Geology of the Loch Lomond Basin and Glengarry Half Graben, Richmond and Cape Breton Counties, Cape Breton Island, Nova Scotia

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Abstract

The Loch Lomond Basin and Glengarry Half Graben are Carboniferous structural basins containing up to 2000 m (stratigraphic thickness) of continental and marine sedimentary rocks. The basins are located in southeastern Cape Breton Island and although they are given separate names, they are genetically related and spatially connected. The basin fill ranges in age from Early Carboniferous (middle Viséan) to Late Carboniferous (Westphalian C-D) and overlies Hadrynian to Devonian metasedimentary and igneous rocks with angular unconformity. The basin fill progressively onlaps basement rocks along the southeastern border, formed by the Fourchu Block or Mira Hills. The northeastern border is the contact of the Lennox Passage Fault with the East Bay Hills (Block). The L'Ardoise Block, comprising an undivided Devono-Carboniferous succession of sandstone, shale and conglomerate overlain by the Viséan Macumber Formation (basal Windsor Group), forms the western border of the Loch Lomond Basin and appears to be allochthonous to the area. In their present configuration, the Loch Lomond Basin and Glengarry Half Graben are structural half grabens apparently preserved by the latest movement (Late Carboniferous or younger) on the Lennox Passage Fault.

The oldest autochthonous Carboniferous rocks in the area are coarse-grained alluvial strata, probably of Viséan age and equivalent to the upper Horton Group or Major Cycle 1 of the Windsor Group. The oldest autochthonous Windsor Group strata (middle to late Viséan) are correlative with Major Cycle 2 and onlap with profound unconformity a basement landscape characterized by substantial erosional and possible fault relief. The Windsor Group is a major mixed marine evaporite, carbonate and continental redbed package up to 500 m thick and subdivided into three mappable formations: Enon, Loch Lomond and Uist. The Windsor Group contains major mineral deposits including celestite, barite and limestone with numerous occurrences of base metals (Cu, Pb and Zn). The McKeigan Lake Formation of the Mabou (Canso) Group conformably overlies the Windsor Group and comprises up to 150 m of grey mudrock with subordinate gypsum and anhydrite. The Silver Mine Formation, comprising up to 650 m of fluvial sandstone fining upward to mudrock with minor coal, disconformably overlies Windsor and Mabou group strata and onlaps basement. The basal unconformity contact zone is a prominent locus for stratabound mineralization, including the Yava (Silver Mine) lead deposit and the celestite deposit at Enon. The Silver Mine Formation is overlain by the Big Barren Formation, dominated by red polymictic conglomerate, which is succeeded by coal-bearing sandstone and mudrock of the Glengarry Valley Formation. These units of the Cumberland Group were formerly assigned to the Riversdale and Morien groups.

Introduction

The Loch Lomond Basin and Glengarry Half Graben are adjoining Carboniferous structural basins situated in southeastern Cape Breton Island, Nova Scotia (Figs. 1, 2 and 3). The Glengarry Half Graben (after Keppie, 1982) was previously called the Salmon River Basin. Although given separate names as structural entities, the Loch Lomond Basin and Glengarry Half Graben are spatially connected and are closely related genetically. The report area is approximately 175 km^2 and is included on parts of National Topographic System (NTS) map sheets 11F/10 East, 11F/15 East and 11F/16 West, and is bounded approximately by latitudes 45°40' to 46°N and longitudes 60°12.5' to 60°42'W (Fig. 2 and Geological Map 85-2 in pocket). The area is accessible via unpaved roads from Highway 4 connecting St. Peters and Sydney, and Highway 327 south from Sydney to Marion Bridge. A good system of unpaved roads provides easy access to most of the map area.

The rocks described in this report occur principally in a lowland area characterized by gently rolling terrain and elevations rarely exceeding 100 m. This valley area is bordered to the south by the Southeastern Lowlands and to the north by the East Bay Hills. Elevations in the highlands rise abruptly to 200 m. The southeastern border of the basin, although included within the Southeastern Lowlands (Mira Hills or Fourchu Block; Figs. 4 and 5), has greater relief with elevations of up to 150 m. The map area is traversed by two principal drainage systems with a divide (Terra Nova Fault) in the area of the boundary between the Loch Lomond Basin and the Glengarry Half Graben. Grand River drains the Loch Lomond lake system and flows to the southwest. The Salmon River and Gaspereaux River system flows northeast into the Mira River. Although the rivers typically have low profiles there is modest bedrock exposure in the river beds. Tributary streams with steeper profiles, particularly on basement rocks, also have moderate outcrop. Mining activity has recently focused on celestite (Loch Lomond - Enon), barite (Pine Brook), and lead (Silver Mine - Yava). Historically, attempts to exploit coal and manganese deposits have generally met with limited success or with failure. There are no currently active mines in the area.

The Carboniferous basins of Nova Scotia have had a long history of exploration for coal, petroleum, and industrial and metallic minerals. These basins are a primary or exclusive source for a variety of economically important metallic and non-metallic minerals including lead, zinc, gypsum, anhydrite, salt, limestone, dolomite, coal, barite and celestite. Production from Carboniferous rocks is the dominant component of the mineral industry in Nova Scotia. The Loch Lomond Basin and Glengarry Half Graben are two of many Carboniferous outcrop areas, others include the Shubenacadie and Musquodoboit basins (Giles and Boehner, 1979, 1982a), the Eureka area (Giles, 1982), Antigonish Basin (Boehner and Giles, 1982, 1992), Sydney Basin (Boehner and Giles, 1986) and Cumberland Basin (Ryan *et al.*, 1990). All these areas have been investigated as part of a Carboniferous basin mapping program by the Nova Scotia Department of Mines and Energy (now Natural Resources). A large volume of subsurface data, principally from more than 1000 diamond-drill holes drilled by the mineral exploration industry, has provided the basis for a greater understanding of the geology and mineral potential of the Loch Lomond Basin and Glengarry Half Graben. These mapping studies either coincided with or followed a peak in mineral exploration and benefited from abundant, previously unavailable subsurface data. The Loch Lomond - Glengarry area contains a large number of mineral deposits and occurrences and has high economic potential.

Purpose

The primary goal of this study was to describe the geology of this intensively explored area, in as much detail as practical, using all available outcrop (very limited) and critically important subsurface information from a large number of mineral exploration drillholes. Previous studies in the area were either detailed and restricted to a portion of the basin, or were regional in scale with no subdivision of the major rock units (generally groups). Emphasis in this study was placed upon determining the stratigraphy and structure of the Carboniferous strata and identifying the related mineral deposits. Comparisons and correlations were to be made where possible with

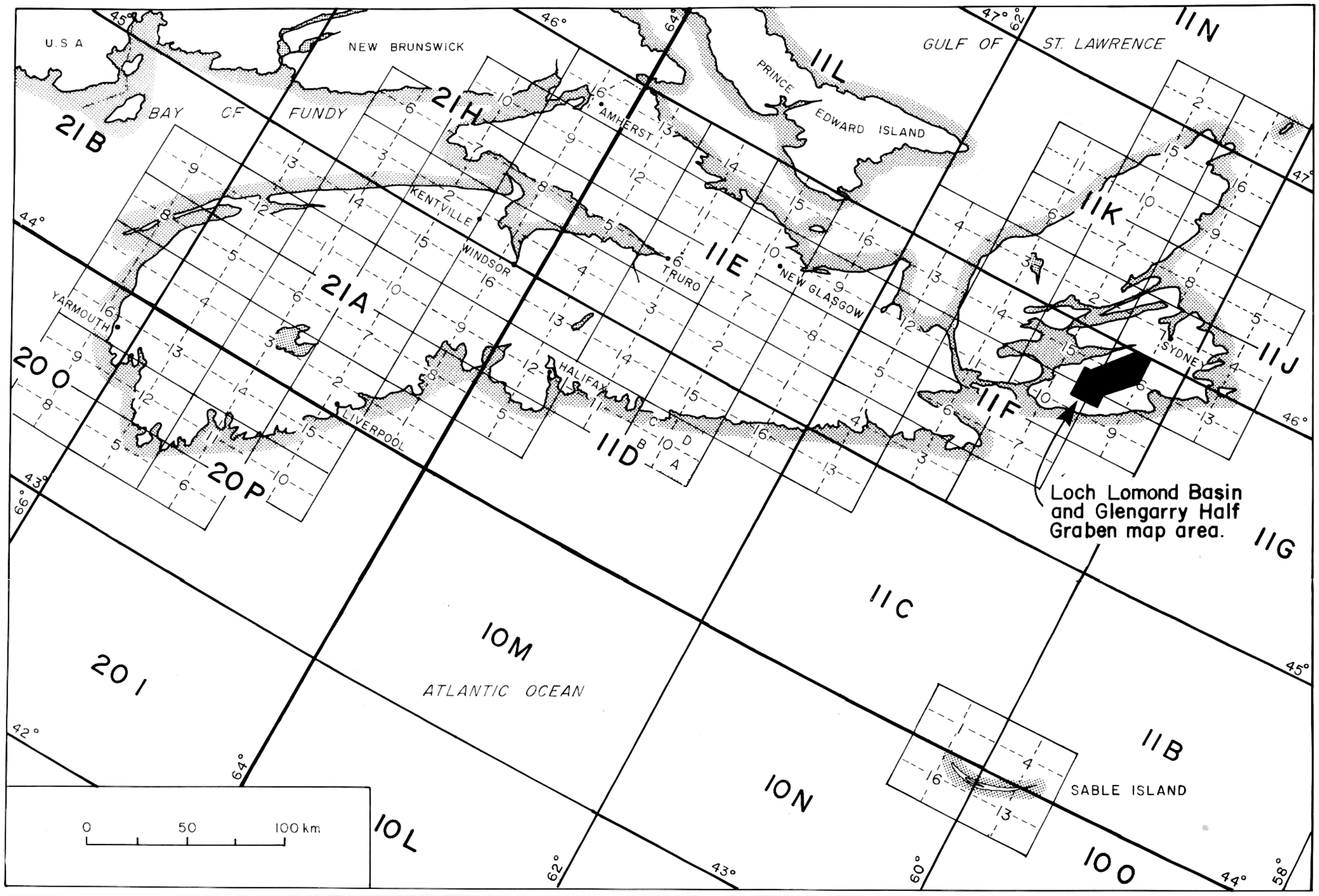

Figure 1. NTS reference map for Nova Scotia showing the Loch Lomond Basin and Glengarry Half Graben map area.

other Carboniferous basins and outcrop areas (e.g. the adjacent Sydney Basin). No attempt was made to examine in detail the pre-Carboniferous rocks, informally considered here as basement to the basin succession and described by Weeks (1954), Smith (1978), Barr *et al.* (1984), McMullin (1984), Macdonald (1989), and Barr and Macdonald (1992). A principal objective was to document the stratigraphic onlap where Windsor Group strata rest on and pinch out against basement rocks. This onlap geology on the pre-Carboniferous erosional landscape coincides with and appears to be genetically important to the localization and concentration of minerals.

Methods

Field mapping and drill core logging were accomplished during the summers of 1982, 1983 and 1984. Traverses were made of all stream and river sections as well as examinations of road cuts and previously reported outcrops. Field data were compiled on field maps at a scale of 1:15 840 (OFR 91-3) for final publication at 1:50 000 (NSDME Map 85-2, in pocket; a simplified version is presented for reference as Fig. 5). All subsurface data from exploration drillholes were compiled, drillhole sections plotted and selected drillholes logged. These data were used to construct drillhole cross-sections which supplement the meagre outcrop information in determining stratigraphy and placement of map unit boundaries.

Acknowledgments

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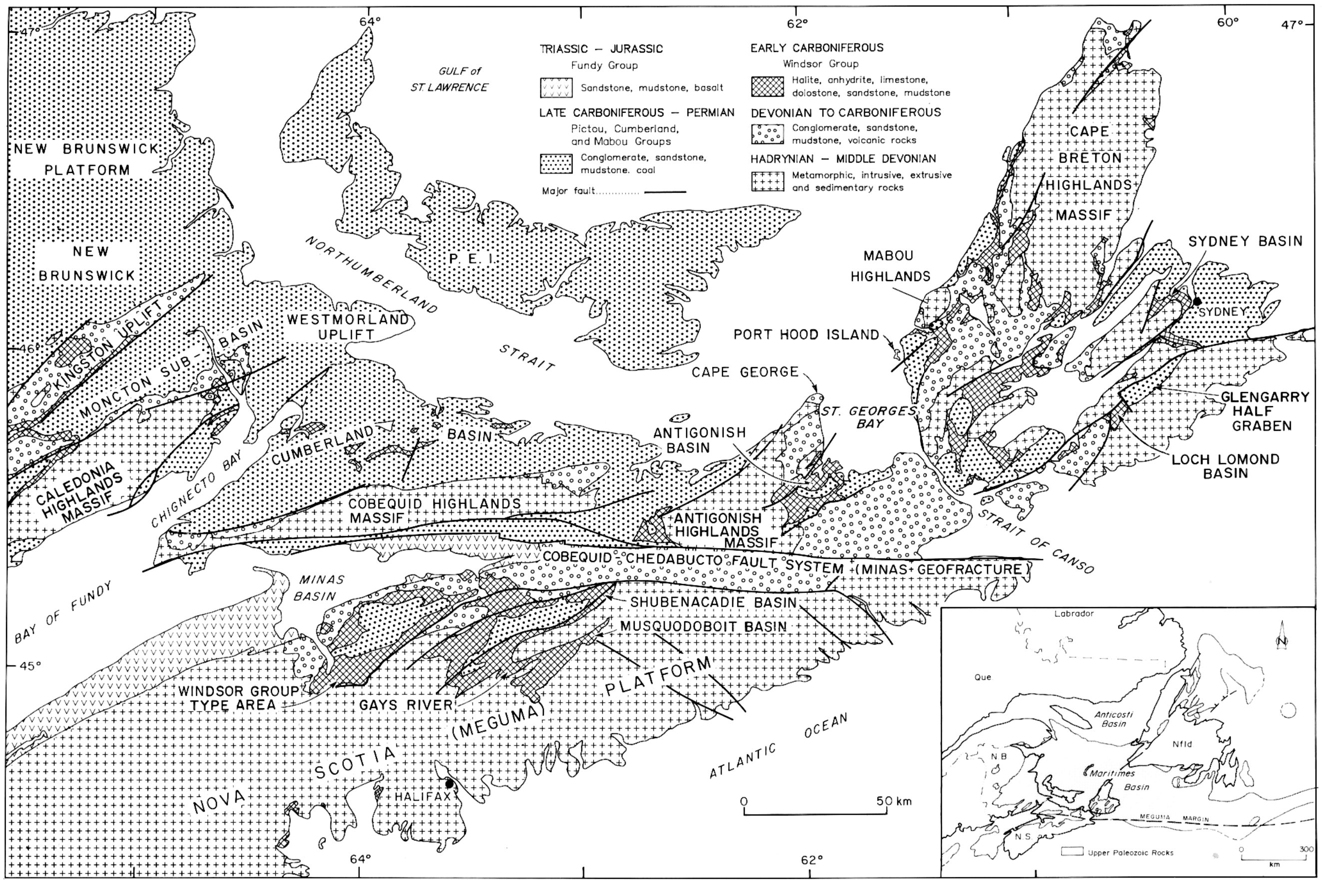

Figure 2. Regional geology and location map.

Please note that several drillholes have been misidentified in the Terra Nova area (TN series) and in the area of Lake Uist (N212 series). Please refer to original identifications located in assessment files.

Identification of spore assemblages used in supporting this project was kindly provided by M. S. Barss and J. Utting of the Geological Survey of Canada and G. Dolby of G. Dolby and Associates, Calgary. The interpretation of these assignments into the lithostratigraphic framework, however, is the responsibility of the authors alone.

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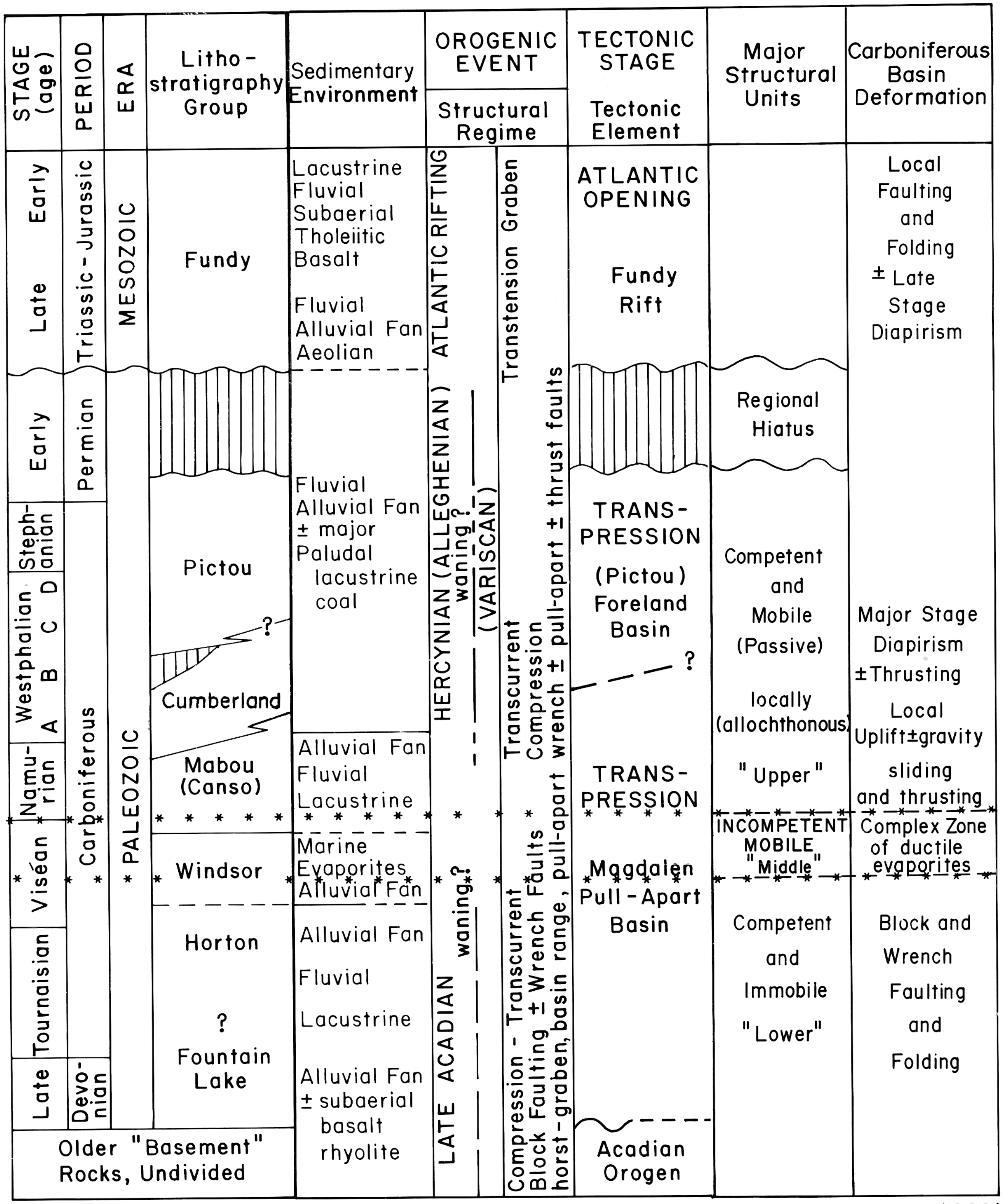
Previous Work

Mineral Exploration and Mining

Mineral occurrences in the Loch Lomond Basin and Glengarry Half Graben area (Fig. 5) have been known for almost a century. In the late 19th and early 20th centuries, mining operations extracted small amounts of manganese along McCuish Brook and coal at Glengarry. In the early 1960s active exploration for base metals by Talisman Mines and Phelps Dodge



adapted from Boehner et al. (1986)

Figure 3. Stratigraphic, tectonic, depositional, and structural summary of late Paleozoic to early Mesozoic rocks in Atlantic Canada.

along the basement basin contact near Silver Mine resulted in the discovery of a substantial sandstone-hosted lead deposit. Beginning in 1962 exploration in the Loch Lomond and Enon area by Lura Corporation located significant celestite mineralization near Enon Lake (Hudgins, 1969). Further exploration and development proceeded and the deposits where put into production by Kaiser Celestite Mining Corporation in 1970. Economic and market conditions forced the premature closure of the mining operation and related chemical plant in Sydney in 1976. Approximately 300 000 tons of ore were produced and excellent summaries of the geology and development history are included in Crowell (1971), Forgeron (1977) and Felderhof (1978).

Specific studies of Windsor Group mineralization in the Enon area were undertaken by Choo (1972) on celestite and Binney (1975) on base metals. Similar studies of the sandstone-hosted lead deposit at Silver Mine where undertaken by Scott (1978), Bonham *et al.* (1982), Bonham (1983) and more recently by Sangster and Vaillancourt (1990a, 1990b). The area was also included in regional base metal distribution studies by Binney and Kirkham (1974), Kirkham (1978), and Smith and Collins (1984).

Since the early 1960s and especially between 1973 and 1980, there has been active exploration for base metal, celestite and barite deposits in the area. Some of the mineral exploration companies involved in those surveys include Phelps Dodge, Gunnex, Kaiser Resources, Cominco, Cuvier, Ranlux Mines, Westfield Minerals, Amax Exploration, Noranda Exploration, Pacific Coast Mines, Imperial Oil Ltd., Barymin, Yava Mines, Novex and Penarroya. These projects generated a vast database of drilling information from more than 1000 drillholes (see DeMont *et al.*, 1986). In addition, two wells were drilled in an ill-fated petroleum exploration program by Corcan Engineering in 1983-1984. The two wildcat wells, North Glen and Loch Lomond, were both dry and abandoned (McMahon *et al.*, 1986). Development drilling in the late 1970s on the west zone of the Silver Mine (Yava) lead deposit was a key factor in putting the deposit into production by Yava Mines in 1979. The lead ore from the Yava Mine was processed between 1979 and 1981 in the refurbished former celestite mill at Enon and lead concentrates were shipped out of Sydney. The operation failed due to low metal prices and high financing costs (Bonham *et al.*, 1982). The most recent mining operation in the area was a small open-pit barite mine at Pine Brook operated during 1983 by Novex Mining and Exploration Ltd. The barite ore was processed in the re-activated former Kaiser-Yava mill at Enon.

Geological Surveys and Stratigraphy

The earliest geological investigations of the area occurred during the mid to late 1800s and were generally of a reconnaissance or exploratory nature. The most significant early observations were reported by Dawson (1868 and later editions). The first systematic mapping and detailed descriptions were included in the reports and maps of Fletcher (1878, 1884, 1887). These maps, at a scale of one inch to one mile, are of particular value in attempting to relocate significant outcrops, as Fletcher carefully located coal, gypsum and limestone indications and outcrops. Previous to NSDME Map 85-2 (in pocket) the basin area was most recently mapped by Weeks (1954, 1955) as part of the Grand Narrows map sheet (NTS 11F/15) and Weeks (1958) as part of the Mira map sheet (NTS 11F/16). Numerous published and unpublished geological reports and maps have also been compiled as the result of extensive exploration activities in the area (e.g. Crowell, 1971; Forgeron, 1977; Scott, 1978; Boehner, 1981, 1983; Keppie, 1982; Macdonald, 1989; Bonham *et al.*, 1982).

Geldsetzer (1977, 1978) made a general study of Windsor Group facies in the area. He placed particular emphasis on relating carbonate buildups to the Macumber - Gays River Formation environment in Cape Breton Island. Shea and Murray (1967) described the limestone and dolomite deposits in the area. Their location maps and descriptions of the deposits are very useful in relocating the stratigraphically important carbonate outcrops. More recently the geology of the carbonate buildups in the area was described in Boehner *et al.* (1988) and Boehner (1987). The lithostratigraphy (Figs. 6, 7 and 8) used herein is based largely upon work by mineral exploration company geologists, including Mudford

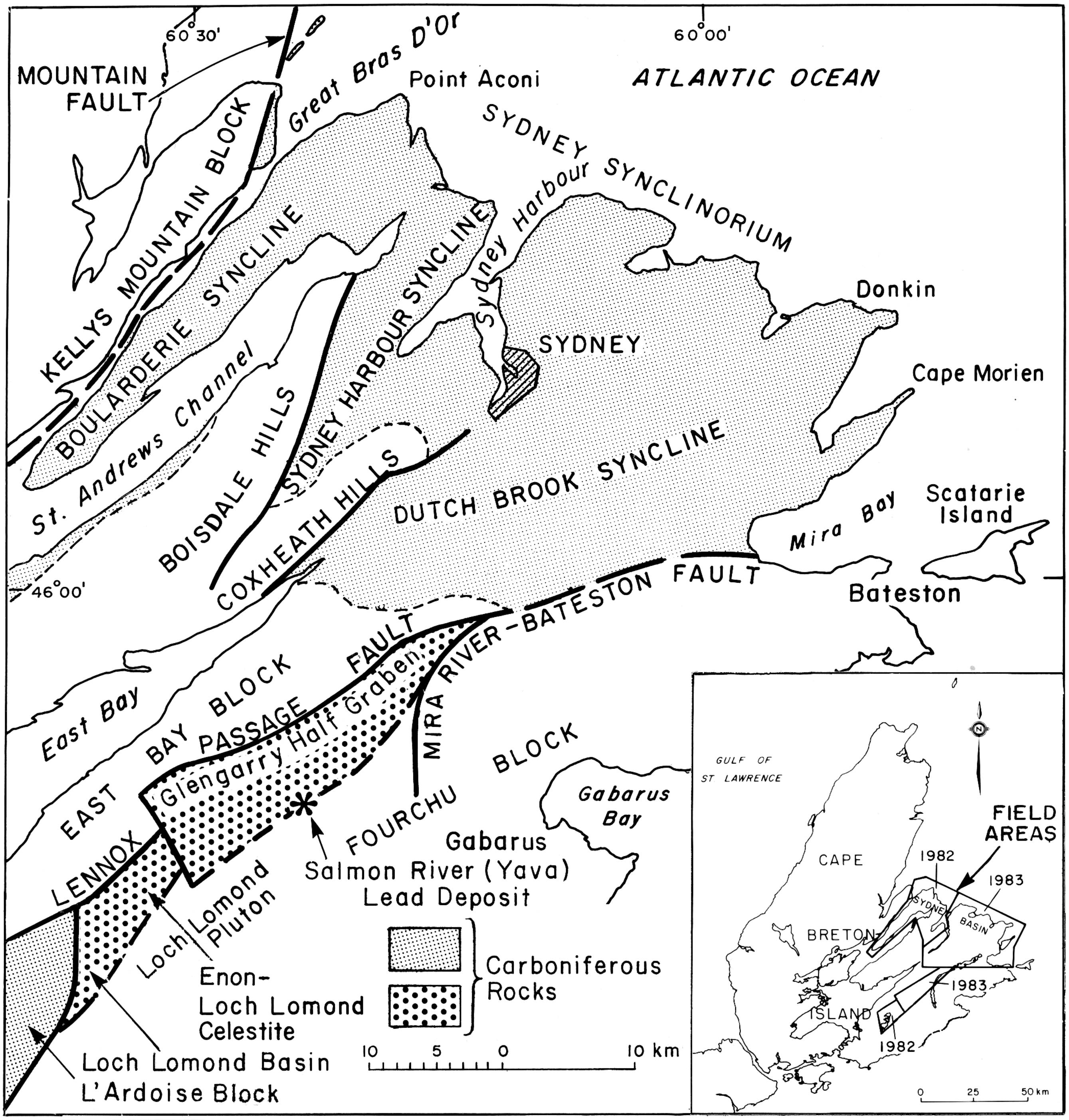


Figure 4. Local general geology and location map.

(1969), Geisler (1963), Solomiac (1968), Hudgins (1969), Crowell (1971) and Forgeron (1977). This work is recorded in mineral assessment reports, Open File Reports and other published reports. Preliminary reports on the results of this study have been previously published by Boehner (1981 and 1983), Prime and Boehner (1984), and Prime (1984). Recent work on the economic geology of the area is included in theses, papers and reports by Binney (1975), Binney and Kirkham (1974), Kirkham (1978), Choo (1972), Felderhof (1978), Scott (1978), Bonham (1983), Smith and Collins (1985), and Sangster and Vaillancourt (1990a and b).

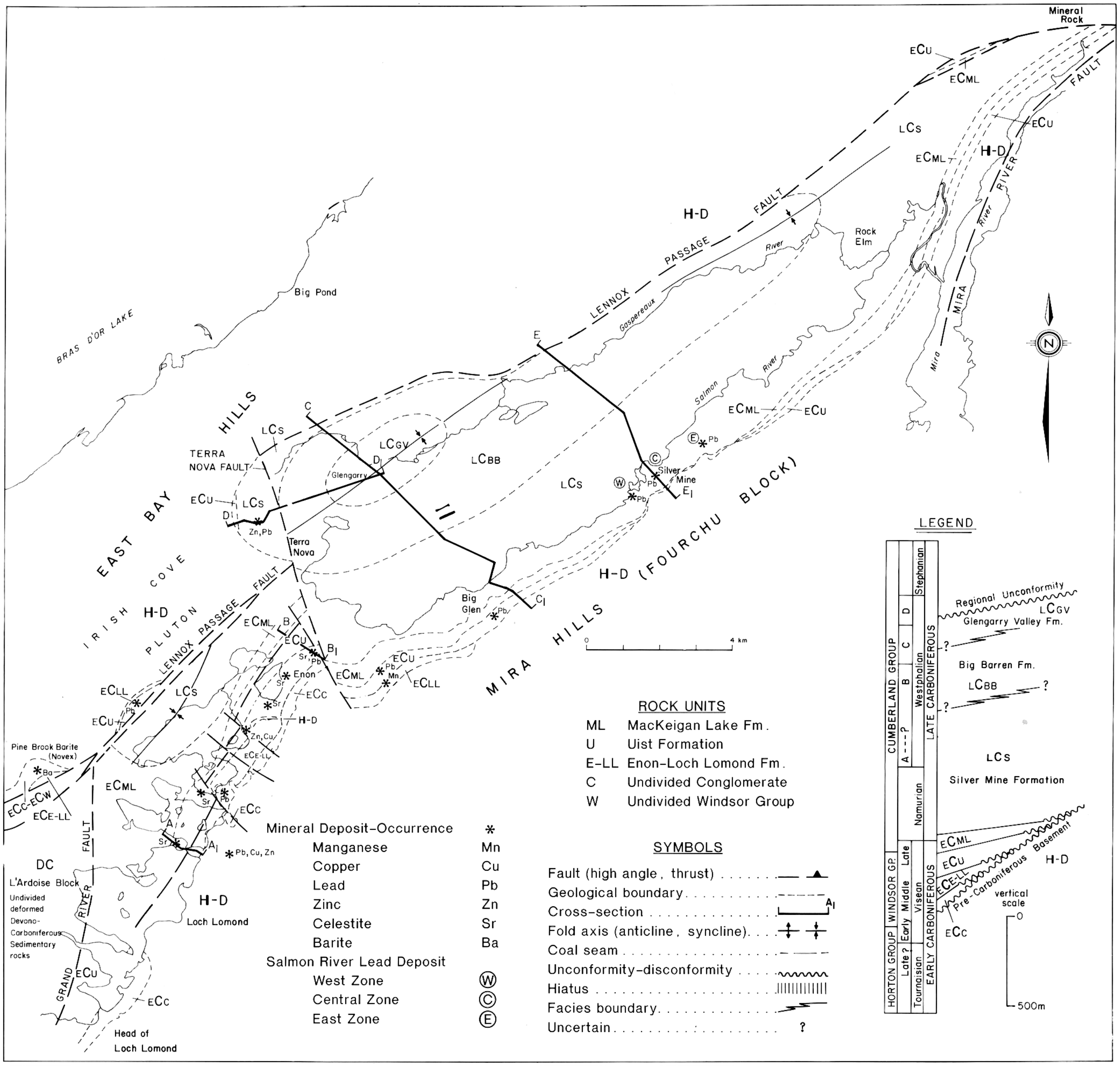


Figure 5. Simplified geological map of the Loch Lomond Basin and Glengarry Half Graben. Cross-sections A-A$_1$ and B-B$_1$ are shown in Figure 12. Cross-sections C-C$_1$, D-D$_1$, and E-E$_1$, are shown in Figure 15.

The stratigraphy of the Carboniferous section above the Windsor Group in Nova Scotia was studied and described by Belt (1964, 1965). Belt (1964) proposed a revised stratigraphic nomenclature that involved dropping the names Canso and Riversdale groups and elevating the Mabou Formation (Norman, 1935) to group status. Various locally-named formations (dominated by red or grey mudrock formerly assigned to the Canso Group and locally the Riversdale Group) were included in the Mabou Group. Although the revised Mabou Group proposed by Belt (1964, 1965) had previously not gained wide usage, it was adopted by Ryan *et al.* (1991) in a related revision of Upper Carboniferous stratigraphy and is adopted in this report.

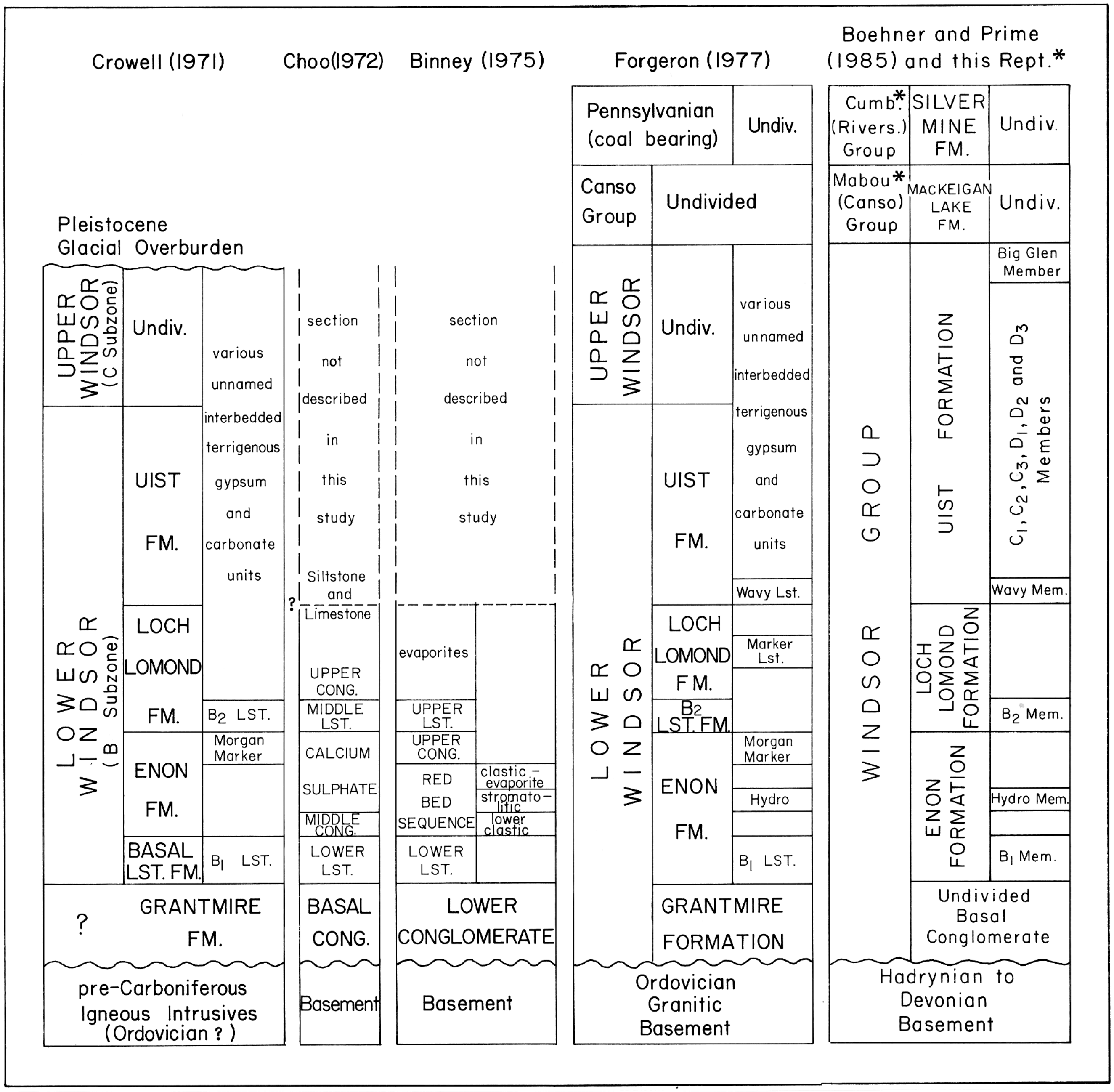


Figure 6. Simplified stratigraphic nomenclature in the Loch Lomond Basin.

Geological Setting

The Loch Lomond Basin and Glengarry Half Graben are small structural elements of an extensive basin system in Atlantic Canada containing Carboniferous rocks (Figs. 2 and 3). The collection of basins has been variously called the Fundy Epieugeosyncline (Kelley, 1970), Fundy Basin (Bell, 1958, and Belt, 1968) and Fundy Aulacogene (Keppie, 1977). The non-genetic, general name "Maritimes Basin" (after Boehner *et al.*, 1988) is used in this report. Structural and stratigraphic models applied to the Carboniferous rocks in the Maritimes Basin have been diverse at both the regional and local scales. The basin nomenclature varies greatly and represents a complex evolution based upon interpretive genetic models. Carboniferous strata are presently distributed as the erosional remnants of a much larger depositional system complicated by subsequent tectonism and erosion. The name Maritimes Basin (after Roliff, 1962, and Boehner *et al.*, 1988) is used here as a non-genetic, general term for reference to areas in Atlantic Canada underlain by upper Paleozoic strata.

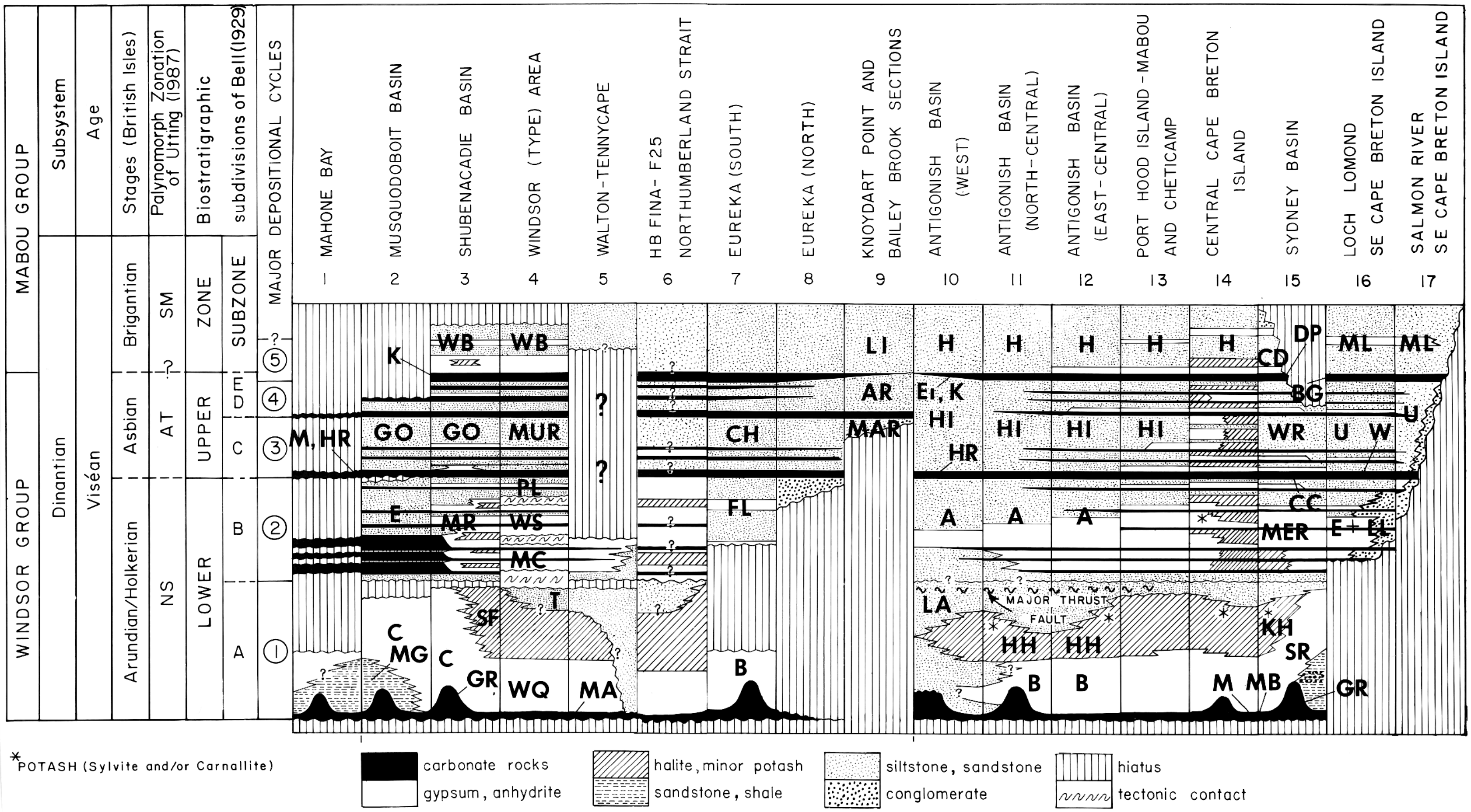
The Carboniferous succession in the Maritimes Basin (Boehner *et al.*, 1988) records deposition in a complex series of fault blocks and downwarped intermontane troughs developed upon the folded Acadian Orogen (Belt, 1968; Ryan *et al.*, 1987). A great thickness (up to 10 000 m) of dominantly molassic sedimentary deposits accumulated in the deeper central mobile area beneath the Gulf of St. Lawrence (Howie and Barss, 1975). Although the sedimentary rocks are predominantly Carboniferous in age (Fig. 3), the regional succession ranges in age from middle - late Devonian to early Permian (Howie and Barss, 1975). The major Carboniferous groups recognized in the Maritimes Basin, in ascending order, are: Fountain Lake Group, Horton Group, Windsor Group, Mabou Group, Cumberland Group and Pictou Group. The Fountain Lake Group and correlatives record the very early phase of basin development following the Acadian Orogeny and comprise a sequence of interstratified continental siliciclastics and volcanic rocks. The Horton Group is a complex intermontane basin fill sequence dominated by alluvial, fluvial and lacustrine strata. The overlying Windsor Group records the only major marine deposition in the Maritimes Basin and is dominated by marine evaporites with subordinate redbeds and marine carbonates. The Mabou Group conformably overlies the Windsor Group and is a fluvial-lacustrine succession dominated by red and grey mudrock. The Mabou Group is overlain by a complex heterogeneous section of fine- to coarse-grained continental siliciclastics of the coal-bearing Cumberland Group. The Cumberland Group is, in turn, overlain by a thick section of continental redbeds of the Pictou Group, which contains strata as young as early Permian.

The Loch Lomond Basin and Glengarry Half Graben (Boehner and Prime, 1985, 1991; Prime and Boehner, 1984) are contiguous but distinct structural basins with the general configuration of half grabens. The basins have unconformable onlap boundaries on the southeast, and the northwestern border is a major fault (Lennox Passage Fault). The basins occur on the Fourchu Block near the southeastern limits of the Maritimes Basin. They contain a succession of Carboniferous rocks that range in age from Viséan (possibly late Tournaisian) to late Westphalian (Figs. 4 and 5; basin geology Map 85-2, in pocket). To the southwest of the Loch Lomond Basin, Devonian to lower Carboniferous rocks also occur in the penetratively deformed L'Ardoise Block, an undivided, highly disturbed fault block. The Carboniferous succession in the study area (Fig. 8) is dominated by a heterogeneous sequence of stratified continental siliciclastics comprising coarse pebble-boulder conglomerate, sandstone, and minor siltstone, with a thin coal-bearing sandstone and mudrock sequence near the top.

The basins have a prominent northeast - southwest structural trend. This trend is principally defined by the regional Acadian basement structure and is emphasized by the Lennox Passage Fault, the major basin-bounding fault. The extension to the northeast is truncated by the Mira River Fault (south boundary of the nearby Sydney Basin) which converges with the Lennox Passage Fault. One of the more interesting aspects of the Loch Lomond Basin and the Glengarry Half Graben is the well developed progressive onlap relationship on the southeast border (Horton and earliest Windsor groups are overstepped) and the association of mineral deposits along this contact (Fig. 9). These areas are also significant because they contain a stratigraphic record of the late Namurian to early Westphalian, which is apparently not present in the adjacent Sydney Basin to the north (Boehner, 1985).

Stratigraphy

The Loch Lomond Basin and Glengarry Half Graben contain a maximum projected thickness of 2000 m (Figs. 4, and 5) of Carboniferous sedimentary rocks, ranging from Viséan to late Westphalian in age, resting on Hadrynian to Devonian crystalline basement. In the map area these strata are assigned to the Windsor, Mabou (Canso) and Cumberland (Riversdale) groups. The sedimentary sequence consists primarily of fine- to coarse-grained continental siliciclastics and subordinate non-marine



A	ADDINGTON FORMATION
AR	ARDNESS FORMATION
B	BRIDGEVILLE FORMATION
BG	BIG GLEN MEMBER
C	CARROLLS CORNER MEMBER
CC	CRAWLEY CREEK MEMBER
CD	CAPE DAUPHIN MEMBER
CH	CHURCHVILLE FORMATION
DP	DIXON POINT MEMBER
E	ELDERBANK MEMBER
E1	E1 LIMESTONE MEMBER
E+LL	ENON & LOCH LOMOND FORMATIONS
FL	FORBES LAKE FORMATION
GO	GREEN OAKS FORMATION
GR	GAYS RIVER FORMATION
H	HASTINGS FORMATION
HH	HARTSHORN FORMATION
HI	HOOD ISLAND FORMATION
HR	HERBERT RIVER MEMBER
K	KENNETCOOK MEMBER
KH	KEMPT HEAD FORMATION
LA	LAKEVALE FORMATION
LI	LISMORE FORMATION
M	MUSQUODOBOIT MEMBER
MA	MACUMBER FORMATION
MB	MACBETH BROOK FORMATION
MC	MILLER CREEK FORMATION
MG	MEAGHERS GRANT FORMATION
ML	MACKEIGAN LAKE FORMATION
MR	MACDONALD ROAD FORMATION
MAR	MARTIN ROAD FORMATION
MER	MEADOWS ROAD FORMATION
MUR	MURPHY ROAD FORMATION
PL	PESAQUID LAKE FORMATION
SF	STEWIACKE FORMATION
SR	SYDNEY RIVER FORMATION
T	TENNYCAPE FORMATION
U	UIST FORMATION
W	WAVY MEMBER
WB	WATERING BROOK FORMATION
WQ	WHITE QUARRY FORMATION
WR	WOODBINE ROAD FORMATION
WS	WENTWORTH STATION FORMATION

Figure 7. Windsor Group stratigraphy and correlation in Nova Scotia.

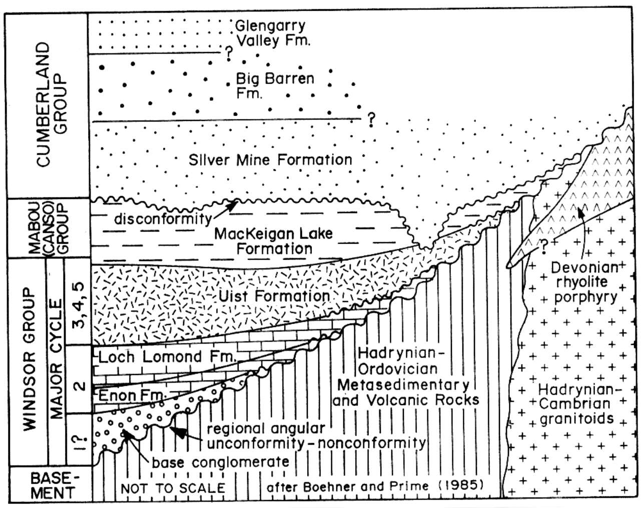


Figure 8. Stratigraphic relationships in the Loch Lomond Basin and Glengarry Half Graben.

shale and thin limestone, and very minor evaporites and fossiliferous marine carbonates. Each Carboniferous formation progressively overlaps the preceding formation directly onto basement highs. The geological evidence indicates that this successive onlapping continued from the Viséan through to at least the early Westphalian, at which time the Carboniferous sedimentary cover may have been thick enough that the basement topography was entirely covered.

The Carboniferous stratigraphy (Figs. 8, 9 and 10) in the area is summarized in ascending order below and in the following sections. The major units in the area are described in ascending order from oldest to youngest and closely follow the sequence of mapped units on Map 85-2 (in pocket). One exception to this is the inclusion and description of the Macumber Formation with the undivided Devono-Carboniferous rocks (part Horton Group) constituting the allochthonous structural unit named the L'Ardoise Block. Note that most of the Carboniferous units occur in a progressive onlap relationship with the underlying basement rocks (Figs. 8, 9 and 11). Therefore, in addition to overlying the older Carboniferous unit, each formation up to and including the Silver Mine Formation rests unconformably upon basement.

The oldest stratigraphic units in the basins proper are all part of the Windsor Group, although the basal conglomerate unit may be equivalent in part to the Horton Group. This undivided basal conglomerate rests unconformably on the Hadrynian to Devonian basement. It is a marginal facies, in part, of the conformably overlying Enon and Loch Lomond formations, which comprise an interstratified sequence of evaporites, redbeds and marine carbonates (Fig. 12). The Loch Lomond Formation is disconformably overlain by the Uist Formation, an interbedded sequence of redbeds, marine carbonates and evaporites. Conformably to disconformably overlying the Uist Formation is the MacKeigan Lake Formation, a section of interbedded grey shale, with minor limestone, evaporites and red sandstone. The Silver Mine Formation, a succession of grey and minor red sandstone, lies disconformably above the MacKeigan Lake Formation (Fig. 8). Conformably overlying the Silver Mine Formation and intercalated with it is the Big Barren Formation, which comprises red conglomerate and sandstone. The top of the succession is marked by the Glengarry Valley Formation, a unit comprising green-grey fine-grained sandstone and mudrock with minor coal seams. This unit is conformable and intercalated with the underlying Big Barren Formation. The entire basin fill package is covered by a thick blanket of Pleistocene till.

The paleontological age assignments stated in this report (see Appendix 2) are based upon palynology of shale units sampled systematically through the available stratigraphic sections. These zone assignments were provided by M. S. Barss and J. Utting at the Geological Survey of Canada, and by Graham Dolby and Associates of Calgary, Alberta. This does not necessarily imply their agreement with the interpretations presented here.

Pre-Carboniferous Basement

All rocks outcropping in the East Bay Hills and Fourchu Block are considered, informally in this report, as basement to the younger sedimentary succession in the basins (Figs. 4, 5 and 8). The basement rocks in the general area of the basins have been described, mapped and subdivided in reports by Weeks (1954), Smith (1978), McMullin (1984), Barr *et al.* (1984), Macdonald (1989), and Barr and Macdonald (1992). No attempt is made here to

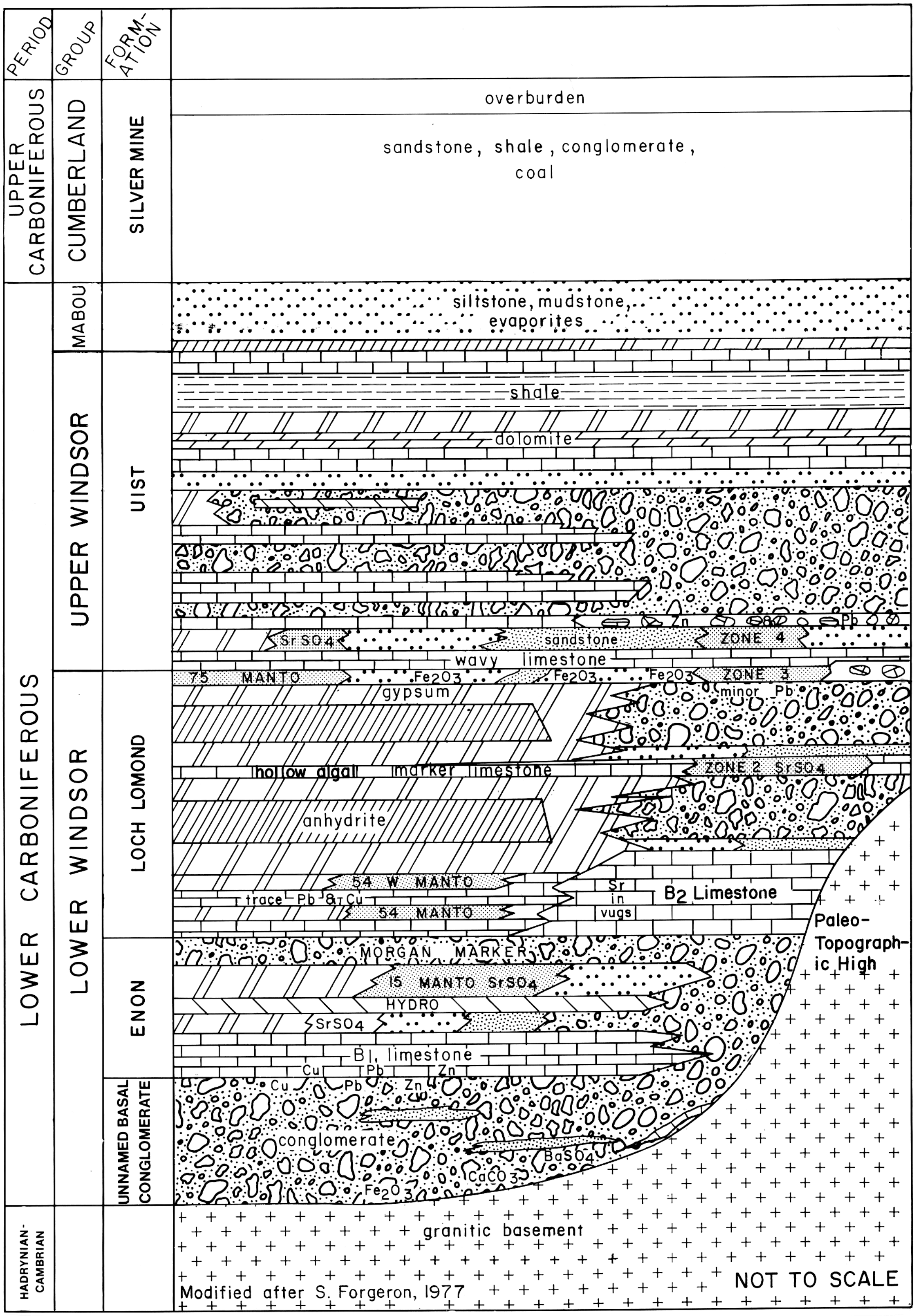


Figure 9. Generalized stratigraphy, mineralization and facies relationships in Windsor Group rocks of the Loch Lomond Basin.

contribute new information on these rocks but a short summary of the major rock types and their nomenclature is useful in understanding the background geology of the area. Two principal map units are recognized in the limited outcrop areas of basement rocks included in the map area. One unit includes all the stratified sedimentary and volcanic rocks and the other unit includes the plutonic rocks.

Sedimentary and Volcanic Rocks

The undivided Hadrynian to Ordovician map unit may include the stratified rocks previously assigned to the Fourchu, Kelvin Glen and Bourinot groups as well as formations of the Cambrian sedimentary sequence. These rocks collectively form a thick suite of interstratified metasedimentary, volcanic and volcaniclastic rocks and are a prominent component of detritus in the coarse-grained Carboniferous basin fill. These rocks are variably deformed with relatively weak deformation prevalent in the basement area to the northeast of Silver Mine. The older rocks typically have well developed cleavage and have undergone greenschist facies or higher degrees of metamorphism. Younger units may have undergone less complicated deformation.

Plutonic Rocks

The metasedimentary and volcanic rocks have been intruded by small granitoid plutons and porphyry. Within the map area several outcrop areas of plutonic rocks are recognized (Barr *et al.*, 1982, 1984; Sangster and Vaillancourt, 1990a and b): the Irish Cove Pluton in the East Bay Block (Fig. 4) on the northwest border of the Loch Lomond Basin, the Loch Lomond plutonic complex (Fourchu Block), including the Salmon River rhyolite porphyry and Chisholm Brook granodiorite along the southeast border, and the Huntington Mountain Pluton on the northwest border of the Glengarry Half Graben. The plutonic rocks form an erosional landscape beneath the Carboniferous unconformity where paleotopographic highs became the location of reef-like carbonate deposition during the marine incursion of Windsor seas (Boehner, 1987, 1988). The plutonic rocks were also a prominent source of immature detritus in alluvial fanglomerates of the Carboniferous basin fill.

L'Ardoise Block and Undivided Devono-Carboniferous

The western part of the Loch Lomond Basin is truncated by highly indurated grey and red siliciclastic rocks of the L'Ardoise Block (Figs. 4 and 5). These deformed and locally fracture-cleaved rocks were given an undivided Devono-Carboniferous designation for mapping purposes. Very limited examination was made of this unit; however, some general conclusions are possible. Some of the rocks assigned to the undivided Devono-Carboniferous map unit (e.g. the L'Ardoise Block) are of uncertain age and are apparently allochthonous to the Loch Lomond Basin. Related to this block are undivided Windsor Group strata, some of which are probably allochthonous (near Lochside - Lake Uist).

Outcrops of the Macumber Formation occur in the Lochside area on the western side of the map area (ECW, undivided Windsor Group on Map 85-2, in pocket) and also in the area to the southwest near Hay Cove (Keppie and Smith, 1978). The Macumber Formation concordantly overlies the siliciclastics of the L'Ardoise Block. These strata would be normally assigned to the Horton Group.

Macumber Formation

The Macumber Formation was defined by Weeks (1948) and originally applied to a well-bedded limestone overlying the Horton Group in the northern part of the Minas Sub-basin of Bell (1958). The Macumber Formation is widely recognized throughout Atlantic Canada (Schenk, 1967a and b, 1969; Kirkham, 1978, 1985). In Loch Lomond Basin, outcrop sections of the Macumber Formation are rare and occur only in the highly disrupted Windsor Group (allochthonous) adjacent to the Lennox Passage Fault and the L'Ardoise Block. Similar outcrops of the Macumber Formation occur in the St. Peters - Hay Cove area to the southwest. Karst topography and rare gypsum outcrops are also associated with these outcrops and probably are part of the normally overlying basal anhydrite of the A subzone or Major Cycle 1 of the Windsor Group. These strata, considered by Weeks (1954) to be the basinal facies of the Windsor Group, are interpreted in this study as

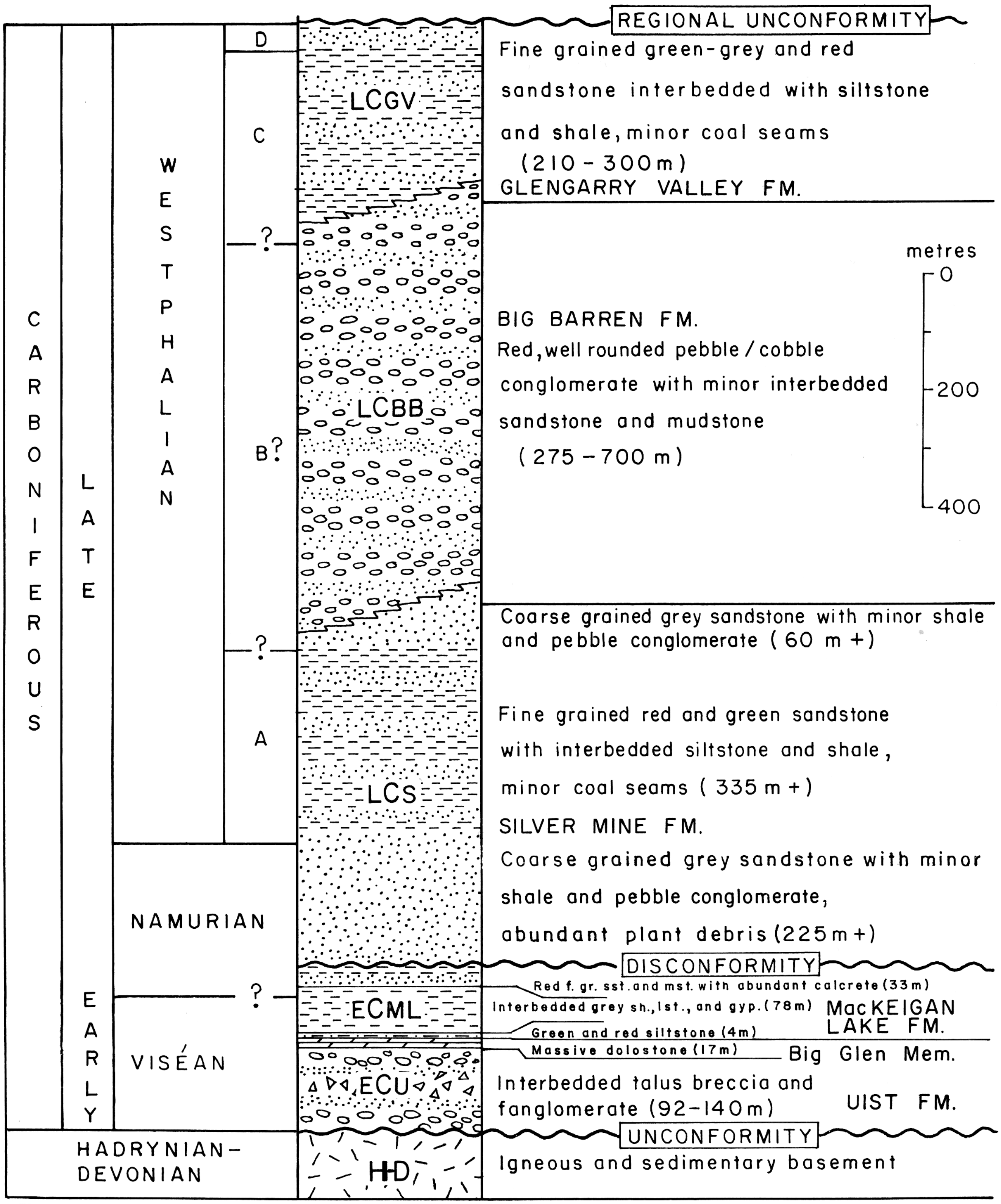


Figure 10. Generalized stratigraphic column, Glengarry Half Graben.

allochthonous to the Loch Lomond area and probably were emplaced with the L'Ardoise Block by strike-slip faulting.

Because of the uncertainty of age and stratigraphic position, as well as the limited available outcrop data, strata in the Grand River Falls area have been included within an undivided Windsor Group map unit. These strata (e.g. Lizzies Lake located to the south of the map area) are similar to the coarse-grained Loch Lomond facies occurring in the vicinity of the MacRae celestite pit adjacent to the Terra Nova Fault.

Carboniferous Lithostratigraphy

Formal changes in the lithostratigraphy in these areas (Fig. 6) include: (1) several new members and formations are introduced, (2) group names are abandoned (Ryan *et al.*, 1991), (3) previous formations are redefined, and (4) existing names from other areas are introduced into the map area. The new nomenclature is as follows (Figs. 6, 7 and 8): Big Glen Member and Wavy Member (new), MacKeigan Lake Formation (new), Silver Mine Formation (new), Big Barren Formation (new) and Glengarry Formation (new). The names Canso Group and Riversdale Group, used tentatively at the time of the original mapping (NSDME Map 85-2), are now abandoned following the precedent of Mabou Group and Cumberland Group lithostratigraphy of Belt (1964, 1965) and Ryan *et al.* (1991). For mapping purposes, the base of the Windsor Group has been placed in accordance with the suggested practice of Keppie *et al.* (1978) for contact situations involving intra-Windsor Group onlap or upper erosion and unconformity. In these situations, continental siliciclastic rocks containing marine strata, and where bounded by unconformities but without basal or upper limestone markers, are included with the Windsor Group (e.g. the undivided basal conglomerate unit and the siliciclastic facies of the Loch Lomond Formation in the area of the Kaiser Celestite Amac prospect and MacRae pit). The top has been placed at the top of the highest mappable marine carbonate (Big Glen Member) in the Uist Formation (Figs. 8, 11 and 12).

Windsor Group

The Windsor Group is one of the most important stratigraphic and economic units in the late Paleozoic basins of Atlantic Canada. It is a complex succession of interstratified evaporites including gypsum, anhydrite, salt (halite) and potash, fine- and coarse-grained redbeds, and distinctive fossiliferous marine carbonate (Figs. 7 and 13). The thickness is variable, ranging from a few metres to more than 1500 m with 750 to 1000 m typical. It is widely distributed throughout the Carboniferous basins that constitute the Maritimes Basin in Atlantic Canada. Cyclic deposition of the marine evaporites and carbonates and continental siliciclastics has provided large deposits of gypsum, salt and limestone which form a major component of the mineral economy of Nova Scotia. The Windsor Group, furthermore, is the host to significant base metal and industrial mineral deposits which have had substantial production at several mine sites (e.g. Walton, Gays River and Loch Lomond; Fig. 14).

The Windsor Group is named for the type area near Windsor (see Williams *et al.*, 1985), Hants County, Nova Scotia, which was described in detail by Bell (1929). The Windsor Group overlies pre-Carboniferous basement rocks (Figs. 9, 11, 12 and 14) with angular unconformity or rests concordantly (perhaps disconformably) upon older basin fill, including the Tournaisian to early Viséan Horton Group. The Windsor Group is typically overlain conformably by the basal units of the mudrock-dominated Mabou Group or unconformably by younger Carboniferous units, including the late Carboniferous Scotch Village Formation (Westphalian B-C) or South Bar Formation (Westphalian B-C). The inherently incompetent character of the Windsor Group has resulted in a variable and locally highly complex structural configuration (Boehner, 1992). Multiple repetition in isoclinal, recumbant folds, thrust and slide faults, and extensive near-surface solution collapse are locally common features in the highly deformed basin areas.

The paleontology and micropaleontology of the Windsor Group has been studied and described by

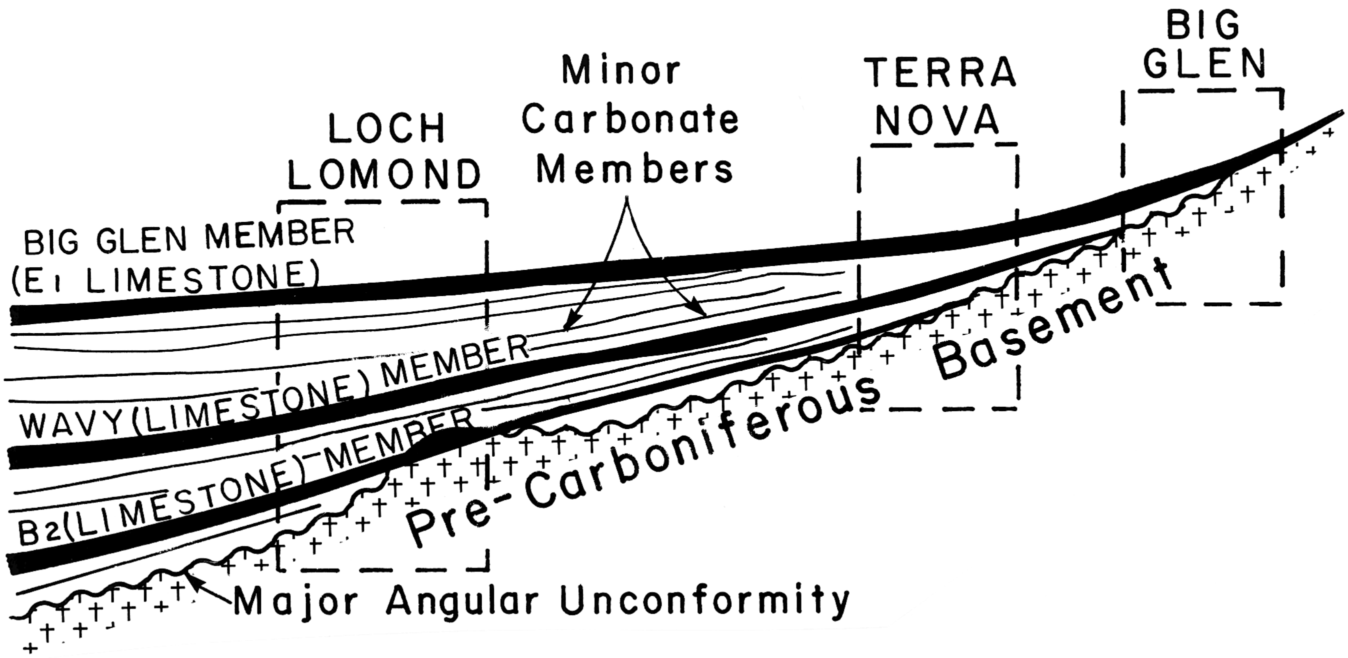


Figure 11. Diagrammatic representation of the progressive onlap of the Windsor Group.

many workers including Bell (1929), Stacey (1953), Sage (1954), Globensky (1967), Moore (1967), Mamet (1970), Moore and Ryan (1976), von Bitter (1976), Boehner (1984), Giles (1981), Dewey and Fahraeus (1982) and Utting (1977, 1978, 1980, 1987). Bell (1929) originally subdivided the Windsor Group in the type area into a Lower Zone and an Upper Zone on the basis of macrofauna. The Lower Zone was subdivided into the A and B subzones and the Upper Zone into the C, D and E subzones. Most of these workers made comparisons and correlations with international stratigraphic schemes both in North America and Europe. Although the biostratigraphic boundaries are not always coincident, Giles (1981) concluded that a general agreement existed in assignment of the Windsor Group to the middle to late Viséan (Fig. 7). Giles (1981) described the Windsor Group as a set of Major Cycles, 1 through 5 (Fig. 7), and assigned them to the following Dinantian stages: Arundian, Holkerian and Brigantian of the British Isles. Major Cycle 1 coincides with the A subzone, Major Cycle 2 with the B subzone, Major Cycles 3, 4 and 5 correlate approximately with the Upper Windsor, Subzones C, D and E. Major Cycle 5 extends into the basal part of the Mabou Group. Geldsetzer (1978) correlated the Windsor Group with the Late Meramecian and Chesterian of the U. S. A.

Utting (1987) introduced a palynology assemblage zonation of the middle to late Viséan Windsor Group with three principal zones, in ascending order the NS Zone, AT Zone and SM Zone. These correlate (Fig. 7) approximately with the lithostratigraphy as follows. The NS Zone extends through the Lower Windsor, A and B subzones of Bell (1929), which correlate approximately with Major Cycles 1 and 2 of Giles (1981) and is late Arundian to Holkerian. The AT Zone correlates with the Upper Windsor, C and D subzones of Bell (1929), approximately Major Cycles 3 and 4 of Giles (1981), and is Asbian. The SM Zone extends through the E subzone of the Upper Windsor (Bell, 1929); up into the basal strata of the Mabou (Canso) Group, and is Brigantian.

The basic stratigraphic framework of the Windsor Group in Cape Breton Island was outlined by Stacey (1953) and Sage (1954) who utilized the major carbonate units as principal markers. The carbonate units were named using an alphanumeric system of faunal subzone letter designations with ascending numerical subscripts. The faunal subzones were based upon the biostratigraphy of Bell (1929). It might appear that Stacey (1953) and Sage (1954) totally emphasized the megafauna zonation in identifying and correlating the carbonate units. However, the distinctive lithologic characteristics of many of the units were equally or more important as diagnostic criteria (see also Giles and Boehner, 1982b).

Paleotopography and tectonism appear to have greatly influenced deposition in the area, especially in the Windsor Group and older units. The importance of paleotopography decreased with time as local erosion and deposition of successive units buried the surrounding landscape. Coarser alluvial fanglomerates are marginal facies of most levels within the Windsor Group only. Sections representing Major Cycles 2 through 5 (Subzones B, C, D and E) display locally profound facies change over distances of less than 3 km, from evaporite-dominated to marginal alluvial fanglomerate-dominated. Carbonate facies show related facies change to calcirudite (limestone conglomerate) in areas of high energy terrestrial influence. Elsewhere, carbonate buildups (bioherm-biostrome) are developed on basement paleotopographic highs (Figs. 12 and 14). The change from coarser fanglomerates to sand-silt redbeds is especially dramatic in the area between Enon and the Terra Nova Fault (Figs. 4, 5 and 12).

Stratigraphic, structural and mineral deposit studies of the Windsor Group are hindered and complicated by several factors, including: (1) solution collapse and brecciation (multi-generations related in part to faults) in the evaporitic sections of the Loch Lomond and Enon formations along the southeast border, (2) coincidence of later (possible) fault re-activation with earlier (inferred) block faulting, (3) typical minimal outcrop and (4) bias toward the high density of drill data at the basin margin with few deeper (>200 m) drillholes in the basinward areas.

The Windsor Group in the Loch Lomond Basin and Glengarry Half Graben is especially interesting because this is one of the best areas to document geological interaction along an expanding basin margin where the unconformity landscape has significant relief (Figs. 8 and 9). The coincidence with extensive mineralization (Figs. 15, 16 and 17) makes it important in understanding and predicting the mineral potential in the area as well as in other basins with potentially similar geology (e.g. West Bay - Dundee area in Richmond County). The level of stratigraphic onlap is of particular interest in view of the relationship of mineralization with carbonate buildup facies in the Windsor Group (e.g. Gays River Formation, Giles *et al.*, 1978). The basal carbonate of the Windsor Group has been a traditional exploration target. The term 'basal carbonate' is a general term which typically has been restricted to the A subzone (Major Cycle 1) Macumber Formation (and equivalents) and during the mid-1970s included the correlative buildup facies, Gays River Formation, which onlaps basement. The Loch Lomond Basin was one of the few areas identified where the B subzone (Major Cycle 2) overstepped Major Cycle 1 and was deposited directly on basement. The basement onlap of Major Cycle 1 was previously well documented in many basins by Giles *et al.* (1979) and Boehner *et al.* (1989a).

Cross-sections A-A_1 and B-B_1 (Fig. 12) illustrate the general geology and structure of the Windsor Group and the two basic end-member facies in the Loch Lomond Basin. Generally the stratigraphic section consists of the following three lithologic packages: (1) pre-Carboniferous basement, (2) the undivided basal conglomerate, Enon and Loch Lomond formations, and (3) the Uist and MacKeigan Lake formations.

The basal contact with basement rocks is a major angular unconformity or nonconformity with progressive stratigraphic onlap and locally developed carbonate buildups (Figs. 11 and 18). The Loch Lomond - Uist contact is a disconformity and in the marginal subcrop areas there is a disrupted brecciated zone at or near the top of the evaporitic Loch Lomond Formation. Strata in the Loch Lomond and Enon formations have dips of 15 to 20° and tend to steepen basinward (Fig. 12). The dips in the overlying Uist Formation are generally similar, except in the area above the breccia at the basin margin where dips are only 5 to 10°. This coincides with the disrupted evaporite dissolution zone and is interpreted to be due to downward tilting and foundering of the Uist Formation. The collapse was apparently

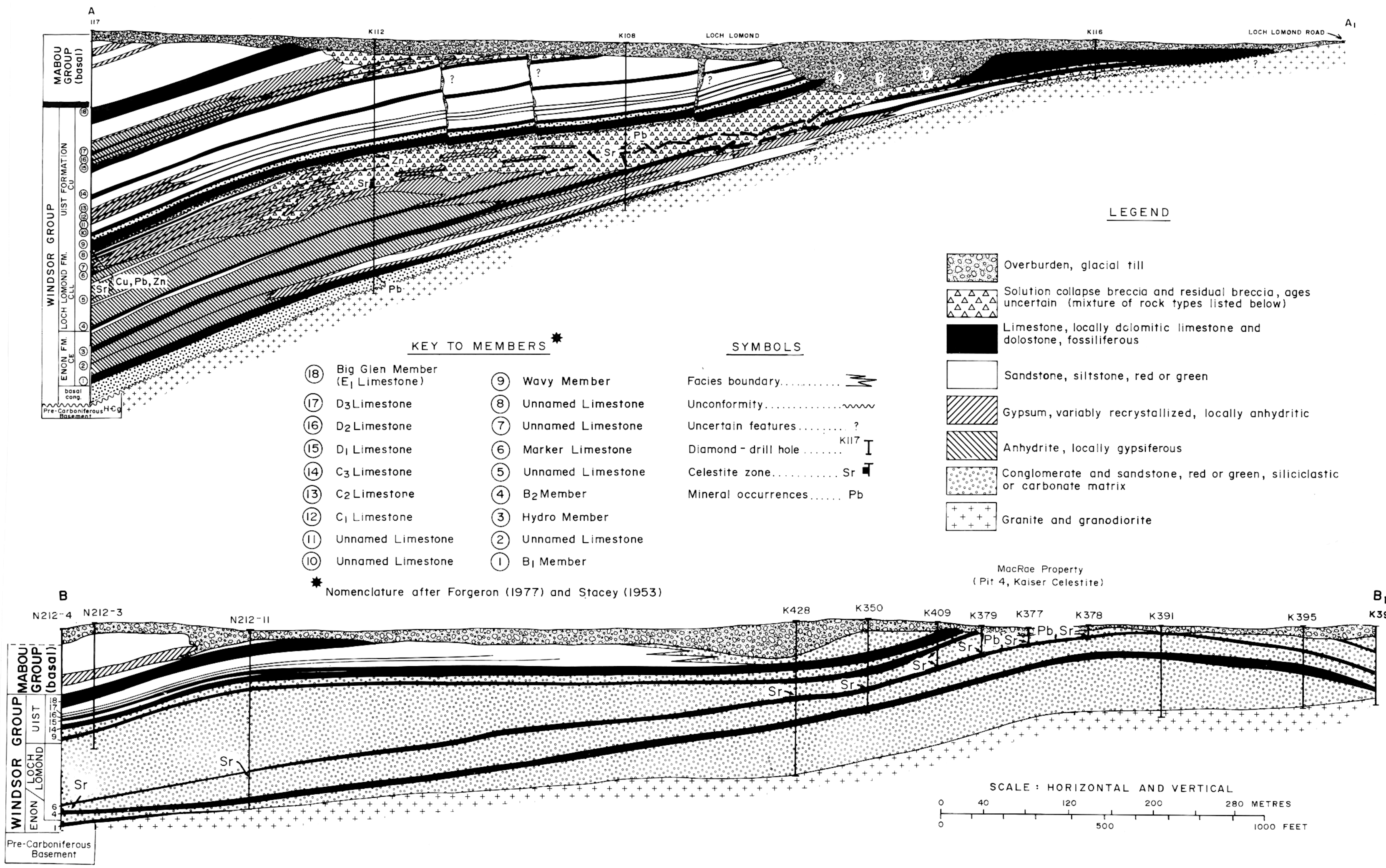


Figure 12. Geological cross-sections A-A_1 and B-B_1 , Loch Lomond Basin, to accompany Figure 5.

accompanied by small scale faulting and perhaps is related to block faulting associated with the Grand River-Lennox Passage faults. The solution collapse process post-dates (at least in part) celestite mineralization (Fig. 12); however, an upper age limit is not clear. It may be related to the pre-Silver Mine Formation disconformity, or may be much younger (possibly Mesozoic), or may be a complex multi-generation paleokarst process. Boehner (1981, 1983) speculated on a potential relationship between karstification and mineralization with base metals and celestite.

The autochthonous stratigraphic units of the Windsor Group (basal conglomerate (Grantmire Formation), Enon Formation, Loch Lomond Formation and Uist Formation) are described, in ascending order, in the following section.

Basal Conglomerate (Grantmire Formation)

The name Grantmire Member was first introduced and defined by Bell and Goranson (1938). They originally applied the name to thick deposits of conglomerate below marine limestone or sandstone in lower Windsor Group rocks in the Sydney area. The Grantmire Member was believed to represent the lowermost unit of the Windsor Group. Weeks (1954) redefined and applied the term Grantmire Formation to conglomerate believed to have been primarily within the lower Windsor. Unfortunately, rocks now considered to be Horton Group were incorrectly identified and mapped as Grantmire Formation (e.g. in the Iona - Grand Narrows area). Kelley (1967) concluded that in the Baddeck and Whycocomagh map areas, which adjoin the map areas containing Grantmire rocks of Bell and Goranson (1938) and Weeks (1954), the Grantmire strata were typical of the Horton Group. The distribution of conglomeratic strata in the Loch Lomond and Sydney areas has been better defined by subsequent exploration drilling. It is apparent that coarse-grained conglomeratic units occur throughout the Horton and Windsor group section. They are relatively uncommon but are locally significant as interbeds and even dominant components within the lowermost Windsor Group units; for example, as in the Enon and Loch Lomond formations adjacent to the Terra Nova Fault and the Amac and MacRae celestite deposits, as well as in the Sydney River Formation in the area adjacent to the Coxheath Hills, and Glen Morrison in the Sydney Basin.

The presence of conglomerate tongues at many stratigraphic levels (Figs. 9 and 12), compounded by basement onlap relationships, makes recognition of the Grantmire Formation as a lithostratigraphic unit in the sense of Weeks (1954) impractical. Giles (1983) consequently recommended the term be restricted in the type area (Sydney Basin) to the section beneath the basal Windsor Group carbonate (Macumber or Gays River formations or equivalents). Much of the original Grantmire unit in its type section is actually Horton Group and occurs stratigraphically beneath the basal Windsor Group carbonate. Similar conglomeratic and siliciclastic facies known to occur at higher stratigraphic levels within the Windsor Group are treated as follows. Where intercalated with definitive Windsor Group facies, such as marine carbonates and evaporites, and especially if a bounding basal carbonate member is present, they are included with the relevant Windsor Group formation (e.g. Enon, Loch Lomond, Sydney River or Meadows Road formations). In extreme onlap areas such as the Loch Lomond Basin, basal conglomeratic strata, where not underlain by a definitive marine carbonate, are assigned to an undivided informal map unit 'basal conglomerate'. This conglomerate may equate in age with rocks ranging from the uppermost Horton Group to the A subzone or Major Cycle 1 of the Windsor Group. The basal conglomerate designation is used principally in the Loch Lomond Basin where the onlap relationship of the Enon Formation (B_1 Limestone) dictates a separation of these redbed conglomerates. The term Grantmire Formation previously applied in the Loch Lomond area by Crowell (1971) and Forgeron (1977) was abandoned in this area by Boehner (1981). This practice is followed here and is consistent with the revised usage of Kelley (1967) and Giles (1983), based upon the type area near Sydney (Boehner and Giles, 1986).

Enon Formation

The irregularly distributed basal conglomerate is overlain, without apparent discordance, by a section of interbedded anhydrite, gypsum, red and grey-green siliciclastics (locally including minor conglomerate), and distinctive marine carbonates. This section is typically dominated by evaporites and was previously subdivided by Crowell (1971) into two formations (Fig. 6, 9 and 12): a lower, Enon Formation and an upper, Loch Lomond Formation. Forgeron (1977) recognized the B_2 Limestone (at the base of the Loch Lomond Formation) as a separate "B_2 Limestone Formation". This study retains the B_2 Limestone as a member at the base of the Loch Lomond Formation, forming a diagnostic pick for the top of the Enon Formation. The Enon and Loch Lomond formations are approximately correlative with the B subzone or Major Cycle 2 of the Windsor Group.

Type Locality

The Enon Formation was introduced by Crowell (1971) and named for the community of Enon in the Loch Lomond Basin, Cape Breton County. It is a prominent unit in exploration drillholes defining the celestite deposits adjacent to Enon Lake. The formation was further described by Forgeron (1977) and Boehner (1981, 1983). The type sections of the Enon Formation and the B_1 Member and Hydro Member (Figs. 12 and 13) are designated in Kaiser Celestite Mining Ltd. drillhole K-112 (Forgeron, 1977), in the interval between 176.2 m and 233.5 m. The drillhole is located near the community of Loch Lomond in the Loch Lomond Basin, Richmond County, Cape Breton Island. The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Lithology

The Enon Formation is an interstratified sequence of evaporites (gypsum and anhydrite), fossiliferous red and minor green siltstone, sandstone, poorly sorted, polymictic paraconglomerate and breccia, and minor marine carbonates. The formation contains two principal fossiliferous marine carbonate members referred to by previous workers (Forgeron, 1977) as the B_1 and Hydro limestones (Figs. 9, 12 and 13). These are given formal member status in this report. There is also a thin, unnamed carbonate member between the B_1 and the Hydro members. The Enon Formation is dominated by evaporites in the basinward sections, with substantial facies change to siliciclastic-dominated rocks in the marginal settings (conglomeratic) where stratigraphic thinning and pinchout are evident. In these marginal sections conglomeratic facies may predominate, evaporites are absent, and the marine carbonates have been entirely removed by erosion. Where dominated by redbed conglomerate, and in the absence of the marine carbonates, the Enon Formation may be inseparable from the 'basal conglomerate' map unit which was established to accommodate these unusual circumstances (e.g. the MacRae pit; Map 85-2, in pocket).

The B_1 Member (Fig. 13) is up to 6 m thick and is a heterogeneous unit that is not well represented in the area. It comprises variably silty, grey-brown and medium- to dark-grey, bioclastic limestone and is locally stromatolitic at the base. The upper units are mottled algal boundstone.

The Hydro Member (Fig. 13) is up to 4.9 m thick and is well represented in the area. It comprises light- to medium-brown and grey-brown bioclastic limestone and is distinctive in having one oncolitic limestone interbed and a gradational basal contact with grey siltstone. The Hydro Member has a thick-laminated stromatolitic limestone at the top.

Relations to Other Units

The Enon Formation conformably overlies the informal unit named the basal conglomerate or rests with unconformity on the pre-Carboniferous basement rocks. It is conformably overlain by the Loch Lomond Formation.

Distribution and Thickness

The Enon Formation is widely distributed in the subsurface of the Loch Lomond Basin but thins drastically and pinches out in the Glengarry Half Graben, although it may be present in the deeper subsurface. It is conformable with the underlying basal conglomerate, where present, and locally directly onlaps the basement unconformity. The Enon Formation is approximately 56 m thick (intersection)

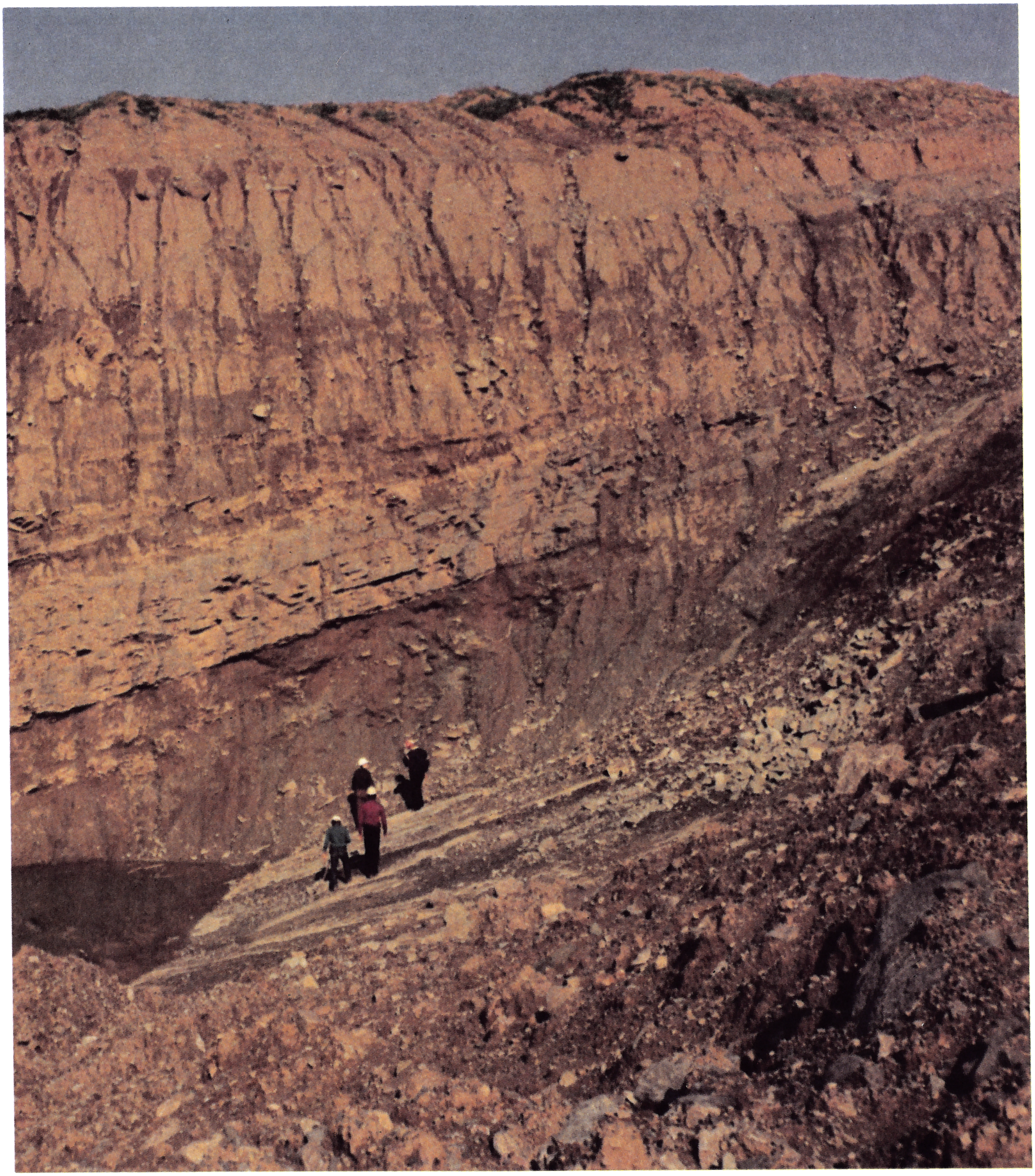


Figure 14. Photograph of the Kaiser Celestite Ltd. open pit at Lake Enon in the fall of 1974 (camera facing northeast). The northwest-dipping strata exposed are the Hydro Member at the water's edge and the B_2 Member. The Hydro Member pinches out against a pre-Carboniferous basement knob to the southeast (right) and toward the camera position. The B_2 Member biostrome/bioherm, in turn, onlaps the basement knob. Evaporites formerly present between the carbonate members have been removed by subsurface dissolution leaving solution collapse and infill.

in the type section and is generally thinner in the siliciclastic-dominated sections where a 25 m thickness (intersection) is typical. The formation is reduced to nil in the pinchout areas where the Loch Lomond Formation rests directly on basement (e.g. Enon celestite pit, Fig. 14).

Age

Spore assemblages recovered from the Enon Formation were assigned to the NS Zone by Utting (1977, 1978) and are of middle Viséan (Arundian-Holkerian) age (Utting, 1987).

Loch Lomond Formation

The Loch Lomond Formation was introduced by Crowell (1971) and further described by Forgeron (1977) and revised by Boehner (1981, 1983). The Loch Lomond Formation (Figs. 5, 8 and 12) is generally lithologically similar to the conformably underlying Enon Formation and undergoes similar facies change in the onlapping sections. The formation is disconformably overlain by the Uist Formation. The Loch Lomond Formation has two principal marine carbonate members: the B_2 Member at the base and a thin but distinctive unit informally referred to as the 'Marker Limestone' or 'Hollow Algal Marker' (Fig. 13). In addition, there are three unnamed carbonate members recognized.

Type Locality

The type section of the Loch Lomond Formation occurs near the community of Loch Lomond in the Loch Lomond Basin, Richmond County, Cape Breton Island, in Kaiser Celestite Mining Ltd. drillhole K-117 (Figs. 12 and 13; Forgeron, 1977), in the interval between 214.7 m and 291.1 m. The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Lithology

The Loch Lomond Formation is an interstratified sequence of evaporites (gypsum and anhydrite), minor red and minor green siltstone, sandstone, conglomerate and breccia with subordinate marine carbonate. The formation contains two principal fossiliferous marine carbonate members, referred to by previous workers (Forgeron, 1977) as the B_2 Limestone and the informal 'Hollow Algal Marker' or 'Marker Limestone', and three unnamed carbonate members. The Loch Lomond Formation is dominated by evaporites in the basinward sections with substantial facies change to siliciclastic-dominated in the marginal setting (conglomeratic) where thinning and pinchout are evident (e.g. MacRae celestite pit). In the marginal pinchout sections (Fig. 12), evaporites are absent and the marine carbonates are rarer and thinner and may be severely recrystallized and degraded to marginal calcirudites, reworked, or entirely removed by erosion.

The B_2 Member (Fig. 13) is 2.7 m thick and comprises light- to medium-brown and grey-brown bioclastic limestone and is similar to the Hydro Member of the underlying Enon Formation. It is distinctive in having only two oncolitic limestone interbeds ('Bun Facies') and the basal contact is sharp with grey siltstone or gypsum-anhydrite. The basal unit is a domal algal stromatolite. The top of the member is marked by an upper domal algal stromatolite and a gradation upward with laminated algal stromatolitic limestone and gypsum-anhydrite ('Lacey Facies'). The B_2 Member is thinner than the Hydro Member, in part because the laminated stromatolitic limestone at the top is mainly evaporite with subordinate carbonate and thus is not included in the thickness of the B_2 Member. Where the B_2 Member onlaps basement, a shelly biostrome-bioherm buildup facies up to 20 m thick is developed (e.g. drillhole K-116, Fig. 12). This type of relationship is typical of several carbonate units in the B subzone described elsewhere in Nova Scotia by Boehner (1987, 1988, 1989).

The B_2 Member is distinctive because it may overstep older units and rest directly on paleo-topographic highs of the erosional basement landscape (Figs. 12 and 15). In this setting, a biohermal-biostromal buildup facies is developed (Boehner, 1988 and 1989). Geldsetzer (1977) originally considered the B_2 Member of the Loch Lomond Formation to be an A subzone onlap and correlative with the Gays River Formation/Macumber Formation. Boehner (1981, 1988 and 1989) concluded that the Enon and

Loch Lomond formations overstepped the A subzone (Major Cycle 1) and can be correlated with the B subzone (Major Cycle 2).

The Hydro Member (Fig. 13) is 2 to 3 m thick and consists of light grey to grey-brown limestone with local hematitic stain. The contacts with overlying and underlying evaporites are sharp. The upper units comprise domal digitate and planar algal stromatolites whereas the lower part contains distinctive hollow laminated tube structures of uncertain, possibly algal affinity.

Distribution and Thickness

The Loch Lomond Formation is widely distributed in the subsurface of the Loch Lomond Basin but thins drastically and pinches out in the Glengarry Half Graben, although it may be present in the deeper subsurface. The formation is approximately 75 m thick (intersection) in the type section and is generally thinner in the siliciclastic-dominated sections where approximately 30 to 40 m thickness is typical. The formation is reduced to nil in pinchout areas where the Uist Formation rests directly on basement (e.g. Big Glen area, Map 85-2).

Relations to Other Units

The Loch Lomond Formation conformably overlies the Enon Formation or rests unconformably upon pre-Carboniferous basement rocks. It is concordantly overlain by the Uist Formation.

Age

Spore assemblages recovered from the Loch Lomond Formation were assigned to the NS Zone by Utting (1977, 1978) and are of middle Viséan (Arundian-Holkerian) age (Utting, 1987).

Uist Formation

The name Uist Formation was originally introduced by Crowell (1971) for the section of interstratified carbonates, redbeds and minor evaporites overlying the Loch Lomond Formation. The Uist Formation was considered to be part of the B subzone of the lower Windsor, but was subsequently re-assigned by Boehner (1981) to the upper Windsor and revised to accommodate a section of undivided upper Windsor strata. The top of the revised formation was placed at the top of the Big Glen Member (or E_1 Member; Sage, 1954), the highest marine carbonate in the section (Figs. 12 and 13). Approximately eight marine carbonate members (Fig. 13) and two unnamed carbonates are recognized in the section, which is very similar to the Hood Island Formation in the Antigonish Basin (Giles and Boehner, 1982b; Boehner and Giles, 1992). It is important to note the presence of the Wavy Member at the base of the formation beneath the C_1 Member. As in the Antigonish Basin, the C_1 Member was historically considered to be the lowermost marine carbonate in the upper Windsor. This was revised by Giles and Boehner (1982b) who recognized the presence of lower units, including the Herbert River Member in the Antigonish Basin which correlates with the Wavy Member in the Loch Lomond Basin.

The alphanumeric member nomenclature applied to the Uist Formation in Loch Lomond Basin is based on the type section for the correlative Hood Island Formation (Antigonish Basin) of Boehner and Giles (1991). The section on Port Hood Island has been described and examined by numerous previous workers and measured sections have been published by Stacey (1953), Sage (1954), Schenk (1969), and Boehner and Giles (1991). It has been sampled extensively for paleontological purposes, including studies of the megafauna (Stacey, 1953), Foraminifera (Mamet, 1970), conodonts (von Bitter, 1976) and palynomorphs (Utting, 1980, 1987). Schenk (1969) described the detailed lithology of the carbonate-sulphate-redbed facies. Giles (1977) examined the section and described the regional correlation of the uppermost carbonate unit (E_1 limestone) throughout western Cape Breton Island and into the Antigonish Basin. Stacey (1953) introduced an alphanumeric nomenclature system for the carbonate members in the Port Hood Island section based on the megafauna subzone system of Bell (1929) with numerical subscripts in ascending order. Giles and Boehner (1982b and 1991) correlated the upper Windsor Group equivalents in Nova Scotia and although several inconsistencies in the alphanumeric assignments were recognized, the nomenclature was

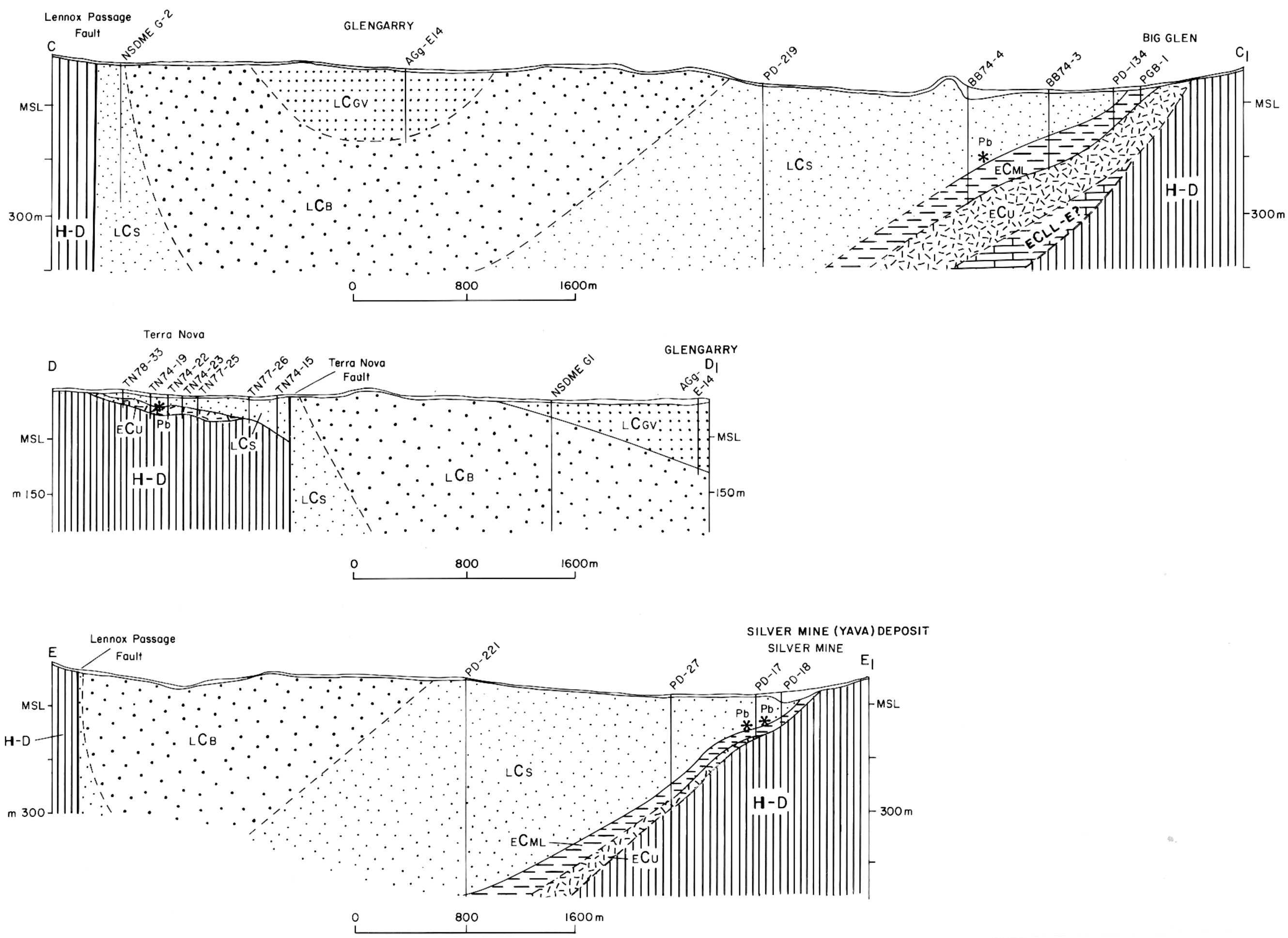


Figure 15. Geological cross-sections C-C$_1$, D-D$_1$ and E-E$_1$, Glengarry Half Graben; for locations see Figure 5.

retained. The Uist Formation correlates with Major Cycles 3, 4 and 5 defined by Giles (1982).

Type Locality

The Uist Formation type section is located near the community of Loch Lomond near Lake Uist in the Loch Lomond Basin, Richmond County, Cape Breton Island (Map 85-2, in pocket), in Kaiser Celestite Mining Ltd. (Forgeron, 1977) drillhole K-117 (Figs. 12 and 13), in the interval between 72.5 m and 214.7 m. The name Uist Formation was introduced by Crowell (1971) and further described by Forgeron (1977) and Boehner (1981, 1983). In the Glengarry Half Graben the Uist Formation thins and onlaps basement and comprises a lower conglomerate unit and the Big Glen Member dolostone unit. These are well represented in the reference section (Appendix 1) from 202.8 to 239.9 m in diamond-drill core BB-74-3 and from 306.3 to 320.1 m in drillhole BB74-4 (both holes: Amax Exploration Inc., 1974) near Big Glen, and outcrop exposure along McCuish Brook south of the Salmon River Road (Map 85-2). The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Lithology

The Uist Formation is an interstratified sequence of redbeds, siltstone and sandstone with local conglomerate and breccia in the marginal areas and especially in the area adjacent to the Terra Nova Fault (Map 85-2). Two key fossiliferous marine carbonate members (Figs. 11, 12 and 13) are present in the Uist Formation and are referred to as the Wavy Limestone at the base and the Big Glen Member at the top (equivalent to the E_1). In addition, the C_1, C_2, C_3, D_1, D_2 and D_3 limestone units and two unnamed carbonate members are recognized beneath the C_1 Limestone (units 10 and 11 on Fig. 12). These members are described in later sections. The Uist Formation is dominated in the basinward sections by fine-grained redbeds with minor grey-green continental clastics, including siltstone, shale and fine-grained sandstone. There is a substantial facies change to coarser siliciclastic-dominated sections in the marginal setting (conglomeratic) where thinning and pinchout are evident (e.g. in the Glengarry Half Graben). As in the underlying Loch Lomond and Enon formations, conglomeratic facies may predominate in the pinchout sections, evaporites are absent, and the only significant marine carbonate present is the Big Glen Member which is dolomitized and recrystallized. Where dominated by redbed conglomerate and in the absence of the marine carbonates, the conglomeratic parts of the Uist Formation may be inseparable from the 'basal conglomerate' map unit. Marine carbonate and evaporite interbeds are the distinctive criteria used in recognizing the formation. The carbonates consist of oolitic algal limestone, and micritic argillaceous limestone and dolostone. Buildup facies described by Boehner *et al.* (1989b) have not been identified in the study area. The gypsum and anhydrite units are nodular with variable siltstone and carbonate matrix.

In the Glengarry Half Graben the Uist Formation (Figs. 5, 10 and 15) consists of two units, the lower conglomerate unit (92 to 140 m thickness) and the upper dolostone unit or Big Glen Member (≤ 17 m thickness). The conglomerate is included within the Uist Formation even though there is no representative of the Wavy Member, which normally would be the key to the basal boundary. For mapping purposes the conglomerates are included because they are so thin and display no apparent break with the Big Glen Member. They conceivably may correlate with conglomeratic facies of the Loch Lomond or Enon formations but are lithologically indistinguishable.

The lower conglomerate unit can be subdivided into two texturally distinct types of conglomerate which are often interbedded. One type has very angular clasts, generally with a clast support framework and a green-grey clay matrix. These beds are almost always massive with no internal sedimentary structures apparent. The other conglomerate type consists of subangular to subrounded clasts and may be either clast or matrix supported, massive or internally bedded. This second type generally lacks internal sedimentary structures, with the exception of local stromatolitic and calcrete nodule layers.

Both conglomerate types can have either red or green coloration and may be accompanied by finer-grained interbeds of either sandstone or mudstone. The clasts are predominantly volcanic and granitic and closely resemble the underlying Hadrynian-Devonian basement. Grain size ranges from pebbles to boulders up to 1 m in diameter.

Distribution and Thickness

The Uist Formation is widely distributed in the subsurface of the Loch Lomond Basin but thins drastically and pinches out in parts of the Glengarry Half Graben. The formation is approximately 140 m thick (intersection) in the type section (Figs. 12 and 13) and is generally thinner in the siliciclastic-dominated sections, where 40 to 45 m is typical, and is reduced to nil in the pinchout areas where the MacKeigan Lake or Silver Mine formations rest directly on basement (e.g. Silver Mine area). In the Glengarry Half Graben the Uist Formation (maximum thickness 157 m in conglomeratic sections) occurs along almost the full length of its southern flank, with the exception of the Silver Mine area where it pinches out. It also outcrops in the northeast near Mineral Rock where it is truncated by the Lennox Passage Fault (Map 85-2).

Along the southern flank of the Glengarry Half Graben the Uist Formation strata dip gently (10 to 20°) to the northwest (Fig. 15). The formation lies unconformably on the Hadrynian to Devonian basement and is conformable to disconformable with the overlying MacKeigan Lake Formation. It appears to be largely undeformed. In the Mineral Rock area to the northeast, the situation may be more complex. Due to poor outcrop exposure and lack of drilling information, the structural relationships in the location remain unknown. The close proximity to a major fault might suggest that it occurs either as a fault slice or a tightly folded anticline.

Relations to Other Units

The Uist Formation disconformably overlies the Loch Lomond Formation and in the more extreme onlap setting between Big Glen and Silver Mine it rests directly on crystalline basement. Coarser-grained siliciclastic strata are often associated with the marginal contacts. The Uist Formation is conformably overlain by the MacKeigan Lake Formation. However, in the area near Terra Nova it is unconformably overlain by the Silver Mine Formation. The basal contact cuts through the MacKeigan Lake Formation and much of the Uist Formation, indicating significant erosion. The contact between the Uist Formation and the underlying Loch Lomond Formation is not exposed in outcrop but was intersected in numerous exploration drillholes. Although locally disrupted by faulting and solution collapse of the underlying Loch Lomond Formation, the contact appears to be concordant and disconformable. In these sections the Wavy Member rests concordantly upon disrupted Loch Lomond Formation rocks.

The base of the Uist Formation is designated at the base of the Wavy Member, or in onlap sections where the Wavy Member is absent due to pinchout with siliciclastics the base is placed at the basement unconformity and includes the section contiguous to the unconformity (e.g. Big Glen Member in the Glengarry Half Graben). The upper contact of the Uist Formation is placed at the top of the Big Glen Member which is well defined in drillhole sections but is typically concealed in outcrop. The upper contact is concordant and conformable with overlying evaporites (anhydrite and gypsum) and grey to red fine-grained siliciclasics of the MacKeigan Lake Formation (Mabou Group). This follows the practice of Giles (1982) and Boehner and Giles (1992) who included the evaporite-bearing grey mudrock section above the uppermost Windsor Group marine carbonate member in the Mabou (Canso) Group.

The Uist Formation is generally similar in lithology and stratigraphic position to the Green Oaks Formation in the Shubenacadie and Musquodoboit basins (Giles and Boehner, 1979, 1982b), the Woodbine Road Formation in the Sydney Basin, and the Hood Island Formation in the Antigonish Basin (Boehner, 1981).

Age

Spore assemblages recovered from the Uist Formation were assigned to the AT Zone by Utting (1977, 1978). In the Pomquet River section in the Antigonish Basin, Neves and Belt (1970) and Utting (1987) place the Viséan-Namurian boundary above the Hood Island Formation (correlative of the Uist Formation) and within the lower part of the Hastings Formation (Mabou-Canso Group). The lower part of the Hastings Formation correlates with the MacKeigan Lake Formation (Fig. 7). Utting (1980, 1987) described the palynology of the Windsor Group, including the rocks herein assigned to the Uist Formation. Spore assemblages obtained from the Uist Formation type section were assigned to his Zone II, which coincides approximately with the middle Viséan or Asbian of George *et al.* (1976). Zone II (AT Zone of Utting, 1987) spore assemblages have been recovered from additional drillhole sections containing Uist Formation rocks in the Loch Lomond Basin and the Glengarry Half Graben (see Appendix 2). The AT Zone of Utting is middle Viséan (Asbian) in age.

Subdivisions

The eight carbonate members (Figs. 12 and 13) that are presently recognized are very similar to those in the Hood Island Formation. Seven of the members were previously recognized and described by Stacey (1953), including the C_1, C_2, C_3, D_1, D_2, D_3, and Big Glen Member (E_1) limestones. In addition, the Wavy Member (a correlative of the Herbert River Member) is newly defined at the base of the Uist Formation. The Herbert River Member was originally defined and described in the Minas Sub-basin by Moore (1967). Giles and Boehner (1982b), Boehner (1981), Giles (1981) and Boehner and Giles (1992) have previously reported the presence of a previously

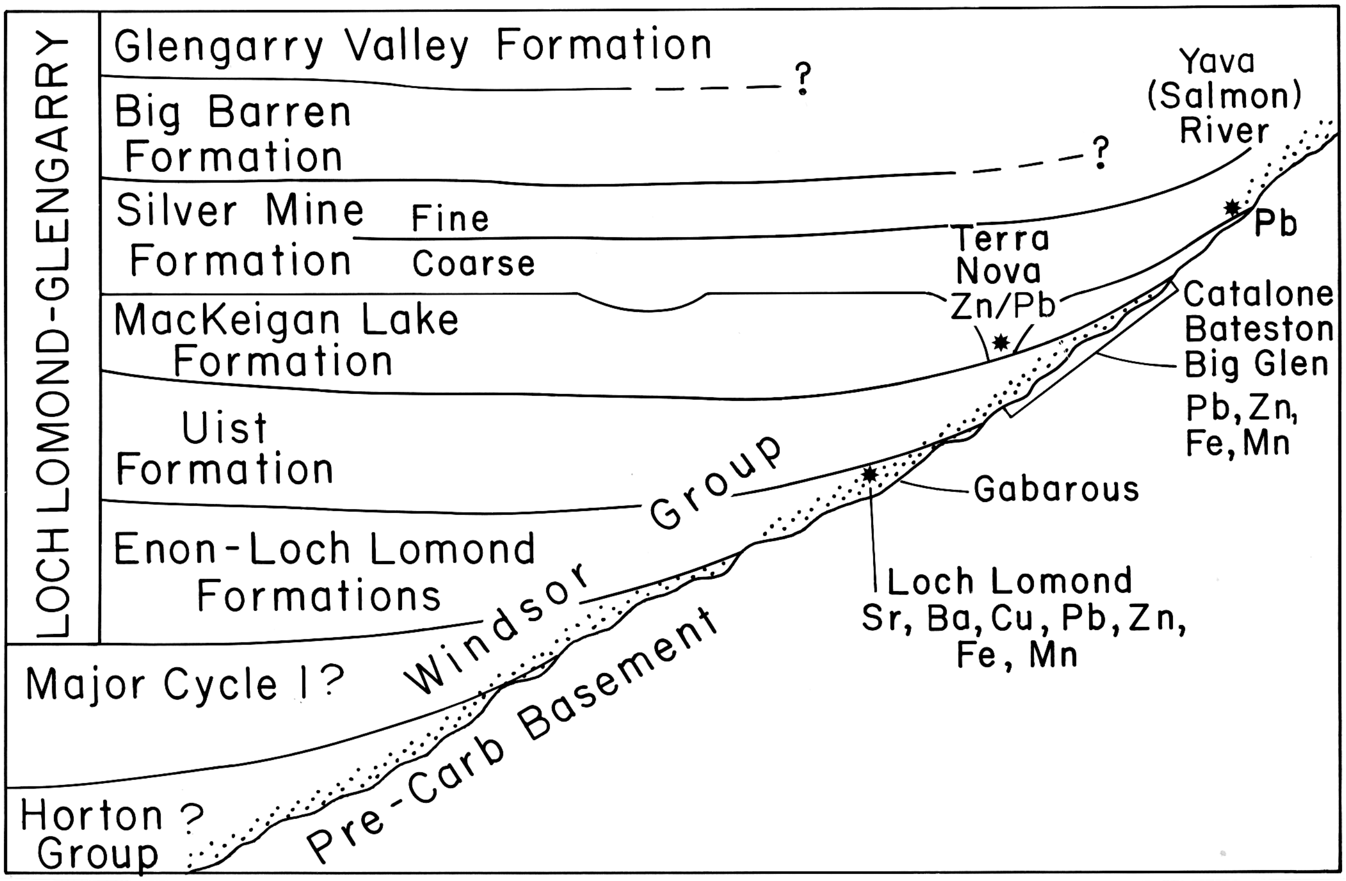


Figure 16. Diagrammatic representation of the distribution of mineral deposits in the Carboniferous basins of southeastern Cape Breton Island.

unrecognized stratigraphic section beneath the C_1 limestone in the Loch Lomond and Strait of Canso areas on Cape Breton Island (Figs. 2 and 4).

Wavy Member

The Wavy Member (Figs. 12 and 13) was intersected in numerous exploration drillholes in the Loch Lomond Basin. The member, similar to most of the carbonate members of the Windsor Group (except the Big Glen Member), does not outcrop in the area. The Wavy Member lithology is not typical of the correlative Herbert River Member described by Moore (1967), which comprises dark grey, argillaceous, shaly limestone with a basal algal stromatolitic and ostracodal unit.

Type Locality: The name Wavy Limestone was first used by Forgeron (1977) as an informal mining term for a distinctive carbonate at the base of the Uist Formation (Figs. 6 and 9). The name Wavy Member is herein formally introduced. The type section for the Wavy Member is from 642.4 to 700.0 feet (195.8 m to 213.4 m; 17.6 m thick) in Kaiser Celestite (Forgeron, 1977) diamond-drill hole K-117 (Figs. 12 and 13) near Drummondville, Richmond County, in the Loch Lomond Basin. The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Lithology: In the type section, the Wavy Member consists of distinctive light grey (whitish weathering) to grey-brown stylolitic limestone which is medium to dark grey-brown and dolomitic near the base. It is a complex lithologic section of locally highly recrystallized, arenaceous to stromatolitic limestone with interspersed grit-sandstone, calcirudite and nodular limestone. It comprises two distinct carbonate sections separated by a siliciclastic unit. The base of each of the carbonate zones is marked by a stromatolite unit in sharp contact with pebbly conglomerate. The siliciclastics are locally a very distinctive bright green. Rugose solitary corals and calcareous algae are locally preserved. The carbonate section commonly contains interbeds of conglomerate and sandstone, and the base of the member is commonly a well rounded conglomerate.

Relations to Other Units: The Wavy Member correlates with the Crawley Creek Member of the Woodbine Road Formation in the Sydney Basin, the Herbert River Member of the Hood Island Formation in the Antigonish Basin, and the Green Oaks Formation in the Shubenacadie Basin.

C_1 to D_3 Members

The C_1 through D_3 members (Fig. 12) are typical of sections described in the Hood Island Formation type section on Port Hood Island and are only generally described below.

C_1 Member: The C_1 Member (Figs. 12 and 13) is approximately 3 m thick and comprises limestone at the top overlying silty dolostone to dolomitic limestone near the base. The basal contact with grey shale and siltstone is sharp, whereas the upper contact is gradational with gypsum-anhydrite or siltstone. The top 1 m is a very distinctive unit of interbedded columnar, domal to mottled algal stromatolites.

C_2 Member: The C_2 Member (Figs. 12 and 13) is 0.9 to 1 m thick and comprises light grey-brown dolomitic limestone. The base is a sharp contact with grey shale and siltstone and the top is gradational upward through nodular gypsum-anhydrite.

C_3 Member: The C_3 Member (Figs. 12 and 13) is 4.5 to 5 m thick consisting of light grey to grey-brown, locally dolomitized limestone. The base is sharp with green siltstone and the basal units include domal to planar algal stromatolites. The upper contact is similar, with a thicker (1 to 2 m) upper unit of mottled algal boundstone.

D_1 Member: The D_1 Member (Figs. 12 and 13) comprises light to medium grey-brown dolostone with wispy dark grey organic stringers and is approximately 4.5 m thick. The basal contact is sharp with green siltstone and the upper contact is gradational with gypsum-anhydrite.

D_2 Member: The D_2 Member (Figs. 12 and 13) comprises light to medium grey-brown dolostone with dark grey shaly bands and is approximately 1.2 m thick. The basal contact is sharp with green siltstone and the upper contact is gradational with gypsum-anhydrite.

D_3 Member: The D_3 Member (Figs. 12 and 13) comprises light to medium grey-brown dolostone and is approximately 0.5 m thick. The basal contact is sharp with green siltstone and the upper contact is gradational upward over an interval of 0.6 m with nodular gypsum-anhydrite.

Big Glen Member (New Name for E_1 Limestone)

The Big Glen Member (Figs. 12 and 13) is well documented in numerous exploration drillholes in both the Loch Lomond Basin and Glengarry Half Graben. This member, in contrast to most of the carbonate members of the Windsor Group, does outcrop in the area. The Big Glen Member is very similar to the correlative E_1 Member, and each is a facies variant of the correlative Kennetcook Member described by Moore (1967) which comprises dark grey, argillaceous, shaly limestone. The Big Glen Member is up to 17 m thick and characterized by light- to medium-brown to grey-brown dolostone with distinctive dark grey, wispy, organic stringers and scattered calcite vug fillings (less than 1 cm in diameter).

Type Locality: The Big Glen Member is herein formally introduced and is named for Big Glen, located in the Glengarry Half Graben approximately 5 km east of Enon on the Salmon River Road. The type section for the Big Glen Member is from 202.8 m to 211.5 m in diamond-drill hole BB74-3 (8.7 m thick; Amax Exploration Inc., 1974) and in incomplete outcrop sections along the Salmon River Road near Big Glen, Cape Breton County. A reference section is designated in the type section of the Uist Formation, Kaiser Celestite (Forgeron, 1977) drillhole K-117 (Figs. 12 and 13), in the Loch Lomond Basin. The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Lithology: In the type area, the Big Glen Member consists of massive, sparsely fossiliferous dolostone. It is often vuggy and is locally infilled by siliceous chert nodules, which appear in part to occupy the sites where nodular evaporites occur in the subsurface. The colour may be dark brown, grey-brown, or grey. In diamond-drill core from Terra Nova and Rock Elm, the dolostone often contains interbeds of conglomerate which are lithologically similar to the lower conglomeratic unit of the Uist Formation. Small, 0.5 to 2 cm, spherical calcite eyes are ubiquitous, as are irregular dark organic stringers which give the carbonate a coarse nodular texture in some sections.

Relations to Other Units: The Big Glen Member correlates with the Dixon Point Limestone of the Woodbine Road Formation in the Sydney Basin, the E_1 Member of the Hood Island Formation in the Antigonish Basin, and the Kennetcook Member of the Green Oaks Formation in the Shubenacadie Basin. The greatest lithological similarity is with the E_1 limestone described in detail by Giles (1977 and 1980b). The E_1 member is approximately 14 m thick and is distinguished (Giles, 1977) by the presence of a basal grey micritic limestone overlain by an oolitic limestone with abundant pelecypod shells (*Schizodus*). Most of the member is thickly bedded, sparsely fossiliferous dolostone.

Sedimentology and Depositional Setting: The depositional model for the Uist Formation is very similar to that described for the underlying Loch Lomond and Enon formations. Evaporite facies are not as extensively developed but the carbonate members tend to be better developed. Conglomeratic alluvial fan facies are locally well developed especially in the marginal setting, for example at Big Glen and near the Terra Nova Fault where they predominate. The angular conglomerate units in the Glengarry Half Graben are probably remnant talus breccia or perhaps sieve deposits associated with alluvial fans. The subangular to subrounded conglomerate subunit is consistent with alluvial fan deposition, including both poorly sorted debris flow deposits with angular clasts and well sorted water-lain deposits. The high proportion of boulder sized clasts, the angularity of the clasts, and poor sorting throughout much of the sequence indicate that these conglomerates were deposited in a proximal position of the fan.

The appearance of stromatolites, interbeds of conglomerate within the dolostone, and breccia clasts suspended in mudstone in the overlying MacKeigan Lake Formation suggests that the fan deposits originated from a proximal source and were deposited into a marine or lacustrine environment during the Viséan. Although paleocurrent indicators were not observed, the clast lithology strongly suggests that the source area was the underlying Hadrynian to Devonian basement (Fourchu Block).

Mabou Group

The name Mabou Group was formally introduced by Belt (1965, 1964), who made an extensive revision of the stratigraphy of upper Viséan to lower Westphalian strata in Nova Scotia. These revisions included abandonment of the name Canso Group, which was replaced by the Mabou Group, and abandonment of the name Riversdale Group. These revisions were not widely accepted but recently they have been adopted and a dual nomenclature exists. Further revisions of Upper Carboniferous to Lower Permian rocks have been proposed by Ryan *et al.* (1991), including adoption of the Mabou Group, as an extension of Belt's original but incomplete revisions. The Mabou Group (Figs. 3, 7, 8 and 9) was described and introduced as a replacement for the Canso Group by Belt (1964, 1965) for the succession of fine-grained red and grey fluvial and lacustrine strata (grey mudrock, and red sandstone and mudrock) that overlie the Windsor Group and are in turn overlain by and laterally equivalent to a sequence of grey fluvial sandstone and mudrock ("Coarse Fluvial Facies" of Belt, 1964, 1965).

Two principal formations representative of the dominant lithofacies (end members) were described, the grey mudrock-dominated Hastings Formation, and the red sandstone- and mudrock-dominated Pomquet

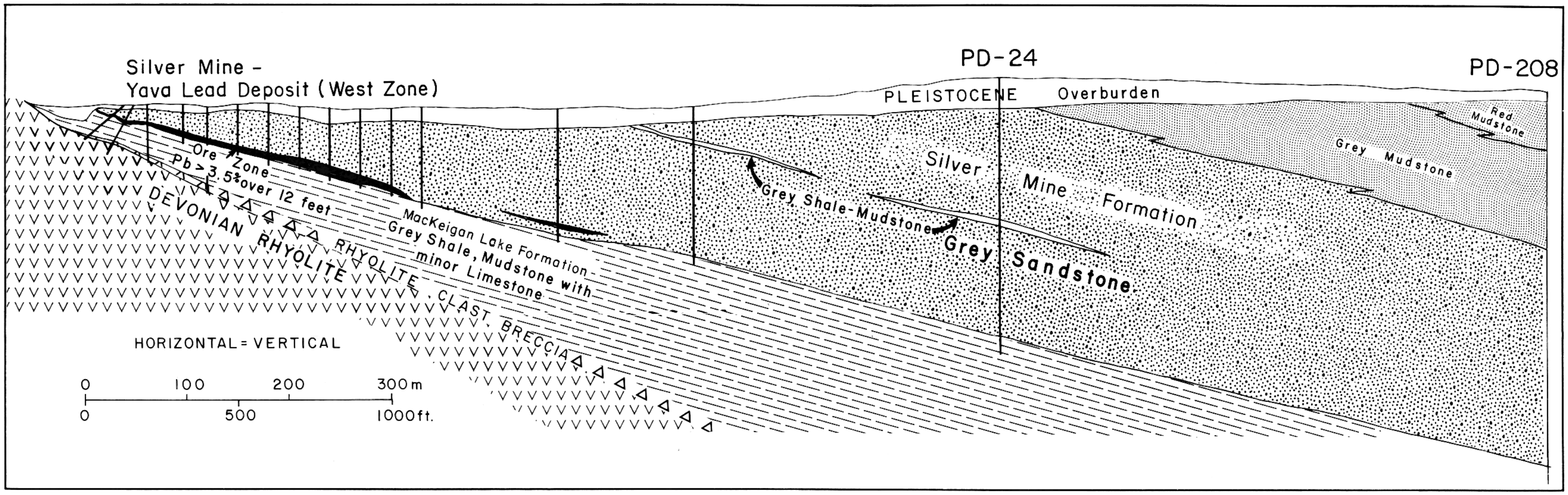


Figure 17. Geological cross-section through the West Zone of the Silver Mine (Yava) lead deposit. Location near section E-E_1, on Geological Map 85-2, in pocket.

Formation. Rocks of the Pomquet Formation are not well represented in the study area, with the exception of some thin redbeds near the top of the MacKeigan Lake Formation, which is primarily a grey mudrock and evaporite unit correlative with the Hastings Formation.

The Hastings Formation of the Mabou Group, in the type and reference areas in the Antigonish Basin (Belt, 1964, 1965; Boehner and Giles, 1992) and Strait of Canso area, comprises a sequence of grey shale with distinctive interbeds of buff to tan-brown weathered limestone and dolostone and locally evaporite interbeds, including gypsum and anhydrite. Some of the laminated carbonates are domal and planar algal stromatolites. Red siltstone and sandstone are locally present as minor interbeds. The thickness of the Hastings Formation in the Antigonish Basin is approximately 700 m. Boehner and Giles (1992) include the gypsum and anhydrite interbeds near the basal contact with the Windsor Group within the lower part of the Hastings Formation. The MacKeigan Lake Formation (new name) is applied to the correlative, predominantly grey mudrock with minor evaporites in the Loch Lomond Basin and Glengarry Half Graben and is the sole constituent formation of the Mabou Group in the area. These rocks are lithologically similar to, and correlate with, the lower part of the Hastings Formation of the Mabou Group, the Watering Brook Formation in the Shubenacadie Basin, and the Cape Dauphin and Point Edward formations in the Sydney Basin. Regionally, the Mabou Group includes strata of late Viséan to early Westphalian A age (Belt, 1964, 1965).

MacKeigan Lake Formation

Type Locality

The name MacKeigan Lake Formation is herein introduced for a section of grey mudrock, evaporites and minor thin carbonates overlying the Uist Formation (Figs. 6, 8 and 16). The formation is named for MacKeigan Lake in the type area near Big Glen, Cape Breton County. The type section description is from Amax Exploration drillhole BB-74-4 (Amax Exploration Inc., 1974) in the interval from 230.6 m to 306.3 m drilled immediately southeast of MacKeigan Lake near Big Glen (Map 85-2, in pocket). A reference section is designated in the Kaiser Celestite Mining Ltd. (Forgeron, 1977) drillhole K-117 (Figs. 12 and 13) in the interval from 14.5 m to 72.5 m. The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Distribution and Thickness

Although the formation does not outcrop, it is widely distributed throughout much of the Loch Lomond Basin and Glengarry Half Graben. It underlies the central part of the Loch Lomond Basin and the southern flank of the Glengarry Half Graben just north of and parallel to the Uist Formation. It extends along the southeastern border of the Glengarry Half Graben, except where it pinches out in the vicinity of Silver Mine (Figs. 15 and 17). The formation is 75.7 m thick (intersection) in the type section in drillhole BB-74-4, 58 m thick (intersection) in drillhole K-117 in the Loch Lomond Basin reference section, and may be reduced to no thickness by erosion where the Silver Mine Formation directly overlies the Uist Formation (e.g. Terra Nova) or basement rocks (e.g. Silver Mine). The formation is characterized as a section of grey and red mudrock with minor limestone, gypsum and anhydrite conformably overlying the Uist Formation or unconformably overlying basement. It is disconformably overlain by sandstone of the Silver Mine Formation.

Lithology

The MacKeigan Lake Formation consists of three to four distinct subunits (Fig. 10). At the base is siltstone (≤ 4 m), followed by interbedded shale, gypsum and limestone, with the gypsum gradually disappearing (≤ 78 m) and ending with fine-grained sandstone and mudstone at the top (≤ 33 m). The basal unit consists of red or green siltstone, generally well bedded and with a large clay content in its matrix, and at some localities interbedded with minor shale, sandstone or limestone.

The overlying, interbedded unit may be further subdivided. At the base, grey-black silty shale is interbedded with gypsum beds (2 to 50 cm) and a lesser amount of thin limestone beds (2 to 10 cm). This pattern typically continues up through the unit for 2/3 of the thickness; above that the gypsum disappears quite abruptly and the limestone beds increase in thickness (≤1.5 m) and number. The limestone beds are locally pelloidal or stromatolitic. Locally, very angular granule conglomerate or sedimentary breccia beds, similar in composition and texture to the Uist Formation, are present in the MacKeigan Lake Formation.

The uppermost unit consists of a mixture of red mudstone, sandstone and conglomerate. Mudstone predominates and often contains green mottling and calcrete nodules. Green-grey layering is locally observed. The sandstone units often exhibit cross lamination and fining-upward sequences. The conglomerate has granule- to pebble-sized clasts. Intraformational clasts of mudstone and sandstone predominate with a minor component of extra-formational igneous clasts. The conglomerate usually has an abrupt lower contact and fines upward into sandstone. Coaly shale beds and thin coal seams (1 to 2 cm) were observed in at least one diamond-drill hole at Rock Elm (SII-2). At the top of the formation a calcrete bed is commonly present.

Relations to Other Units

The MacKeigan Lake Formation is conformably or disconformably underlain by the Uist Formation and is disconformably overlain by the Silver Mine Formation. In some locations it lies unconformably directly on basement rocks (e.g. Silver Mine - Yava lead deposit). It correlates with the Cape Dauphin Formation in the Sydney Basin and the Hastings Formation in the Antigonish Basin.

Age

The MacKeigan Lake Formation has been assigned a late Viséan (Brigantian) age based upon palynomorph assemblages (SM Zone of Utting, 1987).

Sedimentology and Depositional Environments

The shale-limestone-gypsum unit at the base of the MacKeigan Lake Formation reflects a change from mixed marine and continental deposition in the Uist Formation to a saline lacustrine environment with sustained standing-water deposition, perhaps in a marginal limnic or a paralic environment. The thin, stromatolitic limestone beds are similar to those in the Hastings Formation of Belt (1968). Evaporite deposition low in the sequence suggests that saline and arid climatic conditions existed initially, perhaps reflecting inherited evaporitic conditions similar to those responsible for deposition of the underlying Windsor Group. Disappearance of the evaporitic phase up-section could be the result of a moderation in climate and the typical evolution from a saline evaporite basin to a continental lacustrine environment.

These evaporites are interpreted as representing waning and terminal-phase marine deposits grading to continental (playa lake) evaporite deposits. The evaporitic conditions followed the retreat of Windsor seas which left behind an elevated residual salinity in an early-stage lacustrine basin. The sedimentary sequence at the base of the MacKeigan Lake Formation records the transitional period of mixed continental, evaporite and siliciclastic deposition. A large successor lacustrine basin is interpreted to have been the primary depositional setting of the formation. Variations in the lake shoreline and/or fluvial sediment influx into the permanent but fluctuating lake produced a lateral intertonguing of grey shale and marginal basin clastics, including red sandstone, breccia and shale (alluvial and fluvial mudflat deposits).

The fine-grained red clastic unit at the top, disconformably overlain by grey fluvial sandstone of the Silver Mine Formation, appears to represent a high-sinuosity fluvial floodplain system. Evidence of this is the fining upward of the channel lag conglomerate and sandstone beds and their abrupt, erosional basal contact with the relatively thick underlying mudstone. The calcrete nodules and mottling in the mudstone suggest highly seasonal precipitation and perhaps semi-arid conditions, with fluctuations in groundwater levels on the floodplain. The stratigraphic location of this unit beneath the disconformity at the base of the overlying Silver Mine Formation indicates this reddening and duricrust may

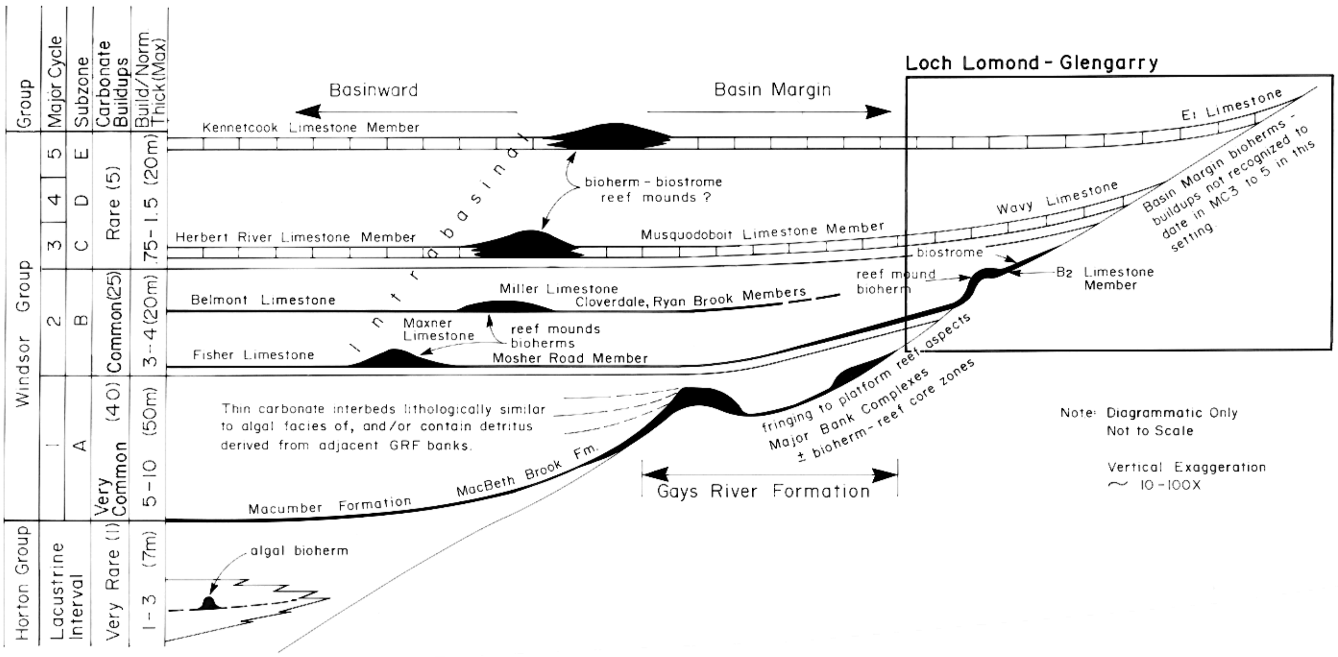


Figure 18. Stratigraphic onlap and carbonate buildups in the Windsor Group, Loch Lomond area, and the relationship to other buildups in Carboniferous basins of Nova Scotia.

have occurred at a time of slower sedimentation, hiatus and perhaps erosion. The local presence of coaly layers may indicate that water was at times sufficiently plentiful to allow peat mire development.

Cumberland Group

Rocks assigned in this report to the Silver Mine Formation (Figs. 5, 8 and 10) have previously been included in the undivided Morien Group or Riversdale Group. Following the precedent of Belt (1964, 1965) and Ryan *et al.* (1991) they are here included in the revised Cumberland Group. It is recognized that the Glengarry Valley Formation and perhaps the Big Barren Formation could be re-assigned to the Morien Group of the adjacent Sydney Basin. The status of the Morien Group is uncertain at this time as all its constituent formations could legitimately be included in the revised Cumberland Group of Ryan *et al.* (1991).

The regional stratigraphy of rocks above the Mabou Group has been problematical. Several group names have been used (Belt, 1964, 1965; Ryan *et al.*, 1991) including Riversdale (abandoned), Morien, Stellarton and Pictou. Although abandoned by Belt (1964, 1965), use of the name Riversdale Group has continued (e.g. Map 85-2, in pocket). Ryan *et al.* (1991) proposed an expanded Cumberland Group which could include the heterogeneous sandstone, mudrock and conglomerate strata (typically grey and coal-bearing) stratigraphically above the Mabou Group. They followed the precedent of Belt (1964, 1965) in abandoning the Riversdale Group and re-instated the constituent formations (e.g. Boss Point Formation) in the Cumberland Group. The upper limit of the Cumberland Group, originally Westphalian B, was extended upward to include lithologically appropriate strata as young as Westphalian D. Strata previously assigned to all, or parts of the Stellarton, Morien and Pictou groups could be included in the revised Cumberland Group. The revised upper boundary with the overlying Pictou Group dictated revision of the Pictou Group to include the thick succession of predominantly redbed strata conformably or unconformably overlying strata of the Cumberland Group. Pictou Group strata range from Westphalian D to early Permian in age and closely reflect the original type section in the Cumberland Basin.

These recent revisions have been incorporated in this report and, consequently, several of the original group assignments on Map 85-2 are obsolete and re-assigned as follows. The Riversdale Group and Morien Group are abandoned and the constituent formations, Silver Mine, Big Barren and Glengarry Valley, re-assigned to the revised Cumberland Group (Ryan *et al.*, 1991).

Silver Mine Formation

The name Silver Mine Formation is herein introduced and comes from the place name on the Salmon River Road approximately 12 km east of Enon. Although hundreds of exploration drillholes have intersected the Silver Mine Formation, no single corehole has a complete section from the base of the Big Barren Formation to the top of the MacKeigan Lake Formation. The only possible complete intersection appears to have been made in the Corcan North Glen wildcat well drilled in early 1984 (McMahon *et al.*, 1986). Details of the stratigraphy in this well are sketchy; however, the interval between 200 m and 840 m appears to be a complete section with the possible complication of faulting reported in a section of shale at a depth of 650 m.

Type Locality

The type section for the Silver Mine Formation is US Borax diamond-drill hole BBG-5 (Map 85-2, in pocket, and Appendix 1) in the interval 11.1 to 342.6 m (true thickness 316 m) located 3 km west of Silver Mine at MacDonald Lake. The upper contact is not present in BBG-5 and a reference section (drill core only partially available in deeper part of hole, NSDNR core library, Stellarton), including part of the upper units, is designated in Phelps Dodge (1964) drillhole PD-221 (from 9 to 591 m) located 1.5 km northwest of Silver Mine. A reference outcrop section is designated immediately downstream from a sharp bend in the Salmon River approximately 1.5 km west of Big Glen. Drillhole ILL-30-4 drilled by Imperial Oil is the designated reference section in the Loch Lomond Basin (interval 6 to 227 m). The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Lithology

The Silver Mine Formation is a major siliciclasic unit in the map area and comprises an interstratified sequence of medium- to coarse-grained, grey to grey-green sandstone, grey to locally reddish mudrock, and minor thin coal seams (Appendix 1). Plant debris is locally abundant, especially in the channel lag at the base of the major sandstone units where fossil logs up to 40 cm in diameter are present in the channel lag debris (Yava Mine). Pyrite nodules and stringers are commonly associated with the plant detritus and are ubiquitous in the sandstone. The lower part of the formation consists of several sandstone-dominated sections. These fine upward into an interbedded sandstone and mudstone unit. The upper part of the formation consists of interbedded sandstone, mudstone and minor conglomerate and is transitional into the overlying Big Barren Formation (Fig. 10).

Subdivisions

The Silver Mine Formation consists of three principal informal units which cannot presently be defined well enough to be given formal member status (Fig. 10). The basal unit is coarse sandstone (>225 m) followed by a finer-grained sandstone (>335 m) and a coarse sandstone at the top (>60 m).

The basal unit is a medium- to coarse-grained, grey to grey-green sandstone and consists of multistoried cycles (commonly incomplete) beginning with an erosional base, followed by massive intraformational or extraformational conglomerate and trough cross-bedded sandstone, with finer rippled sandstone and mudrock at the top. Coalified plant fragments are scattered throughout the coarser fraction and are especially abundant in the channel lag deposits. The percentage of fines in the basal unit, as calculated in two diamond-drill holes, was 5% and 11% in drillholes PD-221 (Phelps Dodge, 1964) and BBG-5 respectively. The lowermost few metres of the formation may be mineralized with galena and sphalerite (Figs. 15, 16 and 17). In these lowermost few metres, the sandstone is distinctly grey and characterized by kaolinization (Sangster and Vaillancourt, 1990a and b).

The middle unit is finer grained and consists of mudstone, siltstone, and sandstone which may be green, grey-green or red. The percentage of fines increases substantially in this unit and varies from 63% to 82% in drillholes PD-221 (Phelps Dodge, 1964) and BBG-5 respectively. Thin coal seams and carbonaceous shale are prominent, averaging 1 to 2 cm thick with one seam being almost 2 m thick (including minor shale partings).

The upper unit exhibits a return of a coarse-grained grey sandstone similar to the basal unit. Coal fragments are abundant and the unit is intercalated with the overlying Big Barren Formation (section in the bottom of drillhole TN78-42, Appendix 1); the upper contact, therefore, is transitional.

Distribution and Thickness

The Silver Mine Formation is widespread in the Glengarry Half Graben and in the north-central part of the Loch Lomond Basin. The formation has a thickness in the range of 600 to 650 m where complete (Fig. 15).

Relations to Other Units

The Silver Mine Formation disconformably overlies the MacKeigan Lake Formation. Evidence for this is a caliche horizon that occurs at the contact and is interpreted to be a paleosol (Bonham *et al.*, 1982). The Silver Mine Formation sandstone beds overstep the underlying mudrock of the MacKeigan Lake Formation and rest directly on basement rocks (e.g. Yava Mine). In the Terra Nova area the sandstone beds rest on an eroded landscape of Uist Formation carbonates and clastics, with the MacKeigan Lake Formation and the upper units of the Uist Formation apparently removed by erosion. The Silver Mine Formation is conformably overlain by the Big Barren Formation and the contact is an intercalated transition.

Sedimentology and Depositional Environments

The basal coarse unit appears to represent the distal reaches of a braided river system, first interpreted as such by Bonham *et al.* (1982). The characteristic fining-upward cycles probably indicate channel fill and channel bar deposits in braid channels with minor mudrock as abandoned channel fill or overbank deposits. The channel lag accumulated on an erosional surface during peak flooding, followed by formation of dunes and rippled bar tops as flood waters subsided. Incomplete cycles and multiple stacked erosional surfaces may be explained by rapid shifting of the braid channels, eroding into previously deposited cycles. An alternative might be renewed flooding with scour and fill within a relatively stationary channel. The coal layers and fragments generally represent plant debris that was deposited as part of a channel lag. The abrupt contact of the mudstone and siltstone with underlying coarse channel sandstone and conglomerate is interpreted to be the result of abandoned channel deposits where fines were introduced only during peak floods. Well defined overbank deposits were not observed. The limited paleodispersion data presented by Prime (1984) are insufficient to interpret the paleoflow history in the area.

There is a gradational change upward into the finer-grained sandstone unit, indicating a shift to a higher sinuosity fluvial system, perhaps an anastomosing system. The associated mudrocks are interpreted as flood basin deposits. Shallow lakes may also have developed on the floodplain, suggested by the thick grey shale beds. The occurrence of coaly shale and thin coal seams suggests that peat mires developed locally on the floodplain. The absence of outcrop and extremely limited availability of diamond-drill core for examination has resulted in a very generalized interpretation of this fine-grained unit.

The top unit appears to represent a return to the distal braided river conditions observed in the basal unit. The intercalated nature of this unit and the limited sections available at this stratigraphic level have made interpretation difficult.

The abundance of coaly material throughout the Silver Mine Formation suggests that a moderate climate prevailed with sufficient water to permit the development of peat mires.

Age

Based on palynomorphs, the Silver Mine Formation has been assigned a Namurian to early Westphalian age (Barss, written communication, see Appendix 2).

Big Barren Formation

The name Big Barren Formation (Figs. 5, 8 and 10) is herein introduced and is derived from the name Big Barren applied to the elevated barren in the central part of the Glengarry Half Graben. This area is underlain primarily by conglomerate of the Big Barren Formation and is situated 3 km north of the Salmon River (Map 85-2).

Type Locality

The type section (327 m true thickness) is from Imperial Oil (Esso Minerals) diamond-drill hole TN 78-42 (Map 85-2 and Appendix I) drilled near Terra Nova, Cape Breton County. An outcrop reference section (87 m thick and incomplete) is designated nearby at a location upstream from where McIsaac Brook enters the Gaspereaux River (Map 85-2). The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Lithology

The Big Barren Formation is dominated by red polymictic orthoconglomerate and has a generally consistent lithologic character from base to top (Appendix 1). It comprises interbedded red conglomerate with subordinate sandstone and mudstone. It is well stratified, with beds generally massive although imbrication and cross-bedding were locally observed. Some beds fine upward. Mottling, green layering, and mud clasts are locally present. The conglomerate clasts ($\leq$20 cm) are well rounded, clast supported, well sorted, and consist predominantly of mature resistant rock types, including quartzite and volcanic rocks, with less abundant granitoids. The Big Barren conglomerate contrasts with the very immature (angular to subangular), heterogeneous and granitoid-rich older conglomerates in the Windsor Group.

Distribution and Thickness

The Big Barren Formation occurs in a very restricted, elongate outcrop area in the central and northern half of the Glengarry Half Graben and has a maximum projected thickness of 700 m. The maximum true thickness of approximately 250 m was intersected in the type section drillhole TN 78-42 (5.4 to 297.8 m), which is incomplete at the top (Appendix 1).

Relations to Other Units

The contacts of the Big Barren Formation are conformable and intercalated with the underlying Silver Mine Formation and the overlying Glengarry Valley Formation respectively (Appendix 1). The inferred early to middle Westphalian age and stratigraphic position of the Big Barren Formation indicate an approximate correlation with the Cumberland Group (Ryan *et al.*, 1991) in the Cumberland Basin and perhaps correlation with part of the South Bar Formation in the adjacent Sydney Basin.

Sedimentology and Depositional Environments

This conglomerate-dominated sequence appears to represent a proximal braided river or braidplain. The well rounded and mature nature of the clasts indicates a distal source and/or extensive reworking. The very limited paleocurrent data obtained were not consistent and were insufficient to define any identifiable transport pattern.

Age

The specific age of the Big Barren Formation could not be directly determined due to the absence of sediment containing dateable palynomorphs. An age range, however, may be inferred from its stratigraphic position between, and its transitional contacts with, the underlying Silver Mine Formation (late Namurian to Westphalian A) and the overlying Glengarry Valley Formation (late Westphalian C to Westphalian D). The limits thus suggested are early to middle Westphalian (possibly late Westphalian A to early Westphalian C).

Glengarry Valley Formation

The name Glengarry Valley Formation (Figs. 5, 8 and 10) is herein introduced for a succession of grey and red sandstone and mudrock with minor coal seams overlying the Big Barren Formation in the Glengarry Half Graben. It is named for a former coal mining area located 2.5 km northeast of Terra Nova and 9 km west of Silver Mine (Map 85-2). The Glengarry Valley Formation is the youngest rock unit in the study area and is incomplete at the erosional upper contact with Pleistocene glacial deposits.

Type Locality

The type section (139 m thick) is designated in diamond-drill hole Algas AGG E-14 (Map 85-2, Appendix 1) drilled near Gaspereaux Lake in the Glengarry Valley. A short outcrop reference section is designated on the Gaspereaux River upstream from the road that goes to the abandoned coal mine site and a reference drillhole section is designated in NSDM G-1. The drill core is stored at the Core Library of the Nova Scotia Department of Natural Resources in Stellarton.

Distribution and Thickness

The formation has a very limited outcrop distribution and is confined to a relatively small elliptical area (4 km by 2 km) in the axis of the Glengarry Syncline. The maximum projected thickness is approximately 300 m.

Lithology

The Glengarry Valley Formation consists of fine-grained green-grey or red sandstone, siltstone, mudstone and shale (Appendix 1). There are extensive thicknesses of interstratified sandstone and shale. Flaser bedding and bioturbation are locally abundant. Fragmentary coaly material is found throughout the section along with local thin coaly shale and coal seams. Nodular calcrete is locally present.

Relations to Other Units

The Glengarry Valley Formation is the youngest Carboniferous rock unit in the map area. The lower contact with the Big Barren Formation is conformable and gradational through intercalation. The upper contact is an angular unconformity with the overlying Pleistocene till. The Glengarry Valley Formation is generally lithologically similar to, and approximately the same age as the South Bar and Waddens Cove formations of the Morien Group in the Sydney Basin.

Sedimentology and Depositional Environment

The Glengarry Valley Formation probably represents a mixture of fluvial and standing water deposition. The sandstone units are fluvial channel deposits whereas the thick units of burrowed siltstone, shale, and flaser bed sandstones are interpreted as marginal lacustrine facies. The strata, at least in this location, appear to represent deposition from a river system into a body of standing water. The coal seams indicate that conditions were locally conducive to peat development. The red and mottled interbeds and calcrete nodules suggest a seasonal climate with dry periods, lowered water tables and subaerial exposure.

Age

Palynomorphs recovered from drillhole sections for the Glengarry Valley Formation indicate a late Westphalian (C to D) age (M. S. Barss, written communication, Appendix 2).

Summary of Sedimentary History

The sedimentary record and facies relationships near the present day outcrop limits indicate the Loch Lomond Basin and Glengarry Half Graben are closely related structural entities and were originally part of the same depocenter. They are, however, the erosional remnants of a formerly much larger depocenter whose original extent is unknown (Figs. 2 and 3). Evidence supporting lateral facies changes characteristic of a self-contained system (e.g. fault scarp alluvial fanglomerates or onlap unconformity) cannot be distinguished on the northwest border of the basins, formed by the Lennox Passage Fault. Coarse-grained alluvial fanglomerates typical of a simple sedimentary half graben basin are not evident in the drill core or in outcrop.

Based upon the stratigraphic record along the southeast border, the earliest sedimentation occurred during the middle Viséan with the development of a pediment alluvial fan complex along the unconformable basin edge (basal conglomerate unit). Subsequently, and probably penecontemporaneously, marine incursion and deposition occurred basinward. The marine evaporitic and continental alluvial fan environments occasionally overlapped during deposition of the Enon, Loch Lomond and Uist formations (Figs. 8, 11 and 12). Alluvial fan development probably occurred in conjunction with uplift of the Fourchu Block source area. The stratigraphically higher conglomerates in the Windsor Group appear to be located proximal to the Terra Nova Fault (e.g. MacRae celestite pit and nearby drillholes, Fig. 12 and Map 85-2). An active link with synsedimentary faulting may explain this coincidence. During the late Viséan and early Namurian, increased basin stability and arid to semi-arid (seasonal) climatic conditions existed, as indicated by the deposition of a thick sequence of shale, limestone and anhydrite-gypsum (MacKeigan Lake Formation, Fig. 8). This intercalated sequence was deposited during the transition from marine to non-marine deposition in the basin. With a change in climate, water chemistry and/or basin configuration, evaporite deposition eventually ceased. Mudrock deposition in standing water continued until a high sinuosity fluvial system became dominant. Arid to semi-arid seasonal conditions prevailed at the end of MacKeigan Lake Formation deposition. This terminated with subaerial conditions and subsequent development of an erosional landscape affecting rocks of the Uist and MacKeigan Lake formations.

A period of non-deposition or erosion is interpreted to have occurred with the development of a paleosol at the top of the MacKeigan Lake Formation. A braided river system then prevailed during the late Namurian (Silver Mine Formation). The overlying Silver Mine Formation (Fig. 8) eroded down through the MacKeigan Lake Formation and into the Windsor Group, and contains locally abundant recycled material including mudstone and carbonate clasts. This erosional relationship indicates an episode of uplift and tectonic instability. During the late Namurian and early Westphalian, the braided river system was gradually transformed into a high sinuosity river system which eventually returned to braided river conditions. These fluvial deposits were probably derived from a distant source outside of the Glengarry Half Graben area, with modest local input from transverse drainage (e.g. off the basement terrain to the southeast). The basins may not have been active fault-controlled features at this time, with sediment accumulation reflecting more regional trends. During the early Westphalian (possibly B to early C), an alluvial fan system (possibly distal) or coarse gravelly braided river system was activated and occupied the basin during a period of increased basin instability (Big Barren Formation; Fig. 8). Stability apparently returned to the area in the late Westphalian with the widespread deposition of fluvial sediments with regional sources intercalated with lacustrine and peat deposits (Glengarry Valley Formation). The lithology and depositional environments of the Glengarry Valley Formation are similar to the correlative Sydney Mines Formation in the adjacent Sydney Basin (Figs. 2 and 4).

It should be noted that the sole appearance of fine-grained fluvial, lacustrine, or marine sedimentary rocks at a specific time does not preclude the existence of coarser-grained sediments being deposited contemporaneously. Coarser marginal facies may have been present along the basin margins, which probably existed outside of the present outcrop limits. The occurrence of the Silver Mine Formation onlapping basement along the southeast border and the modest relief on the surrounding basement indicate much of the basement terrain was probably blanketed by the late Namurian to early Westphalian.

Structure

The Loch Lomond Basin and Glengarry Half Graben (Map 85-2, in pocket) are identified as structural features (Keppie, 1982) and not necessarily as depositional basins. These disrupted structural remnants are contiguous and have a prominent northeast - southwest structural trend. This trend reflects the regional Appalachian structural fabric and is emphasized by the Lennox Passage Fault, the major basin-bounding fault. The extension to the northeast is truncated by the Mira River Fault (the south boundary of the adjacent Sydney Basin) which converges with the Lennox Passage Fault (Fig. 4). The Loch Lomond Basin and Glengarry Half Graben are essentially fault-truncated synclines and are typical of the numerous small structural elements that constitute late Paleozoic structural basins in Atlantic Canada (Fig. 2). They are bounded to the northwest by the Lennox Passage Fault, a northeasterly-trending, high-angle fault which separates the basins from Hadrynian to Devonian igneous basement of the East Bay Block. In the middle of the map area is the Terra Nova Fault, a northwesterly-trending, high angle, transverse fault which separates the Glengarry Half Graben from the Loch Lomond Basin. The southeastern boundary of the basins is a profound angular unconformity with rocks of the Fourchu Block Hadrynian to Devonian basement (Figs. 5 and 8).

Strata within the basin areas form asymmetric synclines in which bedding generally dips gently (10°) toward the basin centre, but with very steep to overturned dips along the Lennox Passage Fault which truncates the basins to the north. Dips on the basement unconformity, as interpolated from drilling data, are in the range of 10 to 15° in the more central parts of the basin and from 20 to 35° along parts of the southern margin. These steeper dips reflect, in part, the greater erosional relief and perhaps are related to early block faulting. The slope on the present day ground surface updip from the unconformity is also typically less than the mean dip on the unconformity, suggesting that post-Carboniferous erosion has probably occurred and that the updip landscape may not necessarily be the unaltered Carboniferous paleotopography as interpreted by Sangster and Vaillancourt (1990a and b).

Folds

Rocks in the Loch Lomond Basin and Glengarry Half Graben have been folded into two asymmetric synclines, the Enon and Glengarry synclines (Map 85-2, in pocket). The major fold features are probably related to movement on the major faults and represent the remains of a fault-truncated, synformal basin. Small scale folding is rarely recognizable in outcrop but locally complex and chaotic folding is probably present adjacent to the faults. A significant fold structure was recently encountered during drilling in the Loch Lomond Basin near Lake Uist. At this location, an isoclinal recumbent fold involving the MacKeigan Lake, Uist and Loch Lomond formations was intersected and is the first documentation of this type of structure in southeastern Cape Breton Island. Although it was unexpected, it is not totally surprising given the proximity to the highly disrupted geology adjacent to the Lennox Passage and Grand River faults and the L'Ardoise Block. A similar structure was previously described in the northern part of the Shubenacadie Basin (Giles, 1977) confirming the radical change in structural character possible over short distances in these basins (Boehner, 1992).

Faults

The major faults in the Loch Lomond Basin and Glengarry Half Graben may be subdivided into several categories using criteria such as their orientation and latest apparent sense of movement, and they include: high- angle longitudinal faults with northeast-southwest orientation (transcurrent wrench), high-angle transverse faults, and high-angle block faults with northwest to north trends. High-angle longitudinal faults (e.g. Lennox Passage, Grand River and nearby Big Pond Fault) are responsible for the pronounced northeast - southwest linearity in the borders of the basins (Fig. 5 and Map 85-2, in pocket). These major faults converge with and are genetically related to the east-west Bateston Fault, on the south border of the Sydney Basin, and the Mira River Fault. They are extensions or components of a complex structural system extending from the Strait of Canso - Chedabucto Bay area, situated immediately north of the Cobequid - Chedabucto Fault System.

All the high-angle longitudinal faults have components of dextral strike-slip and dip-slip offset. The details of the movement kinematics are rarely described, except in the adjacent Big Pond area by Bradley and Bradley (1986) who described evidence for dextral offset. Apparent strike-slip movement on the Lennox Passage and related faults is difficult to estimate. However, the anomalous structural relationships with the L'Ardoise Block and related Windsor Group Major Cycle 1 in the Lochside -Hay Cove area indicate movements in the order of kilometres. Relative dip-slip movement is inferred to be in the range of 1000 m on the basis of the offset evident in adjacent stratigraphic units. The amount of strike-slip movement on the Lennox Passage, Grand River and Bateston system may be in the order of tens of kilometres or more. Although the faults are interpreted as nearly vertical normal faults, some or all may entirely have a high-angle reverse geometry. Drill intersections and outcrops of near vertical to overturned strata along the northwest border contact, together with the isoclinal recumbent fold in a recent exploration drillhole near Lake Uist, offer support for the reverse fault or local overthrust configuration. This may be related to emplacement of the L'Ardoise Block and/or the faulted contact to the north with the East Bay Hills. Northeasterly-trending longitudinal faults are also inferred to be present in the East Bay Hills area south of the Big Pond Fault extension (Bradley and Bradley, 1986). These appear to be a genetically related set and are probably subsidiary to the Lennox Passage Fault.

Major transverse faults in the area are not as common as the longitudinal faults. The Terra Nova Fault is interpreted as a high-angle fault whose offset is not clearly defined. At the north end it offsets the major Lennox Passage fault with at least 1.5 km (apparent sinistral) displacement. To the south, the apparent dextral offset of 1.5 to 2 km is based on the outcrop patterns and the dip-slip offset is perhaps up to 600 m. The apparent relationship interpreted to the north near Terra Nova is incompatible with a simple kinematic interpretation. Two explanations are offered: (1) the fault segment identified near Terra Nova is not the direct continuation of the southern segment, which truncates the Loch Lomond Basin but is a coincident juxtaposition, and (2) the apparent sinistral offset of the Lennox Passage Fault was a later movement confined to the northern segment and related perhaps to high-angle reverse or thrust faulting of basement rocks (e.g. Irish Cove Pluton) over the Loch Lomond Basin, conceivably at a restraining or convergence bend or splay in the Lennox Passage Fault.

Economic Geology

Exploration for mineral deposits in this region has had a long history with minor mining of manganese and coal. Several celestite, lead and barite mining projects were active from the mid-1970s to early 1980s. Major mineral prospects and occurrences (Fig. 5 and Map 85-2, in pocket) include the extensively mined Enon celestite deposits in the Windsor Group (Kaiser Celestite Mining Limited, mid-1970s), the Pine Brook barite prospect in the Windsor Group, the Terra Nova sandstone-hosted Zn-Pb occurrence, and the Yava (Silver Mine or Salmon River) sandstone-hosted Pb deposit (Fig. 17). Although substantial celestite (Andrews and Collings, 1991) and lead resources (Patterson, 1988a, b and c; Sangster and Vaillancourt, 1990a and b) are present in the area they are not currently attractive, mainly due to low prices and poor market conditions. Numerous base metal occurrences have been identified in the area by previous workers. Historically, manganese was mined in limited operations in the McCuish Brook area near the turn of the century (Bishop and Wright, 1974). Lead mineralization is ubiquitous along the Big Glen - Silver Mine outcrop belt and significant production was achieved by Yava Mines at the West Zone of the Silver Mine deposit in the early 1980s (Fig. 17). Gypsum, which occurs in great abundance in the subsurface, does not outcrop and has very limited quarrying potential in the area (Adams, 1991). Limestone and dolostone may have been produced in very small quantities in the past but formal records are not available. Petroleum exploration drilling was undertaken in 1982 by Corcan Engineering Ltd. at North Glen and Loch Lomond (McMahon *et al.*, 1986). However, both of these wildcat wells were dry and were abandoned. Coal was mined in a thin seam in the Glengarry Valley area (Weeks, 1954) but no indications of substantial deposits have yet been identified in the Glengarry Valley Formation. Some potential for coal also exists in the underlying Silver Mine Formation.

Detailed investigations of the mineral deposits in the area were not undertaken in this project and the reader is directed to the numerous available reports, maps, theses and publications cited. Mineral deposits and occurrences in the Loch Lomond area are well documented by Forgeron (1977), Binney and Kirkham (1974), Fowler (1988) and Chatterjee (1983). Barite and celestite resources are further described by Felderhof (1978) and Dawson (1985). The geology and genesis of the sandstone-hosted lead and zinc deposits in the Glengarry Half Graben are well documented by Vaillancourt (1985), Vaillancourt and Sangster (1984, 1986), Sangster and Vaillancourt (1990a and b), Bonham *et al.* (1983), Bonham (1983), Scott (1978) and Patterson (1988a, b and c).

Metallic Minerals

Exploration for base metals has been focused in two basic settings: (1) at several stratigraphic levels in the Windsor Group, especially where carbonates and redbeds onlap basement, and (2) in the basal sandstone of the Silver Mine Formation where it rests directly on basement or older Carboniferous strata. The Windsor Group association is generally similar to most other Carboniferous basins in Nova Scotia, but minerals occur in greater abundance and at higher stratigraphic levels (Boehner and Ryan, 1990; Ryan and Boehner, in prep.). This mineralization at higher stratigraphic levels is related spatially to the progressive onlap unconformity setting (Fig. 16).

Principal base metal occurrences include the Enon - Loch Lomond base metal occurrences identified by Forgeron (1977). The Snake Brook (Pb-Zn), MacVicar (Pb-Zn), MacKeigan (Zn-Pb) and MacIntyre (Pb-Zn-Ag) showings occur in the Windsor Group, and the MacLeod showing (Pb-Cu-Zn) occurs in basement rocks adjacent to the basin. Significant base metals are also associated with the Pine Brook barite prospect and also with the celestite deposit at the MacRae pit (Fig. 5 and Map 85-2, in pocket) and the Shaw celestite occurrence (Forgeron, 1977) near the MacIntyre occurrence. Lead minerals, with or without zinc, are pervasive along the southeast border of the Glengarry Half Graben. Minerals occur in the Big Glen Member at the top of the Windsor Group (e.g. Big Glen) and at the base of the overlying sandstone of the Silver Mine Formation (e.g. Yava or Silver Mine deposit, Pb; Big Glen prospect, Pb; and the Terra Nova prospect, Zn-Pb).

Copper minerals, principally malachite, chalcopyrite, azurite and chalcocite, as well as galena, sphalerite and equivalent oxides, are commonly associated with oxidation-reduction boundaries (e.g. redbed - marine carbonate contacts) in trace to minor amounts. These occurrences are abundant in the Enon - Loch Lomond area near the base of the Windsor Group. The mineral associations are described by Binney (1975), Binney and Kirkham (1974), Kirkham (1974, 1978, 1985), Forgeron (1977) and Smith and Collins (1985). The minerals are concentrated in the green reduced zone in siliciclastic rocks immediately beneath the organic-rich marine carbonates. These occurrences are similar to those of the basal Macumber Formation. They occur as disseminations, minor aggregations and as clast coatings in conglomerate and sandstone and also within the lowermost part of the carbonates. Binney (1975) concluded that the metals were leached from redbeds of the basal conglomerate unit and migrated in metal-bearing groundwater in aquifers controlled by the paleotopography at the unconformity. The metals were deposited in the vicinity of organic-rich reducing strata, especially the B_1 Limestone. This is essentially the model of Kirkham (1978) applied to mineralization in the basal Macumber Formation - Horton Group contact. This type of mineralization has also been described elsewhere in Nova Scotia, including the Antigonish Basin, by Binney and Kirkham (1974, 1975), Binney (1975), Kirkham (1978), Bourque (1981) and Northcote *et al.* (1989). The mineralization has been interpreted as representing early diagenetic sedimentary processes localized at an oxidation - reduction interface where marine rocks were deposited upon continental clastics. Minor to trace amounts of galena occur filling the pores, fractures and cavities of the celestite-barite zones in the Loch Lomond Basin, especially in the MacRae celestite pit where average Pb content of the celestite ore was nearly 0.5%. This deposit is adjacent to and disrupted by the Terra Nova Fault and the disseminated to fracture-fill galena is perhaps related to the lead ore in the Big Glen - Silver Mine outcrop belt.

The bioherm - biostrome buildup facies of the B_2 Limestone were exploration targets as potential hosts for base metal deposits of the Gays River type. Although the buildups (Fig. 18) are locally well developed on the basement highs near Enon, they are not known to occur as large buildups like those of the Gays River Formation (Giles *et al.*, 1979; Boehner, 1988, 1989). They are not extensively dolomitized or mineralized, as only trace to minor chalcopyrite, galena and barite are present as disseminations (e.g. MacVicar showing). Celestite mineralization is locally associated with the B_2 Limestone buildups (Fig. 9).

Trace to minor amounts of lead sulphides and locally zinc sulphides are ubiquitous in the Big Glen Member and in grey organic-rich sandstone at the base of the Silver Mine Formation in the outcrop belt between Big Glen and Silver Mine. The minerals are present in outcrop and have been confirmed in numerous drillholes by a variety of exploration companies. The mineralized rock reaches economic grades in the Silver Mine (Yava) lead deposit (Sangster and Vaillancourt, 1990a and b) at the apex of the onlapping Silver Mine Formation (West, Central and East zones). Bonham *et al.* (1982) identified preproduction reserves in the three zones (proven, probable and potential) as follows: 4% cut-off = 3.97 million tonnes (mt) of 5% Pb with 1.63 mt at 4.9% Pb; 3.5% cut-off = 6.46 mt of 4.1% Pb with 4.44 mt at 3.9% Pb; 2.5% cut-off = 11.0 mt of 3.5% Pb with 5.9 mt at 3.3% Pb. Other workers who have described these deposits include Bonham (1982), Scott (1978), Patterson (1988), Vaillancourt and Sangster (1984, 1986) and Vaillancourt (1985) as well as unpublished mineral assessment reports by staff of Talisman Mines, Phelps Dodge and others. The most recent work on the geology of the Yava lead deposit was done by Sangster and Vaillancourt (1990a and b). They characterize the deposit as a sandstone-hosted lead deposit similar to the Laissval type, but hosted in continental rocks (Bjorlykke and Sangster, 1981). The Yava deposit was formed during very early diagenesis in porous, grey, altered sandstone. Highest grades are localized in organic-rich (coaly debris) fluvial paleochannels above a disconformity landscape. Sulphides infill porosity and are associated with kaolinization of feldspars and related silicification by released silica. The metal component was derived from local basement rocks through the destruction of minerals such as feldspars. Metals were transported down-dip into the sandstone in the basin by groundwater, where the fluids reacted with solutions containing sulphur. The sulphur source is compatible with derivation from the underlying Windsor or Mabou group evaporites.

Non-Metallic Minerals

Veins

Vein mineralization, with calcite and minor amounts of barite, fluorite and dolomite, is commonly associated with the deformed Macumber Formation outcrops in the St. Peters - Hay Cove - McNabs Cove area located 15 km southwest of the Loch Lomond Basin (Felderhof, 1978). Vein mineralization is not abundant in the Loch Lomond Basin except in the vicinity of the Terra Nova Fault where veins disrupt the MacRae celestite ore zones.

Celestite-Barite

Stratiform and stratabound celestite deposits are well documented in Windsor Group rocks of the Loch Lomond Basin by Forgeron (1977), Felderhof (1978), Choo (1972), Andrews and Collins (1991) and Dawson (1985). Felderhof (1978, after Forgeron, 1977) identified total celestite resources in the Enon - Loch Lomond area as approximately 1.9 million short tons with representative composition in the range of 30 to 60% SrO. Barite is also present but is not as extensive as celestite. Barite occurs in a significant stratabound deposit near Pine Brook where it is associated with trace amounts of base metals. In addition, a minor occurrence as a cement in the basal conglomerate map unit occurs near the MacRae celestite pit. Although deposits of the Walton type (Boyle, 1963, 1972; Boyle *et al.* 1976) have not been described in the present study area, the structural setting is generally similar.

The celestite occurs typically as stratabound mantoes ranging from a few centimetres to 9 m in thickness. The celestite is located within marine carbonate members or at various contacts between carbonates and overlying evaporites (gypsum after anhydrite), redbeds and evaporites, or between carbonates and redbeds, locally including conglomerate. Several models have been proposed for the origin of celestite in the Loch Lomond Basin. Hudgins (1969) postulated that the mineralization was partly related to magmatic hydrothermal solutions derived from late post-Carboniferous dioritic intrusions. Crowell (1971) reiterated the Hudgins model and further suggested two alternatives not related to hydrothermal fluids: (1) synsedimentary to diagenetic precipitation associated with $CaSO_4$ and (2) replacement of $CaSO_4$ by celestite through Sr substitution for Ca during late diagenesis. Choo (1972) concluded that the mineralization was related to repeated sedimentary coprecipitation between the deposition of the marine carbonates and the calcium sulphate that typically overlies it (Crowell's alternative 1). Boehner (1981) speculated on an unconformity-related, karst process involving dissolution and hydration of evaporites, remobilizing the strontium-enriched evaporites in an updip position (variation of Crowell's alternative 2). This process had previously been suggested by Forgeron (1971, 1977) in unpublished mineral assessment reports on exploration in the Sydney River and Frenchvale celestite prospects. Anhydrite typically may contain 0.1% Sr, which must be liberated during the hydration process since gypsum will only absorb Sr at a level of tens of ppm. This theory has yet to be fully tested in the Loch Lomond Basin. Tectonism related to major faults in the area and perhaps elevated thermal activity may have been an important driving mechanism for mobilizing the mineralizing fluids that generated the extensive celestite, barite and base metals associated with the Windsor Group.

Limestone and Dolostone

The limestone and dolomite (dolostone) deposits and occurrences in the Loch Lomond Basin and Glengarry Half Graben have been described by Shea and Murray (1967). The most important occurrences are located within the Windsor Group (e.g. Big Glen) although no production has been recorded.

Gypsum

Gypsum exposures and areas of karst topography are very rare in the Loch Lomond Basin and Glengarry Half Graben due to thick cover by surficial deposits. Karst topography is evident in the Lochside area and is well developed in the Hay Cove area southwest of the map area (Adams, 1991). Subsurface data indicate that, throughout much of the study area, dissolution of gypsum has resulted in the virtual removal of this material and the development of karstic collapse and trench fill in its former position. Gypsum and andydrite are thus present mainly in the deeper subsurface environment. Multiple generations of karst development probably occur in evaporitic sections of the Windsor Group peripheral to the basins. The geological timing of the formation of breccia and weathering features is not clearly defined. Karst rejuvenation would make the determination of age relationships very difficult. Local erosion and karstification of the evaporite outcrop areas around the perimeter of the basin occurred both at the same time as sedimentation (Viséan) and at the unconformity beneath the Silver Mine Formation (middle to late Namurian). This depositional hiatus was important in determining the local paleotopographic control of basin margin sedimentation.

Summary and Conclusions

The Loch Lomond Basin and Glengarry Half Graben are connected structural basins comprising strata that range in age from Early to Late Carboniferous (Viséan to early Westphalian D). This sedimentary succession is dominated by siliciclastic strata and has an estimated stratigraphic thickness of up to 2000 m in the Glengarry Half Graben, but less than 1000 m in the Loch Lomond Basin (Map 85-2, in pocket). The strata within the area progressively onlap Hadrynian to Devonian rocks of the Fourchu Block, which collectively form an igneous and metasedimentary basement. The L'Ardoise Block, comprising deformed siliciclastics that correlate with the Horton Group (in part), is interpreted to be an allochthonous block emplaced by strike-slip fault movement.

The basal part of the succession comprises an uncertain thickness, probably exceeding several hundred metres in the Grand River area southwest of the Loch Lomond Basin, of red and green conglomerate, mudstone and sandstone. These rocks were not mapped extensively in this study and were assigned to an undivided basal conglomerate map unit. The basal conglomerate units record the early stages of development of a continental basin with piedmont alluvial and fluvial deposition as local marginal facies of the lower Windsor Group. The thick evaporites that typically constitute Major Cycle 1 of the Windsor Group (Giles, 1982) are not present in the basins and are apparently represented by coarse redbed alluvial fan deposits which are overlain by strata typical of Major Cycle 2 (Fig. 7). The continental alluvial fan to alluvial plain sedimentation at the basin edge was eventually inundated by the Windsor seas during deposition of Major Cycle 2.

Regionally, Major Cycle 2 comprises a package of interstratified gypsum, anhydrite (locally salt and potash), limestone, dolostone, and red siltstone and sandstone. This represents repeated marine transgressions and regressions individually recorded by fossiliferous marine carbonates overlain by nodular sulphate and continental clastics. The marine carbonates and related evaporite and redbed facies of the middle Viséan Enon and Loch Lomond formations indicate that the marine invasions occurred over a terrain with substantial local paleotopographic relief and was accompanied by significant input of marginal basin siliciclastics. The carbonate rocks are shallow water algal, oncolitic, oolitic and argillaceous micritic packstone, wackestone and mudstone. Buildup facies of the B_2 Member were deposited on elevated topographic highs formed by basement rocks both within and peripheral to the depositional basin (Figs. 9, 12 and 14). This type of carbonate facies distribution (Fig. 18) was previously described in the Gays River Formation of the Shubenacadie and Musquodoboit Basins (Giles and Boehner, 1979; Boehner, 1987, 1988). The Loch Lomond Basin is a key area in defining a similar relationship at a higher stratigraphic level. In the marginal siliciclastic-dominated sections (typically conglomeratic) the carbonates are extensively recrystallized and are locally recycled calcirudite. The nodular sulphate and fine-grained redbeds represent regressions with the development of sabkha type hypersaline mudflats and evaporite deposition in hypersaline lagoons (subaqueous) in basinward sections.

There is a close relationship between fine- and coarse-grained alluvial redbed sediments (marginal alluvial fan conglomerate and breccia to basinal mudstone and sandstone) and the evaporites. In areas peripheral to the basin, the Enon and Loch Lomond formations undergo profound and rapid facies change (over a few kilometres) from evaporite-dominated to alluvial fanglomerate-dominated. In the area of the MacRae celestite pit northeast of Enon, the Enon and Loch Lomond formations are characterized by abundant redbed paraconglomerate interbedded with highly recrystallized limestone, which is locally recycled calcirudite (Fig. 12). Evaporites are absent. To the southwest, near the Amac and Enon celestite deposits, the paraconglomerate and sandstone fine to mudstone and sandstone redbeds, and interbeds of evaporites are typical. Farther southwest of Enon, near Loch Lomond, the section is dominated by evaporites with minor fine-grained redbeds. The paraconglomerate-dominated section of the Loch Lomond and Enon formations and the undivided basal conglomerate unit represent alluvial fan deposition along the changing margin of the basin. Regressive periods between the marine transgressions are recorded by prograding alluvial fan conglomerate and sandstone to mudstone, with subaerial erosion and weathering at the top of the limestone interbeds. The absence of evaporites indicates that the area of deposition was elevated above the restricted hydrology required for sabkha evaporite deposition.

The Enon and Loch Lomond formation package is overlain by a similar package of interstratified red siltstone, marine carbonate and minor evaporite constituting the middle Viséan Uist Formation. With the exception of an overall decrease in evaporite content and fining of the constituent redbeds in the Uist Formation, the depositional regime is similar to that described for the Enon and Loch Lomond formations.

The Uist Formation records the last marine carbonate deposition in the area and is succeeded by grey (minor red) shale, minor sulphate evaporites, and thin algal carbonate of the late Viséan MacKeigan Lake Formation of the Mabou Group. These strata represent the residual evaporitic conditions of the underlying Windsor Group and the return of the basin to continental conditions. A large lake or system of saline lakes is inferred to have developed following retreat of the Windsor seas.

Paleotopography and tectonism greatly influenced sedimentation in the area especially during deposition of the Windsor and Mabou groups. The influence of topography decreased with time as erosion and successive deposition of onlapping strata buried the basement relief. The sequence to the top of the Mabou Group displays a generalized pattern of fining upward and basinward. Coarse alluvial facies are developed at all stratigraphic levels up to the top of the Windsor Group.

The lacustrine rocks of the MacKeigan Lake Formation are overlain disconformably by grey to grey-green sandstone and grey to minor red mudrock of the Silver Mine Formation. These braided fluvial strata indicate the return to sustained fluvial and alluvial deposition throughout the late Carboniferous. The disconformable contact with the underlying lower Carboniferous basin fill is revealed by reworking and erosion of older sedimentary units, such as the Uist and MacKeigan Lake formations. The unconformable basal contact of the Silver Mine Formation with the middle part of the Uist Formation at Terra Nova indicates substantial intra-Carboniferous erosion.

The Silver Mine Formation (Namurian to early Westphalian) generally has a three part subdivision consisting of a lower section (225 m+) of grey to grey-green, medium- to coarse-grained sandstone with minor mudstone. This lower section fines upward into a section (335 m+) of grey to red mudrock with interbedded fine-grained sandstone and minor coal, which is in turn overlain by a coarser interstratified section (up to 60 m) of grey sandstone with minor mudrock and conglomerate.

The Silver Mine Formation is transitional upward, through interbedding, into the conglomeratic mid-Westphalian Big Barren Formation, which comprises up to 700 m of red, well rounded, polymictic conglomerate with minor sandstone and mudstone. This mature pebble to cobble conglomerate is dominated by phenoclasts of very resistant rock types with minor granitoids. In this way, the Big Barren Formation conglomerate differs significantly from the immature, angular, poorly sorted conglomeratic rocks in the Windsor Group.

The Big Barren Formation is overlain, through an interbedded transition, by the youngest strata preserved in the area, the Glengarry Valley Formation (Westphalian C-D). It comprises an interstratified sequence of up to 300 m of grey-green to red sandstone and mudrock with minor coal. These rocks presently have very limited distribution in the map area and are unconformably overlain by regionally extensive Quaternary glacial deposits.

The dominant structural features of the map area are the prominent northeast-trending faults, including the Lennox Passage and Grand River faults, the northwest-trending Terra Nova Fault, and the allochthonous L'Ardoise Block bounded by the northeast-trending faults. These structures are part of an extensive complex of northeast-trending fault systems extending from the Strait of Canso area through to the offshore portion of the Sydney Basin. Substantial strike-slip and apparent dip-slip movement is indicated on these faults with a movement history that at the latest post-dates the latest Westphalian. The major folds in the study area are the Loch Lomond Syncline and Glengarry Syncline which are principally defined by Upper Carboniferous strata. The folds are generally open and asymmetric with gentle dips in the southeast, and steep to overturned dips on the fault-truncated northwest border.

Mineral occurrences and deposits in the map area are located principally in the Enon, Loch Lomond and Uist formations of the Windsor Group and in the Silver Mine Formation (Fig. 16). Base metals, including copper, lead and zinc, are found in contact-oriented occurrences at or near the base of the Windsor Group carbonate members. These metals are present in the carbonates and related siliciclastics as chalcopyrite, malachite, galena, sphalerite and hydrous zinc oxides. They are locally associated in trace to minor amounts with celestite and barite, which may occur with or without hematite and manganese oxides. The vein style of mineralization is not common but is locally present in fault-disrupted mineralized zones, such as in the MacRae celestite pit. Economically significant galena occurs extensively at the base of the grey sandstone beds of the Silver Mine Formation where it onlaps older rocks. Locally, such as at Terra Nova, sphalerite is a significant or dominant component of the grey sandstone-hosted mineralization. Limestone and gypsum are present as potential resources and are major rock types of the Windsor Group.

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