmed by abundance when the linear extent of "known" faults is added to that of possible and purely speculative faults.

The arcuate northeasterly-trending formational grain of the country may well have been established in early Pre-Carboniferous time. Superimposed upon this is a longitudinal fault pattern many members of which have been active well into the Carboniferous. Post-Carboniferous faulting has served in many instances to bring the Carboniferous and Pre-Carboniferous into juxtaposition and a considerable portion of the contact is faulted.

One is prompted to entertain the notion that these conjunctions of access channels may possess higher potential; that further selection on the basis of proximity to known occurrences of merit would form a promising point of departure for ore search. In another approach one could envisage the selection of sites where the main longitudinal faults, their subsidiaries, and other transverse faults are all in conjunction with the contact. At some stage it might be incumbent upon the investigator to weigh the merits of different fault systems in terms of "ore carrying potential". This approach could be productive but its application could become overspeculative.

It would seem then that the core of the matter resides in the ultimate source of the metals and the factors that played a part in their mobilization.

As early as 1929 Messurvey (1929) suggested magmatic sources dating in the Triassic to explain the large number of metal occurrences distributed in the Carboniferous rocks. Recently Boyle and Jambar^o (1966) in discussing the Walton area state that, on the basis of geochemical data obtained on the rocks of the area "the shales and sandstones of the Horton Group are an adequate source for all the elements in the deposit". The visualized requirements for mobilizing these metals could reside in the igneous activity of the Triassic. Thus, a blending of the two hypotheses combined with the conjunction of favorable access channels including the Carboniferous-Pre-Carboniferous contact might serve to narrow ore search.

In other words, selection of promising sites would have to meet, in addition to access-channel requirements:

1. A recognizable metal source in the Horton or other source beds, and;
2. An activating thermal source.

The first requirement would involve trace-element sampling of promising source beds. The second requirement might involve ground magnetometer survey or some other geophysical approach to gauge the proximity in depth of basic Triassic rocks.

The province-wide association of sulphides with barite suggests that some factors may be common in the genesis of these deposits. On examination, other associations form a grouping that may be significant.

A test of the foregoing assumptions applied to the area in terms of metallogenic "belts" is outlined below.

Near Walton (on the south shore of the Fundy Triassic basin) are a number of manganese deposits and these occur in proximity to the South Triassic boundary. In fact, manganese occurrences are distributed along this boundary for 25 miles to the east and west. In addition, manganese occurrences extend across Pictou and Antigonish counties in a broad area and recur again in Cape Breton along a belt extending through the Loch Lomon-Salmon River structural trend. On the north side of Minas Basin flanking the Cobequid Hills near the north Triassic contact is a belt of iron deposits. Iron occurrences persist easterly across Pictou and Antigonish counties into southeastern Cape Breton. There is a strong temptation to group this metal association as possibly constituting a "belt" having one type of metal source and related in time of emplacement to the Triassic (or some other appropriately-timed thermal source). In support of this a number of gabbroic intrusives extend from Antigonish and Guysborough counties through St. Peter's and on through southeastern Cape Breton to Scaterie Island. In addition, rocks of the Annapolis Group that underlie the Triassic flows have been found on the shores of Cobequid Bay. d

Corollary to this, the barite-base metal association might be conceivably extended to include manganese and iron, the occurrence of which may be indicators of other more valuable mineralization. In this connection it should be noted that the Nova Scotia Department of Mines is presently pursuing a geochemical investigation of manganese deposits.

In advance of anticipated regional airborne attack and geochemical-Pleistocene dispersion pattern approach in selected areas, it is premature at this stage in the investigation to attempt to define other such trends as the St. Peters-Salmon River belt. The regional tectonic pattern, however, does suggest that parallel belts of Walton-type affiliations could exist. On the basis of the foregoing conjectures their potential would be in proportion to the extent that they measure up to the requirements stipulated above, namely:

1. Proximity to the Carboniferous-Pre-Carboniferous or Horton-Windsor contacts;
2. Conjunction of contact with favorable fault conditions;
3. Conjunction of favorable source beds;
4. Evidence of source for promotion of thermal activity close at hand.

Finally, it should be emphasized that operation of these mechanisms need not necessarily restrict ore emplacement to the Carboniferous-Pre-Carboniferous contact, the Pre-Carboniferous rocks could be receptive hosts provided the ground is well prepared by faulting and favorable formations such as the George River Crystalline carbonates are in association.

The foregoing discussion of discovery possibilities has revolved around broad or long linear geological features - such as "basins" and "belts". Apart from these, other ore potential situations could reside in the possible connection between ore deposition and Pre-Carboniferous intrusives. In all, 72 occurrences are hosted in the

Pre-Carboniferous (Table A) and in most cases intrusives of some sort or other are in attendance. However, in relating occurrences to the main contacts one mile was arbitrarily chosen as a cut-off - Table (B). This resulted in the "loss" statistically of 45 occurrences (Table C) hosted in the Pre-Carboniferous leaving only 27 occurrences "apparently unrelated" to the Carboniferous contacts (Table D).

Representative of the 45 occurrences of Table C, the Lime Hall sphalerite deposit is cited. Here alaskite, believed to be Cambro-Ordovician^c in age (485 M.Y.), has invaded George River crystalline carbonate rock with attendant contact metamorphism in the carbonates. Assumed regional faulting is northeasterly. A subsidiary fault trends northwesterly through the area of mineralization. The deposit lies within a mile of the Carboniferous fault contact (assumed on relatively safe grounds); thus statistically the occurrence has been classed as contact-related. It becomes pertinent to pose the following questions:

Is the mineralization genetically associated with the alaskite and thus Cambro-Ordovician in age?

Has faulting played the dominant role in ore deposition?

If faulting guided ore emplacement, was it necessarily during the Pre-Carboniferous or could the introduction of ore minerals be as late as the Triassic?

Questions of this type may be applicable to all the contact-related Pre-Carboniferous host occurrences and are in the present context of more than academic interest. It is by no means certain that they could not be posed with equal validity to the 27 "unrelated"

occurrences of Table D. The strong tendency of the intrusives to host Cu and Cu-Mo has been noted in the preceding section and has prompted the inference that a genetic association pointing in the "porphyry copper" direction, may exist. Nevertheless, this intrusive-Cu and Cu-Mo association is also contact-related. At best this would appear to do nothing to support the idea of genetic association with the intrusives.

In the final analysis it would appear that, apart from the "porphyry-copper" potential previously noted, there is little evidence to date that would direct attention to the bulk of the Pre-Carboniferous intrusives as sources of ore although gabbroic intrusives in the northern part of the island have associated nickel mineralization. At first glance this appears to be a genetic association that merits further attention. Whether or not such intrusives as the alaskite at Lime Hill and the hornblene syenite at Meat Cove are parent to the zinc mineralization at these two Carboniferous-Pre-Carboniferous contact-related occurrences remains an open question.

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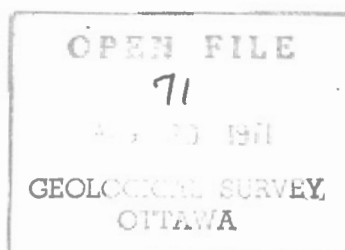
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APPENDIX "A"

MINERAL OCCURRENCE SUMMARY

MINERAL ASSOCIATIONS	PAGE
Cu (dominant); Ni	1 - 7
Pb	8 - 10
Zn, or Zn, Pb	11 - 12
Zn, Pb, Cu	13
BA, F, Sr, Mg	14 - 17
Fe, Mn	18 - 21
Mo ± Cu	22 - 23
Au	24
PLACER	25



MAJOR ELMTS	OCC SER NO	ORE MINS	ASSOC ELMTS	ASSOC ORE MIN	PRIN GANG MIN	MODE OF OCC						CONTACT RELATION	HOST ROCK												ASSOC ROCKS	TYP				
						DISSEM	VEIN	BEDDED	PDS & LNS	MASSIV	OTHER		CNFM	UNCNFM	FAULT	INTRUS	SNDS	SH&SLST	CGLM	LS&DOL	VLCC	META	GRNT	GRDR			MNZN	DORT	GBBR	
Cu	148	Cu - Sulfides	--	--	?	x												x										Trout Brook (M.E.)	Probably granitic rocks seems to show contace metamorhpism.	
Cu	6	CLCP	--	--	--	x												x										George River Gp.	Host Rock cut by red granite surrounded by it.	
Cu	7	CLCP	Ni(?)	PYRR PYRT			x																					George River Gp.	Host rock a roof pen- dant in red granite.	
Cu	23	CLCP(?)	Pb Zn Ag																									DEVN (?) granitic rocks	Inclusions in granitic rocks.	
Cu	29	MLCT CHLT	--	--	CLCT																							Occurs in granitic rocks along shear zones.		
Cu	30	CLCP	--				x																					George River meta- morphic rocks.		
Cu	31	CLCP	--	MLCT MGNT																								George River Gp.	Host-rock cut by granitic intrusives.	
Cu	35	CLCP	--	--	--	x																						Intimately mixed George River meta- morphic rocks and in- trusive granitic rocks.		
Cu	37	CLCP	Ba		CLCT QRTZ BRIT		x																					Diorite		

MAJOR ELMTS	OCC SER NO	ORE MINS	ASSOC ELMTS	ASSOC ORE MIN	PRIN GANG MIN	MODE OF OCC						CONTACT RELATION		HOST ROCK													ASSOC ROCKS	TYP		
						DISSEM	VEIN	BEDDED	PDS & LNS	MASSIV	OTHER	CNFM	UNCNFM	FAULT	INTRUS	SNDS	SH&SLST	CGLM	LS&DOL	VLCC	META	GRNT	GRDR	MNZN	DORT	GBBR			FORMATION	
Cu	39	CLCP	Fe	MGNT HMTT PYRT			x						?	?														Vein occurs at con- tact of granitic rocks and George River limestone.	Horton Gp. CGLM.	
Cu	64	CHCT PYRT	--	---	--	x												x										Fourchu Group.		
Cu	71	CLCP				x													x	x								Disseminated CLCP in granite and George River Gp. meta seds.		
Cu	72	CLCP		AZTE MLCT		x														x								Granite gneiss.	Aspy fault.	
Cu	73	CLCP		PYRT		x		x												x								George River Gp. schist & gneiss.		
Cu	74	CLCP		PYRT		x		x												x								George River Gp. schist & gneiss.		
Cu	79	CLCP?		PYRT?																								George River Gp.		
Cu	81	CLCP				x	x														x							Granite.		
Cu	82	CLCP	Au	--	QRTZ CRBN	x	x														x							Granitic rocks.		

MAJOR ELMTS	OCC SER NO	ORE MINS	ASSOC ELMTS	ASSOC ORE MIN	PRIN GANG MIN	MODE OF OCC						CONTACT RELATION		HOST ROCK															ASSOC ROCKS	TYP
												LITHOLOGY								FORMATION										
						DISSEM	VEIN	BEDDED	PDS & LNS	MASSIV	OTHER	CNFM	UNCNFM	FAULT	INTRUS	SNDS	SH&SLST	CGLM	LS&DOL		VLCC	META	GRNT	GRDR	MNZN	DORT	GBBR			
Cu	83	CLCP BRNT		PYRT MLCT	QRTZ CRBN		x																					Microclimate granite		
Cu	84	CLCP		PYRT MLCT	QRTZ		x																					Hornblende granite		
Cu	85	CLCP		GLEN	QRTZ CRBN	x	x																					Microclimate grantie & amphibolite		
Cu	86	CLCP?			QRTZ CRBN		x																					granitic rocks cut by dikes of RYLT and ANDS.		
Cu	87	CLCP GLEN			QRTZ CRBN		x																					diorite		
Cu	88	CLCP?						?										?										?		
Cu	102	MLCT				x ?													x									Fourchu Gp.		
Cu	108	CLCP		MLCT	QRTZ CRBN		x												x									Fourchu Gp.		
Cu	122	Minerals not identi- fied	Au																x									Bourinot Gp.		

MAJOR ELMTS	OCC SER NO	ORE MINS	ASSOC ELMTS	ASSOC ORE MIN	PRIN GANG MIN	MODE OF OCC						CONTACT RELATION	HOST ROCK														ASSOC ROCKS	TYP
						DISSEM	VEIN	BEDDED	PDS & LNS	MASSIV	OTHER	CNFM	UNCNFM	FAULT	INTRUS	SNDS	SH&SLST	CGLM	LS & DOL	VLCC	META	GRNT	GRDR	MNZN	DORT	GBBR		
Cu	126	CLCP MLCT				x ?																			x		Mineralized, fine grained DORT <u>float</u> .	
Cu	125	BRNT CLCP HMTT PYRT			QRTZ		x													x							Fourchu Gp.	
Cu	127	CLCP PYRT PRTT					x															x					granitic rocks	
Cu	129	No minerals identi- fied																									Small Cu-showing at GRNT-ANDS contact.	
Cu	137	CLCP?																				x					Granitic rocks.	
Cu	147	MLCT CLCP?					x													x							Fourchu Gp.	
Cu Pb	90	CLCP GLEN	Ag	PYRT	QRTZ		x																				Mixed George River Group and granitic intrusives.	
Cu Pb	91	CLCP GLEN	Ag	SPEC	QRTZ		x																				Mixed George River Group and granitic intrusives.	
Cu Pb	96	CLCP GLEN	Au	ARPR	QRTZ		x																				Mixed George River Group and granitic intrusives.	

MAJOR ELMTS	OCC SER NO	ORE MINS	ASSOC ELMTS	ASSOC ORE MIN	PRIN GANG MIN	MODE OF OCC						CONTACT RELATION		HOST ROCK														ASSOC ROCKS	TYP
						DISSEM	VEIN	BEDDED	PDS & LNS	MASSIV	OTHER	CNFM	UNCNFM	FAULT	INTRUS	SNDS	SH&SLST	CGLM	LS & DOL	VLCC	META	GRNT	GRDR	MNZN	DORT	GBBR	FORMATION		
Pb	5	GLEN	Ag	--	--			x						x													Basal Penn. S.S.	Underlain by Windsor Gp.	
Pb	15	GLEN	--	--	--	x												x									George River Gp.		
Pb	25	GLEN	Ag Au F	FLRT	CLCT	x								x						x							Veins cut both Pre- Carb. GRDR and over- lying Horton Gp. sandstone.		
Pb	26	GLEN	--	--	--	x													x								George River Gp.	Precarboniferous Granitic Rocks.	
Pb	27	GLEN	--	--	CLCT QRTZ	x												x									Windsor Gp.		
Pb	28	GLEN	--	--		x								x													Pennsylvanian coal- bearing rocks.		
Pb	59	GLEN	Ag	--	--	x												x									Windsor Gp.	Horton - Windsor contact a few hundred feet away.	
Pb	60	GLEN	--	--	--	x	x											x									Windsor Gp.		
Pb	75	GLEN		PYRT		x		x										x									Windsor Gp.		

MAJOR ELMTS	OCC SER NO	ORE MINS	ASSOC ELMTS	ASSOC ORE MIN	PRIN GANG MIN	MODE OF OCC						CONTACT RELATION	HOST ROCK													ASSOC ROCKS	TYP		
						DISSEM	VEIN	BEDDED	PDS & LNS	MASSIV	OTHER		CNFM	UNCNFM	FAULT	INTRUS	SNDS	SH&SLST	CGLM	LS&DOL	VLCC	META	GRNT	GRDR	MNZN			DORT	GBBR
Pb	76	GLEN	Ag	SPLP PYRT		x			x											x							Granitic rocks		
Pb	80	GLEN?		PYRT?					?																		George River Gp.		
Pb	89	GLEN	Ag	CLCP?					?							x											Horton Gp. (2' thick band)		
Pb	92	GLEN				x												x									Windsor Group.		
Pb	98	GLEN			QRTZ		x												x	x							George River Gp. gneisses and granites.		
Pb	99	GLEN				x												x									CGLM close to Horton-Windsor contact.		
Pb	109	GLEN					x																				Port Hood Fm. (Penn.)	Seems very minor.	
Pb	110	GLEN				x ?																					Port Hood Fm? found in boulders only-bedrock source not located.		
Pb	113	GLEN				x																					Crystalline lime- stone of George River Group.		

[illegible]

[illegible]

[illegible]

MAJOR ELMTS	OCC SER NO	ORE MINS	ASSOC ELMTS	ASSOC ORE MIN	PRIN GANG MIN	MODE OF OCC						CONTACT RELATION	HOST ROCK													ASSOC ROCKS	TYP		
													LITHOLOGY															FORMATION	
						DISSEM	VEIN	BEDDED	PDS & LNS	MASSIV	OTHER		CNFM	UNCNFM	FAULT	INTRUS	SNDS	SH&SLST	CGLM	LS&DOL	VLCC	META	GRNT	GRDR	MNZN			DORT	GBBR
Ba	2	BRIT	Cu F Mn	CLCT FLRT	--		x												x								George River Gp. QRTE & LMSN	Fisset Brook Fm(?)	
Ba	43	BRIT		CLCT FLRT			x																				Rhyolite, apparently of Fisset Brook Fm. (basal Horton)		
Ba	103	BRIT					x ?												x								George River Gp.		
Ba	120	BRIT	Cu Fe	CLCP PYRT PRTT	CLCT		x																				Windsor Group		
Ba	136	BRIT	Zn																								Horton Group		
Ba	142	BRIT		ARPR																							Windsor Group		
Ba	138	BRIT																									Horton Group		
Ba	139	BRIT																									Horton Group		
Ba	140	BRIT																									Horton Group		

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CAPE BRETON MINERAL RESOURCES PROJECT

A P P E N D I X B

MINERAL ECONOMICS

(THE ECONOMIC POTENTIAL OF SELECTED MINERALS)

OPEN FILE

71

AUG 30 1971

GEOLOGICAL SURVEY
CANADA

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INTRODUCTION

This Appendix presents a brief survey of basic factors to be considered in evaluating the economic potential of development and exploitation of some minerals, - as well as, in some cases, a short indication of further economic benefits to be derived from processing and from secondary manufacturing based on mineral raw materials.

Although the surveys are very short as a consequence of the limited time available, it is hoped that they will give a general idea of the type of analysis needed in determining the market potential of the minerals considered.

For a thorough analysis and projection of the overall effects of mineral development on the economy of Cape Breton, it will, of course, be necessary to both widen and deepen this type of information, as well as consider the implications for regional employment and income.

(SOURCES: Unless otherwise mentioned in the text, data for the Appendix have been derived from:

1. MINERAL FACTS AND PROBLEMS 1965,
published by the United States Department of the Interior,
Bureau of Mines. (MFP).
2. CANADIAN MINERALS YEARBOOK 1967,
published by the Mineral Resources Branch, Department of
Energy, Mines and Resources, Ottawa. (CMY).

3. MINING, Annual Review,
published by the Mining Journal, London, England, June 1969.
4. METALS WEEK, The Magazine of Nonferrous Metal Marketing,
published by McGraw-Hill, New York.
5. THE FINANCIAL POST SURVEY OF MINES 1969,
published by MacLean-Hunter Limited, Toronto.)

B A R I T E

Barite (BaSO_4) is commercially the most important barium mineral. It is useful because of its specific qualities:

high specific gravity (4.5).

chemical inertness.

as a source of barium for the barium chemical industry,

although this is the least important of its uses.

By far the most important use (based on specific gravity and chemical inertness) is for well-drilling muds (oil and gas well-drilling).

Statistics of the last ten years show, that in North America, from 90-95% of all barite consumed was for well-drilling. Because well-drilling activity is subject to substantial fluctuations, demand for barite typically fluctuates over the years. Canadian exports to the U. S. A., the principal market, fluctuate as much as 20 to 25% from one year to the other, and in the 10 year period, 1958-1967, the largest export was in 1962 (231,000 tons), the lowest in 1960 (135,000 tons), while it was 146,000 tons in 1967, i. e., 27% less than in 1966, and about 37% less than the peak-year 1962.

WORLD PRODUCTION, 1966-67, SHORT TONS

Total in both years: about 4,000,000 tons, of which U. S. A. about 1,000,000 tons or 25%.

Mexico about 320,000 tons, and Canada: 221,000 tons in 1966, 172,000 tons in 1967.

It is estimated that the U. S. A. imports between 700,000 and 1,000,000 tons including almost all the output from both Mexico and Canada (Nova Scotia), its principal suppliers.

Other major producers are:

West Germany -- about 510,000 s. t.; other West European countries, between them, about 700,000 tons. The output of Russia and China can be estimated at about 400,000 tons.

The balance of world output is shared between a great number of countries.

The U. S. A. is potentially self-sufficient. Its major problem, however, being mine and plant capacity. In wartime, the U. S. A. would depend for imports on Mexico and Nova Scotia, as transportation problems would be minimized from these sources.

CANADIAN PRODUCTION, TRADE, CONSUMPTION

Almost all Canadian production is in Walton, Nova Scotia and mine output was about 221,000 tons in 1966, and 172,000 tons in 1967, valued at \$2,200,000 and \$1,575,000, respectively. This value is very low, as more than 95% received only minimum processing, and is shipped to processing plants in the U. S. Gulf Coast region.

Exports were equal to about 85% of output, most of it to the U. S. A., small amounts to Venezuela and Trinidad--Tobago.

Canadian consumption is about 15,000 tons a year, almost half of it imported (in processed form) from the U. S. A.

Total Canadian consumption by users (1966; round figures).

1. well-drilling	12,000 ton (80%)
2. Paint industry	1,600 ton
3. Glass industry	900 ton
4. Rubber goods	160 ton
5. Other	<u>340 ton</u>
	15,000 tons

THE CANADIAN MINERALS YEARBOOK 1967, (CMY '67) supplies some detailed information about present production and further developments of deposits in Nova Scotia:

1. To date about 95% of all barite produced in Canada came from Walton, N. S., from where crushed and lump barite is shipped to processing plants in the U. S.
2. Other promising deposits in Nova Scotia are:
 - a) East of Lake Aimslee, Cape Breton.
 - b) Near Brookfield, Colchester County.
 - c) In Yarrow Township. (?)
 - d) In the Mineral King tailings?

3. An interesting deposit of Celestite (Strontium sulfate, SrSO_4) exists near Loch Lomond, Cape Breton, estimated at near 1,000,000 tons of 75% SrSO_4 . The Celestite from this deposit and Barite from one or more sources in Nova Scotia will be used by a new plant, (Cape Chemical Corp.) at Sydney, in producing strontium carbonate and barium carbonate for the use in the manufacture of ferrites. (Celestite is similar to barite but has a lower specific gravity, and is used in the manufacture of strontium chemicals. It occurs with fluorite in the Cape Breton deposit near Loch Lomond.)

USES AND SPECIFICATIONS

1. For the principal use of barite, in drilling muds, the main specifications are:
 - a) A minimum specific gravity of 4.25.
 - b) A particle size of at least 90% minus 325 mesh.
2. For the second most important use, as a filler in paints, lacquers, and rubber and plastic compounds, specifications vary, but usually a minimum of 95% BaSO_4 is required and a fine particle size.
3. In the manufacture of glass, barite acts as a flux, improves the workability of the melt and adds lustre.

Usual specifications are: a minimum of 98% BaSO_4 content, a maximum of 0.15% iron (in terms of ferric oxide, Fe_2O_3) and a particle size of essentially minus 20 plus 200 mesh.

4. There are a great number of barium chemicals, used in a variety of industries, e. g. lithophone (70% BaSO_4) used in paint, barium carbonate used in ceramics, optical glass, electronics, and barium chloride used for the hardening of steel.

As these compounds are ('67) not produced in Canada, they are imported. In 1966 imports were about 4300 short tons (about 4000 tons of barium carbonate, 300 tons of lithophone) for a total value of \$405,000.

PRICES (FROM: METALS WEEK, DECEMBER 25, 1967)

1967 prices differed little from 1966; in 1968 prices remained stable.

1. Drilling mud grade:

83-93% BaSO_4 , 3-12% Fe, specific gravity 4.2-4.3: (per short ton)

Crude, in bulk-----U. S.	\$12.00-\$16.00
Ground-----U. S.	\$23.00-\$26.00
Imported in bulk,	
c.i.f. Gulf Ports-----U. S.	\$10.00-\$14.00

From Canada, 1) Crude, in bulk (long tons).

f. o. b. shipping point.-----U. S. \$11.00

2. Ground, short tons, in 100-lb. bags, f. o. b. shipping
point \$16.50.

2. Chemical grade:

Hand-picked lump, 95% BaSO₄.

1% Fe ----- \$20.00-25.50

Flotation or Magnetic concentrate, 96-97% BaSO₄, 0.3-0.7%

Fe, (in 100-lb. bags, \$3.00 extra)----- \$24.50

Wet ground, 99½ BaSO₄, minus 325 mesh, in

50-lb. bags ----- \$45.00-49.00

2. (N. S. tariffs for barite: Crude -- \$2.55 per long ton

Ground - \$6.50 per long ton

Tariffs will be cut under the Kennedy Round Agreements).

POTENTIAL

1. The principal market for barite is in the U. S. A., whose imports can be estimated at an average of about 750,000 tons, although this figure is subject to year-by-year fluctuations. Less than half of these imports are from Canada and Mexico, hence a reasonable estimate would be that about 400,000 tons are imported from Europe and South America. The greater distance of the latter suppliers and the substantial transportation costs involved, would indicate that Canada could have a larger share of U. S. imports.

2. It would seem that there is a domestic market for barite in Western Canada, for well-drilling purposes. In 1967 imports amounted to \$305,000.

3. Barium compounds are not produced in Canada ('67) and imports amounted to about \$500,000 (estimate).

4. There seems to be indications of interesting deposits in Cape Breton. Some have been discovered, perhaps others exist.

5. Although an increase of exports to the U. S. A. to 300,000 or 400,000 tons, which would appear to be a possibility, would (at 1967 prices) increase Canadian exports of Crude barite by several million dollars, further processing in Canada, might (on the basis of U. S. prices) double the dollar amount of exports. Hence increased output plus further processing might increase exports from about \$1½ million to \$6 million.

6. Increased drilling activities in oil and gas-exploration, and, eventually, production, may provide a new domestic market.

NOTE: Market conditions and prices remained stable throughout 1968 and the first half of 1969.

B I S M U T H

PRODUCTION AND CONSUMPTION

Bismuth is used in steel, aluminum alloys, as it increases the fusibility and malleability of these metals. In addition the pharmaceutical and cosmetics industries are important consumers.

Most bismuth is produced as a by-product of smelting and refining lead and is found in ore-form in combination with copper, lead, tungsten, silver, and other minerals.

Peru is the world's largest producer with roughly 20% of world output, followed by Japan, Mexico and Bolivia, while Canada takes fifth place with about 526,000 pounds, out of a total world output of 8,800,000 pounds (1967).

The U. S. A. are the largest consumers at about 3,000,000 pounds a year.

PRICES

In 1967 Cominco, Canada's largest producer of bismuth, quoted bismuth in bars, 99.99 + % pure at \$4.25 a lb. in lots of 2000 pounds or more, and \$4.50 for smaller lots. U. S. quotations throughout 1968 were unchanged at U. S. \$4.00 a pound.

POTENTIAL

The potential for producing and marketing more Canadian bismuth would follow from the following factors:

1. Canada's share of the world market is only about 6%, which seems rather low in relation to mineral ores which in Canada occur and that contain bismuth. (copper, lead, molybdenum, silver ores, etc.). The explanation may be, that substantial quantities of western Canadian ores are shipped to Japan, which country produces about 1,500,000 pounds a year from imported ores.

2. There have been in recent years two factors unfavourable to the market of bismuth:

(a) a decrease in demand for certain purposes in the U. S.

(b) substantial sales from U. S. government stockpiles.

However, these factors seem now to have been reversed, and demand is expected to increase substantially, not only in the U. S. but also in Europe and Japan.

U. S. consumption is expected to increase 12 to 15% for application in fusible alloys, which would push U. S. consumption alone well over 3,000,000 pounds per annum, which would represent a market of roughly \$12,000,000 to \$13,000,000 at present prices.

C O P P E R

PRODUCTION AND CONSUMPTION

Free world production of copper, in 1968, was about 4,200,000 tons, just about equal to output. However, 1969 consumption is estimated to rise to over 4,600,000 tons, due mainly to increased demand in the U. S. and Europe. This would suggest that 1969 output would fall about 350,000 tons below estimated demand.

PRICE

The situation in the copper market is not very clear as a consequence of long strikes in the U. S. A. which have only recently been concluded.

The price of copper has risen substantially in the last three years, which may be partly due to higher cost of production (wages), but ultimately it reflects also a tension between output and consumption.

The producers price of copper in Canada rose from 45¢ in 1967 to 53¢ recently. (Price at the London Metal Exchange at present is almost 50% above the Canadian producers price.)

POTENTIAL

The following factors would indicate the potential for increased mining, processing and marketing of copper:

1. There is estimated to be an increasing gap between output and consumption in the free world.

2. While Canadian output is approximately 600,000 tons a year of which 400,000 tons are exported, at present it would appear:

(a) that Canada can supply more as world demand increases

(b) a substantial part of Canada's exports are in minimally processed form hence more processing and manufacturing would appear possible.

F L U O R S P A R

Fluorspar is the commercial term for the mineral FLUORITE (calcium fluoride, CaF_2), which is widely distributed in many different geological environments.

Fluorspar is commercially important for two reasons:

1. it is an active flux
2. it is the principal source of fluorine..

USES

1. In the form of fluorspar (= fluorite, CaF_2) mainly in the steel, glass and enamel industries.

2. For the production of hydrofluoric acid (HF), which in turn is used:

- a) as a catalyst in the production of high-octane gasolines.
- b) in the production of aerosols, refrigerants, plastics and fiberglass.
- c) to produce synthetic cryolite, which is used in the production of aluminum (natural cryolite is obtained from only one deposit in Greenland, and this is nearly exhausted. No other deposits are known).
- d) to produce a great number of other materials, used in different chemical and metallurgical industries, e. g. aluminum fluoride for the aluminum industry.

3. Fluosilicates, for which there are limited markets, is used, amongst others, in disinfectants, insecticides, etc. Before 1963 the largest users of fluorspar were the steel industries, but since 1963 more fluorspar was used for the manufacture of hydrofluoric acid and the materials derived therefrom. The largest single use of HF was for the production of high-octane gasolines. The steel industry is now the second largest user, but its consumption in recent years has been increasing and is expected to increase in connection with shifts in the type of steel making processes. The third largest consumers are the manufacturers of glass, enameled products, and fiberglass.

TERMS, GRADES, SPECIFICATIONS

Fluorspar is marketed in three basic grades:

1. Metallurgical grade, containing a minimum of 60% fluorite (CaF_2). Market prices for this grade are based on CaF_2 content and a grade of 72½%.
2. Ceramic grade, specifications differ for different uses, but usually this grade is in finely ground form containing 85 - 97% CaF_2 .
3. Acid-grade, containing a minimum of 97% CaF_2 . (Acid-grade fluorspar is used for conversion into hydrofluoric acid).

SUPPLY. World Production.

According to MFP '65 the U. S. A. was the largest producer until 1963.

More recent statistics supplied in CMY '67 show considerable shifts in production in recent years, with Mexico being by far the greatest producer in the 1965 - 67 period (825,000 tons in 1967) and the U. S. A. in fifth place (with 260,000 tons in 1967). Other major producers in the Western World are France, Spain, Italy, Britain and West Germany, producing over 1,000,000 tons between them. Canadian production is estimated at about 100,000 tons, produced almost entirely in Newfoundland by a subsidiary of Alcan Aluminum Ltd. for use in the plants of Aluminum Company of Canada in Arvida, Quebec. The value of Canadian production (1967) is estimated at \$2,100,000 while imports of 94,244 tons for a value of \$2,609,000 were needed (\$2,000,000 from Mexico, \$400,000 from U. S. A., and \$193,000 from the U. K.).

DEMAND

The demand for fluorspar has been increasing steadily, resulting in new developments and increasing prices. The U. S. consumption for 1967 is estimated at 1,200,000 tons, i. e., almost five times its production. Canada depends for about 50% of its consumption on imports. Mexico is the principal supplier for both the U. S. A. and Canada. The trend of increasing demand is expected to continue. Canadian consumption increased steadily from less than 90,000 tons in 1958 to over 166,000 tons in 1966. U. S. consumption increased even faster: from 736,000 tons in 1963 to an estimated 1,200,000 tons in 1967, i. e. an increase of more than 63% in four years.

Cape Breton Resources

According to CMY '67 the most promising Canadian development is that near Lake Ainsley on Cape Breton. From 1940-49, 1400 tons were produced from this deposit, for metallurgical use. At present Yale Lead and Zinc Mines, Ltd. are in the process of developing this deposit, estimated at 2,500,000 tons averaging about 46% barite and 14% fluorite.

PRICES (All prices per short ton).

1963 Average price per short ton of fluorspar was about
 U. S. \$45.00 in 1963, ranging from about
 U. S. \$52.00 for hydrofluoric acid, to
 U. S. \$42.00 for fluorspar sold to the glass and enamel
 industries, to
 U. S. \$34.26 for sales to the iron and steel industries.

(Sources of information on prices:

E & MJ Metal and Mineral Markets
 Steel
 The Oil, Paint and Drug Reporter
 Metals Week)

1967/68 Prices increased sharply in 1967, i. e. from \$1 to
 \$3 per short ton for different grades - and this
 trend continued in 1968.

At the end of 1967 prices were as follows (in the U. S.):

1. Metallurgical grade:

60% CaF ₂ content	- U. S.	\$36.00
70% CaF ₂ content	- U. S.	\$39.00
72 $\frac{1}{2}$ % CaF ₂ content	- U. S.	\$41.50
Pellets, 70% CaF ₂ content	- U. S.	\$44.00

2. Acid grade:

97% CaF₂ content - U. S. \$51 - 55, depending on quality.

3. Ceramic grade:

88/90 - 97% CaF₂, from U. S. \$45.00 to \$51.00

European Suppliers' Prices:

Acid-grade, c.i.f. U. S. ports, about U. S. \$45.00, effective January, 1968.

Mexico:

Metallurgical grade, 72 $\frac{1}{2}$ %, f. o. b.

U. S. border, all rail & duty paid:

U. S. \$32 -33

Texas, barge \$34 -35

Tampico, Mexico \$25.00

Acid grade: delivered Texas (bulk),

97% - \$40 - 45.00

(U. S. Tariff: 97% or under - \$8.40 p. St.

over 97% - \$2.10 p. St.

Canada: none

Under the Kennedy Round of the GATT, U. S. tariffs will decrease substantially from 1968 to 1972).

(Average value of fluorspar imports in Canada: about \$27.50 p. St.)

POTENTIAL

The supply/demand relations in the U. S. A. and Canada are such that there is a great need for:

- a) additional information on resources
- b) more efficient recovery processes, as present U. S. producers face serious cost and quality problems in competing in present markets (MFP '65).

Factors supporting the potential of marketing fluorspar and its derivatives, in the U. S. A. and Canada:

1. A gap of about 1,000,000 tons between annual consumption and output ('67) requiring imports equal to almost 80% of consumption in the U. S. A., 55% in Canada. The value of 1,000,000 tons may be estimated at \$45,000,000 (1967 prices).

2. This gap has been increasing rapidly in recent years and is likely to keep increasing for the following reasons:

- a) increasing demand for fluorspar as a source of fluorine for the chemical industry.

b) increasing demand for fluorspar as a slag-thinner in the steel industry.

NOTE:

Demand for fluorspar has tripled in the decade of 1958-1967 and this trend is continuing. Notwithstanding substantial increases in output in the Western World, there have been periodic shortages of supply.

In 1967 the U. S. and Canada consumed about 42% of world output between them (the U. S. A. 35, Canada 7%) and produced only about 10% (U. S. A. 7, Canada 3%).

3. Reserves of natural cryolite ores are not known, except for deposits in Greenland, which are nearly exhausted. Cryolite is essential in the production of aluminum and can be produced from hydrofluoric acid, the demand for which is, therefore, increasing also as a source of artificial cryolite.

4. There is no satisfactory substitute for fluorspar in its major metallurgical uses.

5. There is no satisfactory substitute for fluorspar as a source for the production of hydrofluoric acid.

6. The economic exploitation of (low-grade) fluorspar deposits may be enhanced by recovery of by-products such as:

7. Development of deposits, not currently of commercial value, may become feasible as pelletizing fine fluorspar provides the steel industry with an acceptable alternative for lump fluorspar, suitable minerals for which are in short supply.

G O L D

PRODUCTION

(Russian gold production is estimated at between 5,000,000 and 6,000,000 ounces a year, which makes Russia the 2nd largest producer, accounting for roughly 15% of world output. Russia does not usually sell gold to foreign countries and has not sold any for three years. Its output may affect the market somewhat, indirectly, whenever it uses gold for foreign payments, e. g. to purchase wheat from Canada).

SOUTH-AFRICA is by far the largest producer with about 31,000,000 ounces a year, 67% of world output and 76% of free-world output.

CANADA takes 3rd place, with about 6% of world, and 7 to 8% of free-world-output; 1968 output is estimated at some 2,700,000 ounces, i. e. almost 10% less than in 1967 and 17% less than in 1966.

Since 1960, when Canadian output was 4,629,000 ounces, output has declined yearly to its present 2,700,000 ounces, a decline in eight years of almost 60%. U. S. A. output, estimated at 1,500,000 ounces in '68 is down almost 20% in the last three years.

CONSUMPTION

Just about half of free-world annual output is absorbed by industrial consumers.

The other half is, at present, largely stockpiled by S. Africa, or finds its way to monetary reserves or to the speculative market.

The situation is rather confused at present, as the U. S. are pressing the International Monetary Fund to disallow S. Africa to sell gold to Central Banks at the official price of U. S. \$35 ounce, implying that all her gold should be sold for industrial purposes and the balance of output over industrial demand in the free gold-markets, in order to depress the free price of gold, which for almost 18 months has been around U. S. \$43 and has (August '69) in the last few weeks risen to a slightly higher level.

Substantial gold sales in the free market would probably reduce the free price to the official level of U. S. \$35. This gold-policy would tend to freeze the amount of gold held as monetary reserves and at the same time boost the respectibility of the U. S. dollar.

However, almost all other Central Banks and also the I. M. F. do not think they should follow U. S. pressure, as they think gold is to stay as the basic monetary reserves for a long time to come.

POTENTIAL

There is, of course, great potential for marketing gold, provided good-grade ore can be found. The potential would depend on the following factors:

1. The amount demanded for industrial use, including jewelry, dentistry, etc. This factor would seem to be favourable, as demand is increasing steadily.

2. The amount demanded for monetary purposes (reserves). The situation here is uncertain. The U. S. A. would want to freeze reserves at about present levels, while other countries and the IMF disagree. Although the shortage of gold for reserves will, in the next few years, be somewhat relieved by the introduction of "paper gold" via the IMF., it is unlikely that gold will be abandoned for this purpose. Its relative scarcity and monetary neutrality make it an ideal means of international payments.

3. An important factor, affecting the future market position of gold, is that S. Africian production is assumed to be at present at peak-level, because its ore-reserves of (at present prices) commercial grade ore diminishing rapidly, and by 1980 her output will probably have fallen by 50%. If no other sources of supply are found, it would follow that by 1980 total supply would not even cover industrial demand, not to speak of monetary demand.

NOTE:

It is generally thought that if gold were abolished for monetary purposes, its price would drop sharply, perhaps by 50%. However, it is unlikely that this will happen in the foreseeable future.

GRAPHITE

Recent data on production, consumption, and prices of graphite are not available, world output for 1968 is estimated at 400,000 tons of which 50% is from North and South Korea. Other important producers in past years were:

Austria, Russia, and Mexico, while a great number of other countries produced small quantities.

We can find no indication of production of graphite in Canada.

Reserves of commercial-grade graphite in the U. S. A. seem to be negligible. U. S. supplies are obtained from Ceylon, Malasia, Mexico, and a number of small sources. MFP '65 provides 1964 prices for flake and crystalline graphite: \$90 to \$200 per ton, depending on a great variety of specifications. The same source mentions large indicated reserves of crystalline flake in Canada.

POTENTIAL

Potential for graphite would follow from the fact that the U. S. imported (1963) over 50,000 tons from mainly oversea sources, the value of which would be between \$5,000,000 and \$10,000,000.

G Y P S U M

Canada has large, well-located commercial-grade gypsum deposits, many of them containing gypsum of high purity. Although most provinces produce gypsum, Nova Scotia accounts for 70 to 80% of total Canadian output and ships almost all of it to gypsum-product plants in the eastern U. S. A.

Total Canadian production of crude gypsum (1967) was 5,200,000 tons, of which 3,730,000 was produced in Nova Scotia for a value \$7,100,000 down about 12% from 1966.

Canadian exports of crude gypsum amounted to almost 4,000,000 tons in '67, (worth about \$7,500,000), all of it to the U. S. A.

The Canadian Minerals Yearbook 1967 values Canadian gypsum production at just over \$2.00 per ton, while exports to the U. S. A. fetched less than \$1.90.

POTENTIAL

While Canadian, and more specifically Nova Scotian, exports are sizeable at \$7,500,000, the potential for gypsum may not specifically lie in more exports to the U. S. A. but in manufacturing gypsum products.

A quick calculation would indicate such potential:

Canada imported a small amount (10,000 tons) of plaster, made from gypsum, which plaster is valued at about \$55.00 a ton.

In addition, some imports took place of other gypsum products, including wallboard, worth between \$70 and \$75 a ton.

It would appear, therefore, that Nova Scotia, and Cape Breton in particular, would stand to gain much from the manufacturing of gypsum products, as these products would be worth, perhaps, between \$50 and \$75 a ton, as compared with less than \$2.00 a ton received for exporting crude gypsum.

L E A D

PRODUCTION AND CONSUMPTION

Free world consumption of lead is approaching 3,000,000 tons a year and in recent years mine production has been (by metal content of ores and concentrates) less than consumption, hence stock has been subject to depletion.

In the 1966-68 period mine production was, on the average, more than 700,000 tons below consumption. (For the Soviet Block, production was roughly equal to consumption).

PRICES

As a consequence of the gap between demand and supply, the prices have been rising and at present (December, 1968) U. S. 14 $\frac{1}{2}$ ¢ per pound (refined metal or metal content). The equivalent in Canadian funds is roughly 15 ¢ per pound. (August 15, 1969: 15 $\frac{1}{2}$ ¢).

POTENTIAL

The potential for marketing lead would follow from the following facts:

1. European consumption is about $2\frac{1}{2}$ times the metal content of European mine production, indicating dependence on imports for about 750,000 tons.

2. U. S. consumption is roughly equal to European consumption, but roughly four times U. S. mine production, indicating import needs for the U. S. A. of almost 800,000 tons per annum.

3. Canadian mine production is about 350,000 tons a year (metal content) of which roughly half is refined in Canada, while less than 20% is consumed in Canada. Although exports, in all forms, exceed \$50,000,000 a year (half the total value of output), the Canadian economy would obviously benefit:

(a) by increased mine production

(b) by increased processing of mine products

as the gap between U. S. as well as total free world production and consumption is about eight times Canadian exports at present.

L I M E S T O N E

Demand for limestone depends on activity in the construction industry, which has been very high in Canada, and may be expected to maintain high levels in the foreseeable future. As, in Canada, over 90% of limestone quarried was used in various phases of the construction industry, demand may be expected to increase substantially.

Canadian production is roughly 65,000,000 tons, worth \$75,000,000 of which most is produced in Quebec and Ontario which provinces account for about 62,000,000 tons. Nova Scotia produces less than $\frac{1}{2}\%$ of the Canadian total.

POTENTIAL

In assessing the potential for limestone in Cape Breton, exports cannot be of much importance. However, it would seem there are some factors indicating a greater potential:

1. Expanding activity in the regional construction business, including buildings as well as highways and secondary roads, might provide a regional market for limestone.
2. As cement production will keep pace with the needs of construction activities, this might add to the potential.
3. Increased capacity in pulp and paper production in the region may also be an important factor regionally, although the overall consumption of limestone by the pulp and paper industry is small (Total for Canada, 1967, 340,000 tons at \$1,050,000).

4. It would seem that Nova Scotia's share of total Canadian output, at less than $\frac{1}{2}\%$ is exceptionally low, hence could be increased.

M A N G A N E S E (Mn)

The importance of manganese derives from the following facts:

- (a) it is necessary for the commercial production of steel
- (b) there is no satisfactory substitute for manganese in its major metallurgical uses.

USES

1. Ferro-manganese

The functions of manganese in the steelmaking process are:

- (a) to counteract the effects of sulfur
- (b) to add strength, toughness, hardness, and hardenability to certain types of steel
- (c) to act as deoxidizer.

For these purposes Mn is introduced in the steelmaking process in the form of ferro-manganese.

- 2. Manganese-dioxide ores are important in the manufacture of manganese chemicals, as oxidizing agent and as a de-polarizing agent in dry-cell batteries.
- 3. Electrolytic manganese metal is used in metallurgical and chemical operations to offset the impact of impurities.

GRADES:

Generally all ores containing a minimum of 35% Manganese are considered manganese ores and included in calculating existing reserves. However, for commercial purposes the ores are classified according to their uses and subject to more detailed specifications.

1. Metallurgical grade ore, containing 46 - 48% Mn
2. Battery grade ore, in which the principal requirement is a high Mn - dioxide (MnO_2) content, usually at least 68%.
3. Chemical grade ore, containing at least 35% Mn.

In addition, various grades of ores are used in the production of electrolytic manganese metal and in the production of synthetic Mn - dioxide.

= (Because of the strategic importance of manganese, methods have been developed to use low-grade ores for the production of synthetic manganese and more especially manganese dioxide. For these purposes use has been made of:

- ferruginous manganese ore, containing from 10 - 35% Mn,
- manganiferous ore, containing from 5 to 10% Mn) =

Ferromanganese contains usually 74 - 76% Mn, sometimes more.

Electrolytic manganese metal requires a degree of purity of 99.9%.

SUPPLY:

World production of manganese ore of commercial grade is at present about 20,000,000 tons, of which Russia, which has the largest reserves by far, accounts for about 44% and Mainland China for 6% - for a total share of the Communist world of about 50%. Russia did not supply manganese to the western world since 1948.

The commercial reserves of Canada, the U. S. A., and Western Europe, are of little significance and their requirements are supplied by more than 20 different countries, the most significant of which are Brazil, Gabon, India, South Africa and Ghana. These countries account for 35% of world output, hence for 70% of the supply available to the Western world.

DEMAND

The demand for manganese depends on the level of production of the industries in which manganese is used. In Canada 99% of the consumption is by the steel industry, the balance by chemical and battery industries. Total consumption is between 150,000 and 160,000 tons at present, requiring imports of almost \$15,000,000 in the form of ores and ferro-manganese.

The U. S. consumption in 1967 was 2,300,000 tons*, for which purpose mostly ores were imported for a value, estimated in excess of \$75,000,000.

* about 95% by the steel industry

It follows that with the continuous expansion of the steel and chemical industries, there will be a market in North America for about \$100,000,000 (in round figures) within the next few years, for manganese ores and concentrates.

PRICES

All prices of manganese ore are established by negotiation and depend on many factors. Hence prices reflect only the general market conditions. However, a trend can be established by comparison of prices over a number of years.

It must be noted, that ore-prices quoted are c.i.f., eastern U. S. ports, and that ocean freight constitutes one-third of these prices, reflecting the fact, that ore is obtained mostly from South America and Africa.

1. U. S. Government price (for strategic stockpiling purposes) was - for the period of 1951-1959, about 10 1/4¢ per pound of manganese content, based on ore containing 48% Mn. This was - in most years - about twice the open market price.

2. Throughout the 1960's prices were maintained at about 4¢ per lb., but in 1967/68 prices of manganese declined as supplies of good-grade ore was abundant.

In the middle of 1968 U. S. prices had fallen to U. S. 74-75¢ per long ton unit (about 3.3¢ per lb.), and it was thought that large quantities were sold at well under 60¢ per long ton unit.

POTENTIAL

Provided that commercial deposits are located in Eastern Nova Scotia and/or satisfactory methods of beneficiating and concentrating of ore from known reserves are becoming available, the following factors would indicate a potential for profitable development and exploration of such deposits:

1. A demand for about 2,500,000 tons in the U. S. A., and Canada, based on present consumption, which in terms of manganese ores represents a value of approximately \$80,000,000.
2. The expectation of an estimated annual increase in demand of about 5%, i.e. in proportion to the increasing output of the steel industry and other industries using manganese. Hence, demand for manganese would double within 15 years to about 5,000,000 tons, and again in the next 15 years, so that by the end of the century, demand for manganese in the U. S. A. and Canada would be 10,000,000 tons, which at present-day market prices would represent a value in excess of \$350,000,000 in terms of ores.
3. Concentration of ores to ferromanganese would increase the value of output by about 100%, to \$ 700,000,000 - of which Eastern Nova Scotia could have an attractive (even if relatively small) share.

4. The present sources of supply, as mentioned above, all share two disadvantages:

- (a) great distance from the North American market
- (b) political instability of the supplying countries

5. The great distance of the sources of supply increases the cost of manganese very substantially, as - on the average - about 33% of the cost of the ores is attributable to ocean freight. In addition there are such transportation costs as the following:

- (a) In Brazil, the ore has to be transported in barges for up to 1200 miles to the nearest seaport and trans-loaded into sea-going vessels.
- (b) In Mexico the loading in the sea-ports is proceeded by transportation of the ores by truck over 100 miles of difficult terrain.
- (c) In Gabon 45 miles of transportation by aerial tramway is required before a railroad is reached.

Etc.

These factors add to the cost of manganese, over and above the cost of ocean freight.

In addition, there have been times that there was a shortage of vessels, congestion in the ports, causing delay and further costs.

6. There is no satisfactory substitute for manganese, which is essential to commercial steelmaking.

7. Known reserves in the U. S. A., of manganese ores containing 35% or more Mn are estimated at only 1 million tons, which is less than half of the U. S. present annual consumption.

8. Considering these factors as well as the need for regional economic development, it would appear warranted to request government support for purposes of exploration and possible development of any reserves available in the area.

M O L Y B D E N U M

The principal commercial mineral of M_o is

MOLYBDENITE (M_oS_2 , molybdenum disulfate, containing about 60% M_o and 40% sulfur). Molybdenite is produced from ores usually containing only a few pounds of M_oS_2 per ton.

Molybdenite concentrate, on which price quotations are usually based, contains 95% molybdenite.

About 70% of all molybdenum is produced from molybdenite containing ores, the balance as by-product from copper and also from tungsten. At present the U. S. A. and Canada account for over 90% of the world's output of M_o -the U. S. A. for about 70%, Canada for about 20%.

Canada's position as producer of M_o in the world was 6th (with 1% of world output) in 1963, second in 1967/68, and Canada's output increased in that period from less than 1,000,000 to 21,200,000 lbs., valued at \$38,000,000.

There are, in Canada, more than 700 known deposits. Production capacity in Canada was about 26,000,000 lbs. at the end of 1967. (U.S.A. 100,000,000 lbs., 70% of which is accounted for by two mines in Colorado).

USES

In the United States, the largest consumer of M_o , uses are as follows:

69% of all M_o is used in alloy steels

14% of all M_o is used in cast iron and steel mill rolls

4% in high-temperature alloys

87% in iron and steel industry (total)

4% as M_o metal (wire, rod, etc.)

9% in chemicals, lubricants, and miscellaneous.

100%

Miscellaneous uses include:

uses in electrical, electronics, and missile industries, which are increasing in recent years.

Potential for increased consumption exists in certain fabricating processes, e.g. a combination of 70% M_o and 30% tungsten for injection nozzles used in pouring molten zinc in dies. Both M_o and tungsten have a high degree of resistance to high temperatures.

FORM IN WHICH MOLYBDENUM IS USED:

(based on U. S. A. consumption)

68% in the form of molybdenum trioxide (M_oO_3).

22% in the form of ferro-molybdenum.

5% in the form of molybdenum powder.

95%

The balance is used in different forms as additive to chemicals, lubricants, etc. and in the form of molybdenite (MoS_2) in the steelmaking process.

Canadian production is about 20 times its consumption and the value of exports was about \$42,000,000 in 1967. These exports consisted of ores and concentrates with a total molybdenum content of about 24,000,000 pounds. Imports in the form of molybdic oxide and ferromolybdenum amounted to about 770,000 lbs. worth about \$920,000.

PRICES (f.o.b. shipping point)

Prices have increased over the years as follows (based on molybdenite concentrate, containing 95% MoS_2):

1932 - \$.70 (U.S.) per lb. of M_0 contained

1963 - \$1.40 (U.S.) per lb. of M_0 contained

1967 - \$1.62 (U.S.) per lb. of M_0 contained

Other prices (Dec. 1967) (Metals Week):

M_0O_3 (per lb. M_0 contained) U.S. \$1.81 - 1.82

Ferromolybdenum (per lb. M_0 contained) U. S. 2.11 - 2.17

M_0 - powder \$3.35

POTENTIAL

1. It is expected that demand for M_0 will increase at a rate of at least 5% per year.

At this rate consumption would double every 15 years, hence, be four times present consumption at the end of the century.

2. Production capacity, especially in the U.S.A. and Canada, has been increased substantially in the last few years. However, it is estimated that the U.S.A. will start to experience tension between its potential output and consumption by 1980. Although this tension may be relieved from stockpiles for some time, it would appear the U.S.A. will be interested in substantial imports within the next decades.
3. While about 30% of all molybdenum is produced as a by-product of copper, - the molybdenite ores from which the other 70% are produced, have as attractive by-products:
 - tungsten concentrates
 - pyrite
 - cassiterite, and
 - bismuth
4. There are no feasible substitutes for M_o , as technically possible substitutes (e.g. tungsten) are usually more expensive.

5. It would seem that Canada could benefit very substantially from increasing its capacity for concentration and fabrication of molybdenum, as exports at present are mainly in the form of ores and concentrates.

S I L V E R

The Annual Review, published by the Mining Journal (London, June 1969), states: "The silver market underwent its most dramatic year in modern times during 1968". The cause of this "drama" is the abolishment of a ceiling price of U. S. \$1.29 oz. which long ago was introduced in production of U. S. silver mines, but had in recent years lost its effectiveness, as the open-market price of silver moved well above \$1.29, as a result of ever increasing industrial demand, notwithstanding a sharp decrease of the use of silver for coins.

PRODUCTION: CONSUMPTION

Free world production in 1968 rose to over 238,000,000 oz. of which Canada, the largest producer, accounts for almost 20% or 46,000,000 oz. (estimated), an increase of 10,000,000 oz. over '67. Canada is followed by Mexico (42m. oz.), Peru (37), U. S. A. (35) and Australia (23), while many other countries produced smaller amounts for a total between them of about 55 million oz. However, these figures tell only part of the story. Total demand for 1968 was about 605,000,000 oz., subdivided as follows:

1. Industrial use	350,000,000 oz.
2. Coinage	75,000,000 oz.
3. Other (bought by non-consumers, including hoarding for future selling or use)	<u>180,000,000 oz.</u>
	<u>605,000,000 oz.</u>

TOTAL DEMAND.

New mine production covered only 238,000,000 oz. leaving an excess demand over output of 367,000,000 oz., which were covered as follows:

1. U. S. Treasury Sales	217,000,000 oz.
2. Sales by non-U. S. governments	10,000,000 oz.
3. De-Coinage (melting of coins)	40,000,000 oz.
4. From "scrap"	20,000,000 oz.
5. Illegal exports from India and Pakistan	<u>80,000,000 oz.</u>

Supply from other than producers' sources

<u>Total</u>	<u>367,000,000 oz.</u>
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PRICE

The lowest price in 1968 was U. S. \$1.81, the highest \$2.565 oz. (average price \$2.14).

Large sales from stocks, such as the U. S. Treasury and other treasuries (because much less silver is used in coins), have lowered the price again, which at present (August, '69) is quoted at \$1.79 in The Northern Miner.

POTENTIAL

There is obvious potential in marketing silver and it would appear that the future looks bright. The following factors would support this:

1. The demand for silver for industrial and coinage purposes was 425,000,000 oz. in 1968. Allowing for decreased demand for coinage, "normal" demand should, perhaps, be put at 400,000,000 oz., which however, is subject to increase as industrial demand is apt to increase. Hence present output is 162,000,000 oz. below normal demand.

2. U. S. Treasury stocks will be exhausted sometime in 1970, at the rate of sales established in 1968.

3. The substantial amount of silver recovered from coins (de-coinage) is bound to decrease rapidly.

4. Sales by speculative holders are, of course, introducing an uncertain factor in the market. Although panic-sales might substantially reduce the price, this is bound to be only temporarily, as hoards are by their nature, limited. And, on the other hand, sustained purchases for hoarding may well be a market-supporting factor.

S T R O N T I U M

(NOTE: The following data are derived from MFP '65, with most recent data of 1963. The other available sources do not deal with strontium at all).

The principal strontium minerals are Celestite (SrSO_4) and strontianite (SrCO_3), of which there are large reserves in the U. S. A. As the market is small, and the cost of preparing the mineral for market and the cost of transportation is high, U. S. producers cannot compete with minerals supplied from Britain and Mexico.

U. S. imports were about 16,000 tons, worth \$370,000 in 1963.

To be of commercial value, Celestite must contain 56.4% strontium oxide. Strontianite contains 70.1% strontium oxide, but it is less abundant and often occurs with celestite.

USES

Celestite and strontianite minerals are used as such, as are strontium metal and alloys, but the greatest use is in the form of strontium compounds.

Principal use of strontium is for ammunition and pyrotechnical purposes. Strontium carbonate is used in ceramics, compounds in medicine, chemicals, optics.

There are no satisfactory substitutes for strontium compounds.

POTENTIAL

It is not possible to suggest the potential for strontium on the basis of available data. It would seem that reserves are abundant and that the main problem lies in recovering, beneficiating and refining of the minerals involved.

S U L P H U R

World consumption of sulphur has been increasing very rapidly in recent years. While before 1963 world demand increased at an annual rate of between 4 and 5%, since 1963 annual consumption jumped ahead at a rate of 8% and reached 27,600,000 tons in 1968, and will be about 30,000,000 tons in 1969 according to estimates.

While production could not keep up with demand from 1963 to 1967, inclusive, it is estimated that 1968 production matches demand and that by 1970 most of the tension in the market will be eliminated by increased production facilities.

Canada, after having been a net importer of sulphur up to 1960, has increased its production very substantially, accounting for over 10% of world production and taking thus second place only behind the U. S. A.

Total value of Canadian output is roughly \$80,000,000 for 3,000,000 tons, of which about 2,000,000 tons are exported for a value of about \$60,000,000.

PRICES

Prices have been very attractive from producers' point of view and increased almost 40% in recent years. Since production is catching up with demand, contracts between producers and buyers for 1969 provide for somewhat lower prices than in 1968, when sulphur sold - depending on specifications - at between \$41 and \$44 a ton, f. o. b. Vancouver.

(These prices are still about 35% higher than at the end of 1967).

POTENTIAL

The potential for marketing sulphur and sulphuric acid would follow from:

1. the rapidly increasing demand at a rate of 8% per year, consumption would double every nine years.
2. the proximity of the world's largest consumer, the U. S. A. while Canada's own consumption is also substantial.

TUNGSTEN (W)

1. The specific properties on which the usefulness of tungsten is based are

1. its high melting point, 6, 170°F, the highest of any metal
2. its extreme hardness, which it retains even under high temperatures

It is therefore used:

1. as a structural material in nuclear and space applications
2. in lighting and other electrical applications (as W-metal)
3. as tungsten carbide in metal-shaping tools, rock bits, etc. where resistance to wear is required.

Current research is directed towards development of tungsten coatings and alloys in order to make use of the properties of tungsten in reactor and aeronautical structures.

2. MINERALS

Of the many tungsten-bearing minerals only six are of commercial importance and these six can be classified in two groups:

I Calcium tungstates, including:

- a. = Scheelite (CaWO_4), or calcium tungstate proper, which is by far the most important. Commercially a 63.9% tungsten content is required.
- b. = Powellite or calcium tungsto-molybdate ($\text{Ca}(\text{Mo}, \text{W})\text{O}_4$) for which tungsten content is not fixed.
- c. = Cuprotungstite or copper tungstate, requiring 45% tungsten content.

II Iron Manganese tungstates,

containing from 20 - 80% iron and from 80 to 20% manganese. Included are:

- a. Ferberite or iron tungstate; commercially required tungsten content: 60.6%.
- b. Wolframite or iron-manganese tungstate; W-content required: 60.6 - 60.7%
- c. Huebnerite or manganese tungstate, requiring 60.7% W-content.

3. GRADING, SPECIFICATION

The grading and specification is by tungsten-trioxide (WO_3) content. Hence, concentrates are specified and quoted by short-ton units of WO_3 . One short-ton unit is equal to 1% WO_3 -content = 20 pounds, which contains 15.862 lb. of W-metal.

(Sometimes long tons or metric tons are used, in which case a unit equals 22.4 or 22.046 lb. of WO_3).

4. BY - AND CO - PRODUCTS, ETC.

Most ores from which tungsten is produced contain less than 0.5% of WO_3 , hence economical methods of beneficiation and concentration are very important. Almost all tungsten produced in the U. S. A. is a by-product of molybdenum.

While tin and molybdenum are the most important by-products of tungsten mining, tin and molybdenum mines most often produce tungsten as a by-product.

Synthetic Scheelite can be produced from low-grade tungsten concentrates. This product, if nodulized, is ideal for steel-making purposes (alloys).

For many purposes molybdenum can be used as a substitute for tungsten, and vice-versa.

5. USES

The major uses of tungsten and its concentrates are as follows:

1. in alloys, mainly steel alloys

(the U. S. A. uses about 40% of its total

W-consumption for this purpose, Canada also 40%).

2. in carbides

(U. S. A. 40%, Canada 55%).

3. as a (pure or substantially pure) metal

(U. S. A. - 19%, Canada 2%).

4. in various chemical compounds

(U. S. A. 1%, Canada 3%).

6. PRODUCTION AND CONSUMPTION

World output in 1968 is estimated at about 62,000,000 pounds of contained tungsten, of which the free world accounted for about 25,000,000 lbs., China, Russia and Korea for most of the balance. U. S. production was just over 8,000,000 lbs., its consumption is estimated at about 18,000,000 lbs. Canada's output of about 525,000 lbs. compares with a consumption of about 950,000 lbs. Hence both the U. S. and Canada are substantially dependent on imports.

The only West European country with a substantial output (almost 5,000,000 lbs.) is Portugal. West European consumption is about 10,000,000 lbs.

The U. S., Canada, and Western Europe account for about 95% of free-world consumption, and for little more than 20% of free-world output.

7. PRICES

Average annual prices per short-ton unit of contained WO_3 in the U. S. A. have fluctuated as follows:

(f.o.b. U. S. mines):

1925: \$15.00

1940's: about \$20.00

1950's: about \$60.00 (government stockpiles)

1960-63: about \$20.00 (low price) (caused by Chinese dumping on world on world markets, which remains an important factor)

Since 1967 and continuing into 1969, prices have been as follows:

(in U. S. \$\$, c.i.f. U. S. ports)

1. TUNGSTEN ORES & CONCENTRATES:

per short ton unit of WO_3 content, based on 65% WO_3 content:

= WOLFRAM \$43.00

= SCHEELITE \$43.00

These prices include about \$7.93 for duty. (The tariff will be reduced in steps to \$3.97 in 1972, under the "Kennedy Round").

In 1967 about 6,500,000 lbs. were sold from U. S. government stockpiles.

2. TUNGSTEN METAL:

98.8 minimum purity,

per lb. in 1000 lb. lots \$2.75

99.99% pure (hydrogen - reduced) \$4.60 to \$5.44

3. FERROTUNGSTEN:

per lb. contained W,

based on 70 - 80% content \$3.00

(Included duties per lb. of W. of 50¢, which by 1972 will have been reduced to 25¢).

It is expected that these prices will be maintained, provided China will not again engage in dumping.

8. ASSESSMENT OF POTENTIAL

The following factors would indicate a potential for the marketing of tungsten and tungsten concentrates:

1. The low output/consumption ratio in the U. S. A., Canada, and Western Europe. This ratio is at best 50 - 55%, reflecting a dependence on imports from other parts of the world for roughly 15,000,000 lbs., the value of which is conservatively estimated at \$40,000,000.00.
2. The high rate of expansion in the industries using tungsten, which rate is at least 5% per annum, so that demand would double approximately every 15 years.

While at present price levels free world consumption is roughly \$80,000,000 this would be \$160,000,000 by 1985 and \$320,000,000 by the end of this century.

3. Recent developments in the steel industry tend to increase (relatively) the demand for nodulized ferro-tungsten, for which low-grade ores and/or concentrates can be used.

4. There are two factors which may considerably affect market conditions:

a. China's marketing policies

(Whenever China needs foreign currency in excess of its normal receipts, for instance to buy western wheat, chances are it will use amongst other means sales of tungsten to earn such foreign currency).

b. U. S. stockpiling policies

which depend largely on the international political situation. (In 1956 purchases of tungsten for stockpiling purposes were stopped, and substantial quantities were, since 1956, sold out of stockpiles.)

5. United States known reserves are, at present prices, all sub-marginal, except where tungsten can be produced as a by- or co-product.

Present import requirements of the U. S. are roughly 10,000,000 lbs. per annum, while Canada's are roughly 500,000 lbs.

As far as the U. S. are concerned, economic factors favour imports over domestic production.

Z I N C

PRODUCTION AND CONSUMPTION

Consumption of zinc is rising at a faster rate than output, although so far mine production in the free world has covered demand. In 1968 production was 3,936,000 tons, consumption 3,727,000 tons.

European consumption of 1,365,000 tons is roughly 700,000 tons more than its mine production, while U. S. consumption of 1,260,000 tons is 735,000 tons in excess of production. Canadian production at 1,250,000 tons is almost eleven times its consumption.

PRICE

The price of zinc has been relatively constant in the last five years, but rose slightly in 1968 and is, at present, 14¢ (U. S.) a pound (about 15¢ Canadian).

ASSESSMENT OF POTENTIAL

The potential for marketing more zinc would be supported by the following facts:

1. The U. S. and European markets can absorb close to 1,500,000 tons per year. In addition, the demand in Asian, African and South American countries is increasing rapidly, while the excess of their output over consumption is diminishing rapidly also.

2. Canada's excess of output over consumption is about 500,000 tons less than the free world's excess of consumption over output.

3. In addition, the Canadian economy could benefit by a greater degree of processing ores and concentrates as about 70% of Canada's exports are in ores and concentrates.