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# Tectonic Evolution and Mineral Deposits of the Northern Appalachians in Southern New Brunswick

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# TECTONIC EVOLUTION AND MINERAL DEPOSITS OF THE NORTHERN APPALACHIANS IN SOUTHERN NEW BRUNSWICK

## INTRODUCTION

The complex tectonic history of the Northern Appalachians, in Southern New Brunswick, is reflected in a great variety of mineral deposits, which occur in several distinct belts. In general, the field trip emphasizes contrasting geologic environments and structures as related to metallization (Fig. 1).

## CALEDONIA BELT

The oldest rocks containing sulphide deposits of economic interest occur in the Caledonia Belt (Fig. 2), which extends for about 160 kilometers along the Bay of Fundy Coast, in Southern New Brunswick. This area is mainly underlain by late Precambrian volcanic and sedimentary rocks (Coldbrook Group), in part overlain by Cambrian, possible Silurian and Carboniferous sedimentary and minor volcanic rocks. The Coldbrook Group consists mainly of andesitic, dacitic and rhyolitic flows, tuffs and breccias, which have been intruded by granitic, dioritic and gabbroic plutons. In the southeastern part of the belt, arkosic and quartzitic clastic sedimentary rocks (shallow water environment) are intercalated with the lower part of the volcanic sequence, whereas poorly sorted volcanogenic sedimentary rocks are abundant higher in the section. Volcanic flows and ignimbrites (terrestrial) predominate in the northwestern part of the belt.

The Coldbrook Group in the Loch Alva – Kingston Peninsula area (Kennebecasis Deformed Zone), adjacent to the Palaeozoic Mascarene-Nerepis Belt (see next section) have been subjected to intense polyphase deformation probably during the Acadian (Middle Devonian) Orogeny (Ruitenberg **et al.**, 1973). Late Precambrian and Early Carboniferous (and/or Late Devonian) rocks in a broad belt, along the Bay of Fundy, have been deformed by intense cataclasis (Fundy Cataclastic Zone). This deformed zone conforms roughly to a northeast trending upwarped belt, defined by a well developed penetrative cleavage. Effects of at least one, and locally two, subsequent deformation phases have been re-

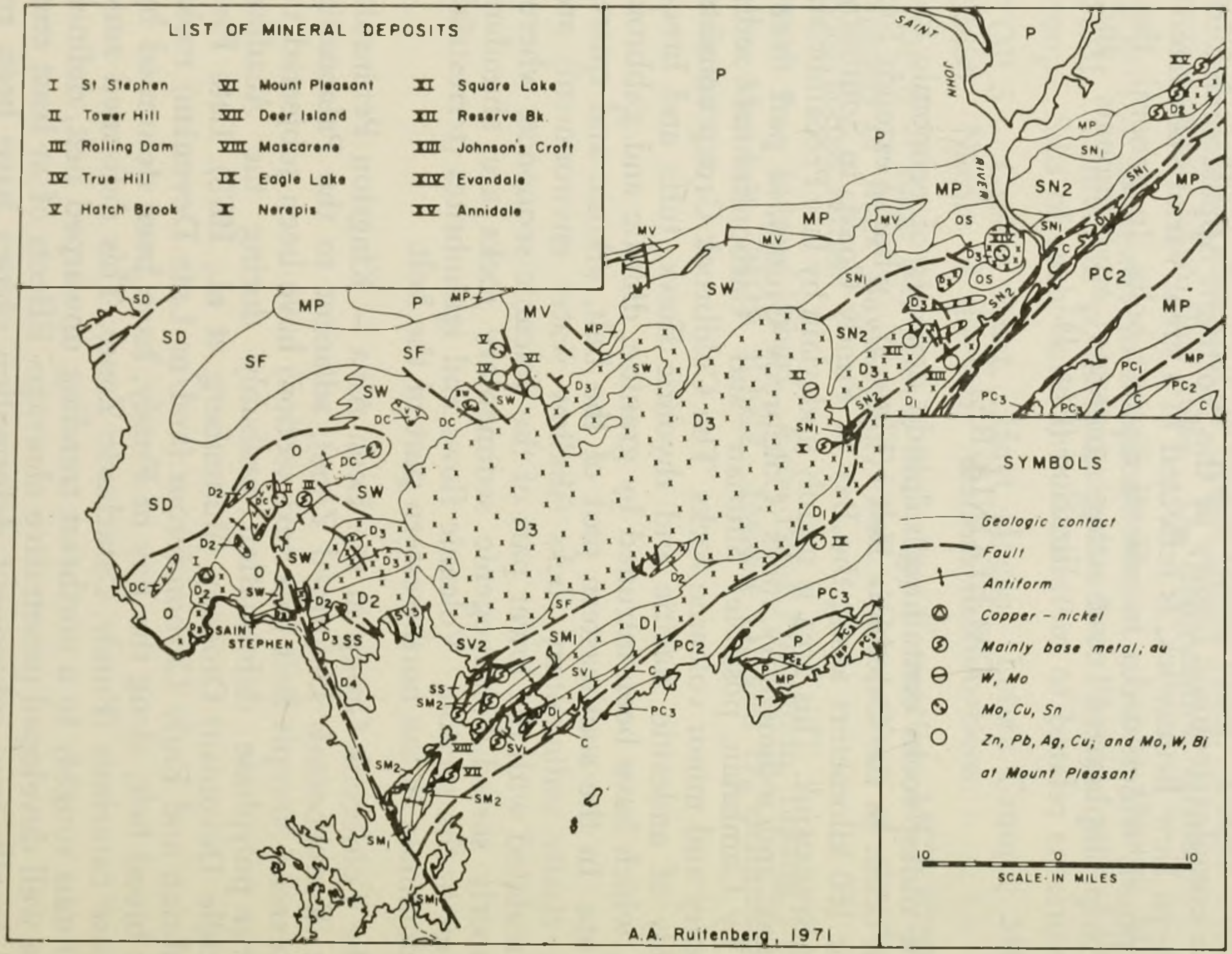
LIST OF MINERAL DEPOSITS
I St Stephen
II Tower Hill
III Rolling Dam
IV True Hill
V Hatch Brook
VI Mount Pleasant
VII Deer Island
VIII Mascarene
IX Eagle Lake
X Nerepis
XI Square Lake
XII Reserve Bk.
XIII Johnson's Croft
XIV Evandale
XV Annidale
SAINT JOHN RIVER
SAINT STEPHEN
SYMBOLS
Geologic contact
Fault
Antiform
Copper – nickel
Mainly base metal, au
W, Mo
Mo, Cu, Sn
Zn, Pb, Ag, Cu; and Mo, W, Bi at Mount Pleasant
10 0 10
SCALE-IN MILES
A.A. Ruitenberg, 1971
TRIASSIC
T Conglomerate, sandstone
PENNSYLVANIAN
P Conglomerate, sandstone, shale
MISSISSIPPIAN AND/OR PENNSYLVANIAN
MP Conglomerate, sandstone, shale
MISSISSIPPIAN
MV Minor Permian volcanic rocks
LATE DEVONIAN TO CARBONIFEROUS
DC Devil Mountain
LATE DEVONIAN
D4 Sandstone, conglomerate, minor volcanic rocks
MIDDLE DEVONIAN
D3 St George Batholith
DEVONIAN AND EARLIER
D2 St Stephen mafic intrusion
D1 Deformed granite and rocks
UPPER SILURIAN AND LOWER DEVONIAN
SF FLUME RIDGE FORMATION
SS Mainly red calcareous sedimentary rocks, minor volcanic rocks
SV SV3 - Felsic pyroclastic rocks
SV2 - Mafic, minor felsic volcanic rocks
SV1 - Felsic, minor mafic volcanic rocks
SM SM1 Mascarene Group 1
SM2 Mascarene Group 2
SM1 Nerepis Group 1
SM2 Nerepis Group 2
SD SD - DINGEQUASH FORMATION
SM - MARIS FORMATION
ORDOVICIAN
O COOKSON FORMATION
ORDOVICIAN OR SILURIAN
OS Slate, siltstone
CAMBRIAN
C Arenaceous and argillaceous sedimentary rocks
PRECAMBRIAN OR EARLY PALAEOZOIC
PC3 Granite and related plutonic rocks
PC2 Mainly mafic and ultramafic volcanic rocks
PRECAMBRIAN
PC1 Gneissose and migmatoses metasediments

Fig. 1

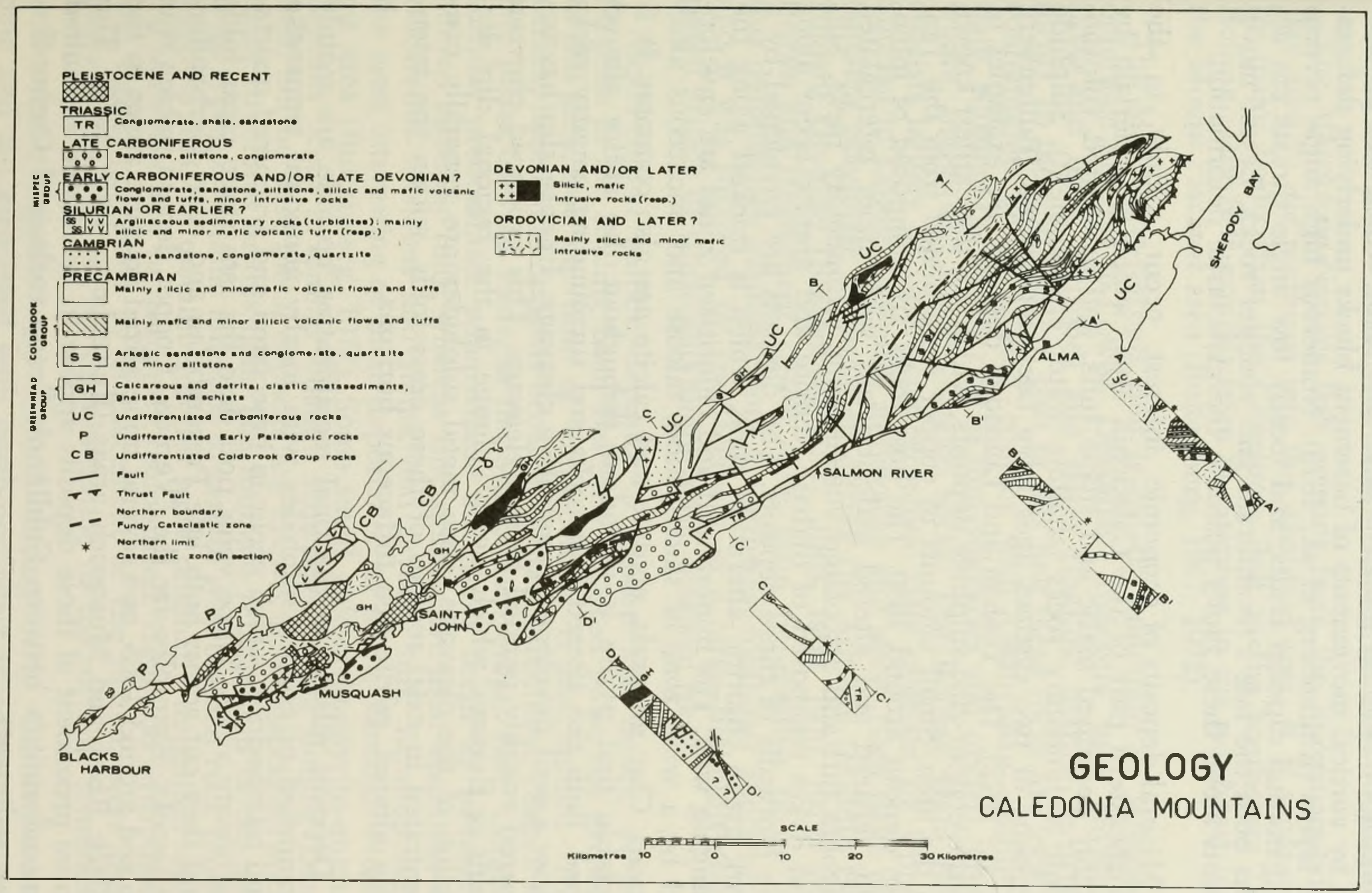
PLEISTOCENE AND RECENT
TRIASSIC
TR Conglomerate, shale, sandstone
LATE CARBONIFEROUS
Sandstone, siltstone, conglomerate
MISPEC GROUP
EARLY CARBONIFEROUS AND/OR LATE DEVONIAN?
Conglomerate, sandstone, siltstone, silicic and mafic volcanic flows and tuffs, minor intrusive rocks
SILURIAN OR EARLIER?
Argillaceous sedimentary rocks (turbidites); mainly silicic and minor mafic volcanic tuffs (resp.)
CAMBRIAN
Shale, sandstone, conglomerate, quartzite
PRECAMBRIAN
Mainly silicic and minor mafic volcanic flows and tuffs
COLDBROOK GROUP
Mainly mafic and minor silicic volcanic flows and tuffs
S S Arkosic sandstone and conglomerate, quartzite and minor siltstone
GREENHEAD GROUP
GH Calcareous and detrital clastic metasediments, gneisses and schists
UC Undifferentiated Carboniferous rocks
P Undifferentiated Early Palaeozoic rocks
CB Undifferentiated Coldbrook Group rocks
Fault
Thrust Fault
Northern boundary Fundy Cataclastic zone
Northern limit Cataclastic zone (in section)
DEVONIAN AND/OR LATER
Silicic, mafic intrusive rocks (resp.)
ORDOVICIAN AND LATER?
Mainly silicic and minor mafic intrusive rocks
SHEPODY BAY
ALMA
SALMON RIVER
SAINT JOHN
MUSQUASH
BLACKS HARBOUR
SCALE
Kilometres 10 0 10 20 30 Kilometres
GEOLOGY
CALEDONIA MOUNTAINS

**Fig. 2**

cognized. The penetrative deformation probably resulted from upwarping or bending (under a lithostatic load), which was produced by vertical movements of basement blocks underlying deformed layers (Ruitenberg et al., 1973). Numerous high angle reverse and normal dip-slip faults, and locally low angle thrusts cut across both the late Precambrian and younger rocks. Latest movements along these faults postdate the cataclastic deformation.

Mineral deposits of economic interest occur mainly in the southeastern part of the Caledonia area, which is underlain by highly deformed mafic and silicic tuffs, and associated volcanogenic sedimentary rocks (shallow water environment). Sulphide deposits of two distinct ages have been recognized (Ruitenberg et al., 1972). The Teahan and Lumsden deposits are examples of pyrite-copper-zinc sulphide deposits, which are the earliest known in the area. Small amounts of copper were mined from the Teahan deposit around 1880. The host rocks are composed of intensely sheared and altered andesitic tuff with minor intercalated rhyolite tuff and associated volcanogenic sedimentary rocks. Sills and dykes composed of diabase, diorite and granite occur along the footwalls of these deposits. The deposits are enveloped by a dark green chloritic alteration zone, which is thickest along the hanging wall. The mineralized and chloritized zones are enveloped by a wide zone of silicification, talcose and micaceous alterations. Clay minerals, epidote and calcite are also common. It is notable that pyrite is abundant throughout the entire altered zone. Both the altered host rocks and surrounding country rocks show a well developed penetrative cleavage. Intense slip has occurred roughly parallel to this cleavage. This produced chevron folds or flexures, which mostly plunge in the regional dip direction of the cleavage. Base metal sulphides are generally concentrated in axial regions of these cross folds, within the intensely altered, pyrite-rich tuffaceous horizons.

Deposits related to the final metallization episode are mainly composed of copper sulphides with locally abundant tennantite and tetrahedrite, which occur in brecciated and fractured quartz-carbonate veins. These veins post date the late stage cross folds and they cut across both late Precambrian and early Carboniferous rocks. Examples are the "Vernon" Copper deposit, which was mined around 1865, and several mineralized fracture zones in the Black River and Musquash areas (Ruitenberg, 1969, 1970). The more prominent of these deposits appear to be related to faulted unconformities between Coldbrook Group rocks and Carboniferous sediments.

## MASCARENE – NEREPIS AND ROLLING DAM BELTS

The Mascarene-Nerepis Belt extends from the Passamaquoddy Bay area to the northeast into the Annidale area. It is separated by major faults from the Caledonia Belt to the southeast. The Rolling Dam Belt extends from St. Stephen to the northeast into the Mount Pleasant area (Ruitenberg, 1967, 1972).

The Mascarene-Nerepis Belt is chiefly underlain by intensely deformed Silurian to Lower Devonian andesitic and rhyolitic flows and tuffs, siltstones and slates (shallow marine environment). In the northeastern part of this belt these rocks are locally conformable or in faulted contact with Ordovician graphitic slate, siltstone (generally rich in iron sulphides and oxides), greywacke, mafic and silicic volcanic rocks. The Rolling Dam Belt consists largely of Ordovician graphitic slate overlain by Upper Silurian to Lower Devonian greywacke and slate. Both belts underwent polyphase deformation during the Acadian (Middle Devonian) Orogeny (Ruitenberg, 1967, 1968, 1969, 1970, 1972) and Brown and Helmstaedt (1970). The main penetrative phase of this deformation resulted from a northwest-southeast shortening and it was followed by emplacement of a large batholith composed mainly of silicic and minor mafic plutonic rocks.

Nickel-copper sulfide deposits in gabbro and norite, at St. Stephen in the Rolling Dam Belt, are believed to be the earliest in this area, but the time of emplacement is not certain. The earliest base metal deposits occur in dilatant structures, related to late phase chevron folds, in the Mascarene-Nerepis Belt. Copper sulfides predominate where these structures occur in intensely altered andesitic tuffs, whereas zinc sulfides are most abundant in calcareous siltstones and slates, and rhyolite tuff. Economically the most interesting of these deposits occur in the Annidale-Nerepis area (Ruitenberg, 1972). Some small gold-arsenopyrite-quartz deposits occur in similar dilatant structures in the Rolling Dam Belt, but no base metal deposits are known to be associated with these structures in this belt. The intimate relationship of the various types of metallic minerals to certain well defined rock types, suggests that the metallic sulfides were originally deposited with the hostrocks and subsequently remobilized. Heat and hydrothermal fluids, generated by emplacement of the pluton, were probably responsible for the remobilization of the metallic minerals.

The latest deposits were formed during early Carboniferous time and are associated with north-northwest trending zones of intense wrench and block faulting (rifts), close to the contact of

the major batholith. The base metal tin-tungsten-molybdenum deposits at Mount Pleasant are the largest known of these deposits and occur in intensely fractured and silicified rhyolitic fragmental rocks (Ruitenberg, 1967, 1972; Parrish and Tully, 1971). Numerous smaller tin, silver-base metal and copper-molybdenum deposits occur in and along silicic stocks and dykes, which were emplaced during this period.

## MONCTON – SUSSEX BELT

Numerous interesting mineral deposits occur in Carboniferous rocks of southeastern New Brunswick. Limited time available for this field trip does not permit intensive examination of the geologic environment of these deposits. The following is a brief resume.

Gypsum has been produced at Hillsborough for many years. Limestone is being quarried at Havelock. Great thicknesses of salt and potash have been intersected by diamond drilling in the Penobsquis-Plumweseep areas near Sussex. Economically interesting amounts of celestite and barite have been discovered at Upper Dorchester. Albertite (solid asphalt) was formerly mined at Albert Mines. The Stony Creek oil field is situated about five miles north of this occurrence.

The most interesting metallic mineral deposits are cupriferous (chalcocite and malachite) sandstones in the Dorchester, New Horton and Goshen areas. These deposits appear to be associated with the first grey (channel) sandstone sequence overlying Hopewell red beds (van de Poll, 1973).

## SCHEDULE AND DIRECTIONS

*October 11:*

P.M.

(1) **Lecture Tectonic History and Mineral Deposits, Northern Appalachians** in Southern New Brunswick, Hopewell Rocks Motel, 8 P.M.

(2) The itinerary can be modified to meet specific interests of participants.

*October 12:*

A.M.

(1) Albert Mines – brief stop at albertite occurrence and nearby outcrop with numerous palaeoniscid fish skeletons first discovered by Greiner (1961).

(2) Old Teahan Mine — intensely altered and mineralized rocks at the old mine site will be compared with nearby country rocks. Effects of penetrative deformation and subsequent deformation will be demonstrated.

(3) Bennett Lake — rhyolitic and andesitic tuffs of the Coldbrook Group are well exposed along Highway 114 in this area. The well developed penetrative cleavage in these rocks was produced by intense cataclasis (Fundy Cataclastic Zone). The well developed crenulation cleavage resulted from a second deformation.

P.M.

(4) Old Annidale Copper Mine — Effects of cross-folding on the distribution of copper sulphides in andesite tuffs will be demonstrated. It is notable that pyrite-rich slates on the footwall of the deposit have been similarly deformed, but contain no copper sulphides.

*October 13:*

A.M.

(5) Black River — sedimentary and volcanic rocks of the Mispec Group (Early Carboniferous or Late Devonian) are to the north in faulted contact with Coldbrook (Late Precambrian) volcanics. These rocks form part of the Fundy Cataclastic Zone and have been affected by two phases of deformation. An interesting occurrence of copper sulphides is exposed in fractured Mispec rocks close to this faulted contact. Further north in this section, deformed Coldbrook rocks have been thrust over sedimentary rocks of possible Silurian age, which show no effects of penetrative deformation.

A.M. – P.M.

(6) Mount Pleasant — Cross-cutting relationships of various rock types in this volcanic complex will be examined. Effects of several metallization and alteration phases will be shown.

P.M.

(7) Digdeguash River at Rolling Dam (7a) and Tryon (7b) Typical Ordovician and Upper Silurian — Lower Devonian facies will be compared. Effects of polyphase Acadian (Middle Devonian) deformation on various lithologies will be demonstrated.