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Le Programme national de cartographie géoscientifique du Canada

DESCRIPTIVE NOTES

INTRODUCTION

The Westphalian Stellarton Basin is located on a complex of faults in central mainland Nova Scotia. The basin occurs at the intersection of the Cobequid-Chedabucto Fault System and the Hollow Fault. Coal has been mined in the area since before Pictou Coalfield and has historically been the site of substantial mining, more recently the basin has been explored for coalbed methane. As a result of many years of coal exploration, the basin contains over 400 recorded boreholes, approximately 30 coal seams and about 80 oil shale units may be correlated laterally between boreholes (e.g. Naylor et al. 1989).

Data sources

Because of the economic interest, mapping efforts in the Stellarton Basin date back into the last century. Early maps by Poole (1904) and Faribault (1907) were compiled at a scale of 1:63,360 and 1:126,720 respectively. Dimroth (1963), at a scale of 1:24000, determined the biostratigraphic ages of most of the stratigraphic units and established the present division of the Stellarton Formation into members. More recently, the Stellarton area was included in a 1:50 000 compilation of the Pictou area (Ryan et al. 1991) and a 1:25 000 compilation of the Westville area (Ryan and Boehner 1994). Structural trend on a detail or fault system (Fralick and Schenk 1981; Yeo and Gao 1993). Detailed maps at 1:5 000 scale, by Naylor et al.(1989) and Smith et al.(1989), cover all outcrops known at that time in the basin 16.

Since the 1980's, exploration for coalbed methane has resulted in a substantial subsurface field mapping in the areas of later detailed previous coverage, notably the basin margins. Within the basin, the observations shown on this map summarize the results of earlier mapping at larger scales. We show an interpreted geometry of the basin margin which is largely based on Naylor et al. (1989) and Ryan et al. (1991). The basin margin is modified from Naylor and Boehner (1994), Yeo (1987) and Murphy et al. (1991). At the east end of the basin, outcrop is poor, and lithostratigraphic correlations somewhat in doubt; our interpretation of the geometry is consistent with Chandler et al.(1987).

An extensive subsurface data set is available for the central, coal-bearing part of the basin. Unpublished maps, based on surveyed coal mine plans by T.S.Hafley (held at Nova Scotia Department of Natural Resources), formed the basis for the Naylor et al.(1989) compilation. Subsurface data from boreholes have been compiled by Naylor et al.(1989) in the area shown for the Foord Seam. Data from boreholes have been compiled by R.D. Naylor (unpublished reports) and by D. Hughes (Hughes & MacNeil 1982; Hughes 1990). In addition, several seismic lines, shot during more recent exploration for coalbed methane, have been interpreted by Hughes (1990) and Hughes and Jones (1993). These data are the basis for our contour interpretation of the Foord seam (east of East River). Both the boundary and the seismic data base extend slightly in the trends of subsurface fault intersections with the Foord seam. Our interpretation is therefore based on the assumption that fault trends are similar to those in the better known area of historic mining, west of East River.

STRATIGRAPHY

Pre-Westphalian Units

Pre-Carboniferous units occur only in the southwest corner of the map area, where they are not subdivided. They are described in detail by Boehner et al.(1989) and Ryan and Boehner (1994). Because of the poor quality of exposures and outcrops and subsurface exploration occur in this structurally complex area. Recent interpretation by Chandler et al.(1987) suggests that low-angle detachment surfaces are present within the Windsor stratigraphy. Small areas of Windsor Group outcrop are present in the Alma area, in the valley of the Middle River.

The Windsor Group is overlain by clastic sedimentary rocks of the Mabou Group, predominantly of Namurian age. The group consists of variably gray to red, poorly fossiliferous and very fine to medium sandstones with trough cross-beds. Only a few, thin coal seams are present in the Mabou Group. Outcrops are rare, but the Mabou Group forms a large area to the south and west of the Stellarton Basin, where they are intensely deformed by folding and faulting, and are locally overturned. The lack of penetrative fabrics makes this area difficult to interpret structurally. The Mabou Group is also present in the Stellarton Basin, where it occurs in the core of the Foord Syncline, and in the area of Boss Point. The area mapped as Mabou Group may include some strata laterally equivalent to the Windsor Group, as suggested by two Visean spore ages obtained from oyster-laminated units adjacent to the southwest margin of the Stellarton Basin. Other Visean ages have been obtained from the Pictou Group Riversdale Formation, in boreholes at the east end of the Stellarton Basin, where they are overlaine with the Lismore Formation that lies further east (Chandler et al. 1987).

Stellarton Formation

The mid to late Westphalian 'B' of the Stellarton Basin was designated the Stellarton 'Group' by Bell (1943), but is herein referred to as the Stellarton Formation, following Boehner et al.(1989) and Ryan et al.(1991). The lithostratigraphic nomenclature proposed by Ryan et al.(1991) the Stellarton Formation is included, together with other coal bearing Late Carboniferous units, in the Cumberland Group.

We have include in the Stellarton Formation some early Westphalian rocks at the southwest basin margin, equivalent to part of the Middle River Formation of Yeo (1987) and the Cumberland Group of Bell (1943). We infer that this unit was deposited in the early stages of the Stellarton Basin, before the development of the Boss Point Fault. Because the units does not justify separation at formation level. The base of the Stellarton Formation, thus re-defined, is placed at the mapped boundary between steeply dipping to overturned, indurated fine-grained clastic sediments of the Mabou Group and overlying, gently dipping, poorly consolidated sediments of the Stellarton Formation. The contact is an inferred angular unconformity, a not exposed, but its location is constrained within about 50 m at Brown Brook.

The Middle River Member of the Stellarton Formation (formerly part of the Middle River Formation of Yeo 1987) occurs in the area of Middle River, where it is exposed in the valley of Middle River and in the adjacent valley of Brown Brook. It is subordinate well-rounded, red, granule and pebble conglomerate. Upward, the mudrock becomes increasingly mottled with gray-green reduced patches, transitional into the overlying Skinner Brook Member. Previous biostratigraphic work, by Yeo (1987), suggests a Westphalian 'B' age for the Middle River Member.

The Skinner Brook Member consists predominantly of red to gray-green rod-mottled mudrock, siltstone, and fine sandstone. Subordinate coarser sandstone and local conglomerate are present near the basin margins. Spore samples from the Skinner Brook Member, collected by Yeo (1987), are assigned to the Westphalian 'B' and appear to be Westphalian C. It is possible that the Westphalian 'B' interval is condensed or missing within the member.

The Westphalian C Westville Member consists of predominantly gray claystone, wave-rippled siltstone, and minor sandstone, with coal seams near the base. The South and Acadia seams have been extensively mined. The upper part of the Westville Member is poorly exposed and is known mainly from boreholes. It consists of a generally monotonous succession of gray claystone, siltstone, and fine sandstone.

The base of the overlying *Albion Member* (Westphalian C) is drawn at the reappearance of coal in the subsurface Academy seam, or at laterally equivalent shale where the Academy seam is absent. The present interpretation of structural relationships in the Stellarton Basin suggests that the Albion Member is thicker than the Westville Member. Because an interval of redbeds (Pictou Member) separates the Westville and Albion Members. There, the base of the Albion Member is drawn at the transition from predominantly red to predominantly gray lithologies. The Albion Member is a richly coal-bearing unit, containing the Foord, Coal Brook, Thorburn and Harbour Seams. The Foord Seam is the thickest coal seam in the basin and seams become more abundant towards the north and stratigraphically upward in the member, culminating in the thick Foord seam, the top of which marks the top of the member.

The *Pictou Member* is the youngest unit of the Stellarton Member (also Westphalian C). The Plymouth Member consists of predominantly red mudrock, interbedded with red and gray sandstone and minor conglomerate, confined to the southern marginal part of the basin.

The Westphalian C Coal Brook Member consists predominantly of gray to black shale, including abundant, laterally continuous oil shale units, and only one coal. Much of the member is finely laminated. Near basin margins, sandstone and conglomerate are more abundant and coarser. The only coal seam in the member, the Coal Brook seam, the Mcleod, occurs in the middle of the member, but it passes laterally, toward the basin centre, into oil shale.

The base of the overlying Thorburn Member (Westphalian C/D) is placed at the base of the McSean coal seam. The Thorburn Member is a coal-bearing unit, with numerous coal seams, including the Thorburn and Harbour seams that pass westward into oil shale. Minor conglomerates occur at the south margin of the basin. The highest strata of the Thorburn Member occur in two structural basins at the east end of the Stellarton Basin; the upper limit of the member is not seen.

Other Westphalian Units

The New Glasgow Formation (equivalent to part of the Middle River Formation and the New Glasgow Formation of Yeo 1987) consists of boulder to granule conglomerate, cross-bedded red sandstone, and subordinate red shale. It is of Westphalian D age. The New Glasgow Formation is exposed in the valley of the East River, at New Glasgow. Outcrops are dominated by sandstone; conglomerate predominates in the Upper Member. (Lower and Upper Members are not distinguished on this map).

The Boss Point Conglomerate (Westphalian C/D) is poorly exposed in the area of this map. At the base, a thin limestone is locally present at the boundary with the underlying New Glasgow Formation. The contact appears conformable, but regional map relationships (Ryan and Boehner 1994; Chandler et al.1988) suggest a significant unconformity. Boss Point conglomerate is exposed in the area of Boss Point, consisting of thinly bedded gray claystone and sandstone (also subordinate thick shale and coal) that is overlain by massive cobble conglomerate. Clasts are well rounded, pale gray, fine- to coarse-grained sandstone interbedded with gray and red mudrock. Sandstone units typically comprise multi-lateral channel successions (1+40 m). Nine to four coal seams are present.

Younger units

The only known younger units in the area are extensive tills and river gravels of Interval Quaternary age. These have not been investigated in the present study, and are not represented on the map, which shows only the bedrock geology.

STRUCTURE

Structural work in the Stellarton Basin dates back to the last century, when the geological setting of coal mines was investigated by Poole (1904). Subsequent extension of coal mines into the Albion Syncline led to further work by the Nova Scotia Department of Mines and Energy, and by the Acadia Coal Company, which operated the Albion Mines. During the 1940s and 1950s exploration and mining by the Acadia Coal Company led to the preparation of detailed contour plans of coal seams (T.S. Hafley, unpublished data held at Nova Scotia Department of Natural Resources). Hafley's data were incorporated in the maps of Naylor et al.(1989) and Smith et al.(1989). Mining activity in the areas of the Albion and Westville members was intermittent as equipment. Subsequent paleostructural studies (e.g. Hacquebard and Donaldson 1969) have not confirmed this hypothesis. Fralick and Schenk (1981) suggested the Stellarton Basin was a pull-apart basin, developed between overlapping strands of the Cobequid-Chedabucto Fault System. Subsequently, Yeo and Gao (1987) and Fralick (1991) revealed an array of structures consistent with formation of the basin at a releasing bend on a dextral fault system.

Basin boundary structures

Along the southwest basin margin, a variety of Stellarton Formation strata occur in contact with Mabou and Windsor groups. Between Alma and Hazel Glen the Middle River Member dips gently northeast, away from the mapped contact with intensely deformed, locally overturned Visean and Namurian rocks. This contact, though not exposed, is interpreted as a fault, because of the abrupt change in dip. The fault is interpreted as a segment of the Cobequid-Chedabucto Fault System. The basin fill is therefore inferred to onlap the southern basin margin with higher parts of the fill overlapping farther over an adjacent Westphalian upland formed by deformed Mabou and Windsor rocks. In the area of Hazel Glen, Alma, and Brown Brook, Stellarton Formation strata dip steeply northeast, in the same direction as the Mabou Group. It is likely that this boundary represents a fault-modified unconformity. An angular unconformity is exposed at the contact in East River, where Stellarton Formation conglomerates (Plymouth Member) rest on cross-bedded Mabou Group sandstone.

Several fault-bounded slices occur at the north and northwest basin margin. A block of gently dipping redbeds, provisionally assigned to the Skinner Brook Member, is upthrown along the Fletcher Fault against Coal Brook and Thorburn members. The Fletcher Fault is a high-angle fault, with a steep dip to the southeast. The Waters Brook Fault is characterized by conglomerates, provisionally assigned to the Middle River Member, overlying deformed siltstone of the Mabou Group. Both these blocks are bounded to the north by the Waters Brook Fault. North of this fault is a slice consisting of Skinner Brook Member redbeds, bounded to the north by the Bridge Fault. Drilling and surface mapping by National records of gypsum exposures in this area (Poole 1904) confirm the existence of Windsor Group rocks. At the north edge of the block is a slice of poorly indurated siltstones of uncertain affinities which young to the north but dip steeply south.

In the Alma area, conglomerates and sandstones immediately outside the basin (New Glasgow Formation) are gently dipping, but are cut by steeply dipping faults. In the area of Hazel Glen, Boss Point conglomerates are also cut by gently dipping conglomerates and sandstones to the north; the structure is tentatively interpreted as a faulted plunging syncline.

The overall structure at the northwest edge of the basin is thus marked by fault slices which are uplifted relative to the units both north and south. Along both edges of the zone of uplift, strata are near-vertical to overturned, and face outward, away from the structure. This margin of the basin is therefore interpreted as a positive flower structure (e.g. Harding 1985).

The southeast basin margin is also marked by faults, but the structure is less complex. Contacts between the basin western end of the basin were expected as overstrike with the Bonnet Brook and Westville Members by Bell (1943) and are shown as such in the map, but this correlation is based on lithological similarities only. In the area of McLellan's Brook, Boss Point strata dip steeply southeast, in contact with Mabou and form mapped sedimentary rocks faulted. However, the prevalence of coarse clastic facies along the south margin of the basin suggests that the present faulted boundaries are close to the original depositional margin of the basin in this area.

Structures within the basin fill

The basin fill is tilted broadly toward the northeast, but the structure is complicated by folds and faults. En-echelon folds are developed in the Foord Seam, in the area of Coal Brook and Thorburn. The axes of these anticlinal trends have a north trend. Extensional structures (mainly normal faults) strike generally NW-SE to NNW-SSE.

A major fault system strikes NW-SE across the basin west of the worked area of Albion coals. Deformed rocks seen in outcrop (Fletcher Fault) and in boreholes (Waters Brook Fault) are interpreted as a fault zone on the basis of borehole records, which suggest that the westernmost fault is the zone (the Acadia Fault of Bell 1943) due to the northeast and has a stratigraphic throw of at least 350 m. An apparent 'rollover' of strata toward this structure, and the change in strike across it, suggest that it is a growth fault, active during deposition of the Foord and younger seams. The Fletcher Fault and Waters Brook Fault are mapped at the surface, but a continuation of the Waters Brook Fault strikes is again observed in the subsurface (Foord Seam, Figure 2). The Fletcher Fault is also interpreted as a Albion terminal fault. Displacement appears after the extensional faulting affected strata of the basin fill during the development of the basin.

Map-scale folding of the basin fill increases intensity toward the northern margin. Several large folds can be traced both from patterns of bedding orientation in scattered outcrop and from subsurface mine-plan information (Dilla 1991). Most prominent of these folds is the Albion Syncline, which plunges northeast at about 10°. Smaller folds, both anticlinal and other folds follow an en-echelon pattern, possibly produced by timing of two originally separate folds. West of this area, correlation of surface and subsurface folds suggests that fold scale surfaces dip steeply north, consistent with the inferred position of the basin margin fault (Acadia Fault).

Further east in the basin, a complex fold pattern in the Thorburn area involves two structural basins located on the Marsh and McLellan synclines. The individual basins may be related to NW-SE shortening but the overall structure appears to be controlled by the position of the basin margin, suggesting that the synclinal structure may result from slip-slip movement on non-planar basin-bounding faults.

EVOLUTION OF THE BASIN

Initiation of the Stellarton basin was preceded by major late Namurian or early Westphalian deformation, which led to the development of the Boss Point Fault, the folding and faulting of the Windsor and Mabou Groups. The Stellarton Formation was deposited with angular unconformity on these units.

The Stellarton basin was initiated at a releasing bend in the Cobequid-Hollow fault system in early Westphalian time. Stratigraphic analysis of the Stellarton Formation by Naylor et al.(1989) and others has shown that coarse clastic facies (mainly sandstones, local conglomerates) are concentrated at the south and east basin margins. The present structural relief on the basin fill is due largely to folding and faulting during deformation, but the original basin was asymmetric. However, to the southwest, the basin may originally have extended significantly beyond its present erosional limit.

The thickest coal and oil shale successions are found in the centre of the basin and extend into the highly deformed area of the Albion Syncline. Coal seams are thin and rare at the basin margins. The distribution of coal and oil shale accumulation were most rapid at the southern basin margin, interpreted as fault-bounded (Naylor 1989). Fast formation during this interval was concentrated at the north basin margin where overall syndepositional subsidence was slowest (Naylor et al.1989). Rapid subsidence at the south basin margin is inferred to be due to the activity of the Acadia Fault, part of the Albion Member. locally there may be an unconformity at or near the base of the overlying Coal Brook Member. During deposition of the later parts of the formation, the basin floor probably subsided more evenly, with the most rapid subsidence in the area of the Albion Syncline. The thick fill in the area of the subsidence history is limited, because erosion has removed the youngest units from the west end of the basin.

Significant shortening affected the basin after the deposition of the youngest basin fill (Thorburn Member), and the basin fill was folded into the Albion Syncline and related structures (Naylor et al.1989). The Albion Syncline is large enough to be interpreted as a positive flower structure. This interpretation is inferred on the basis of the fault system (possibly to a more east-west direction of motion) which placed the Stellarton Basin on a restraining bend. There is no stratigraphic upper limit on the timing of the deformation; on regional grounds it is assumed to have occurred in latest Carboniferous or Permian time.

ACKNOWLEDGMENTS

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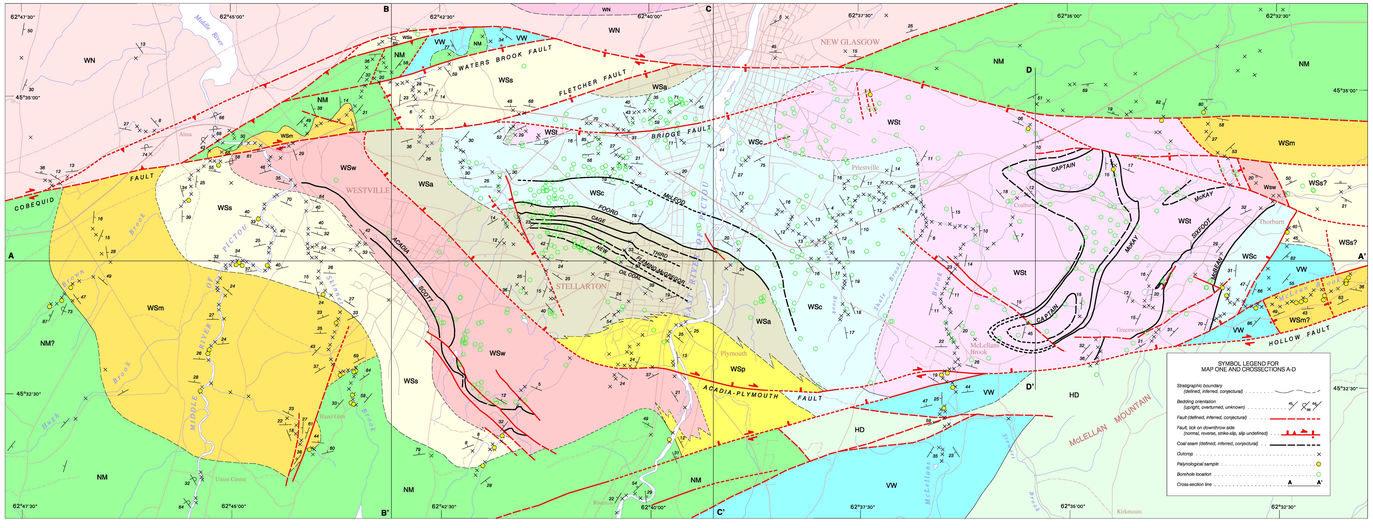
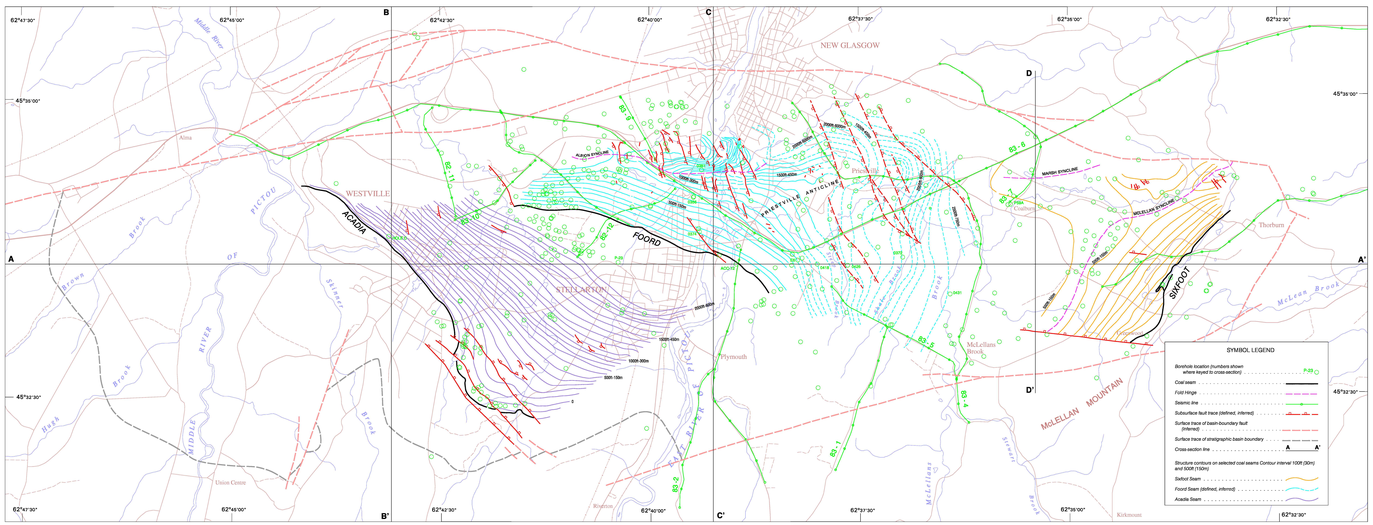


Map 1. Geology and selected coal seams



Map 2. Structure contours on selected coal seams

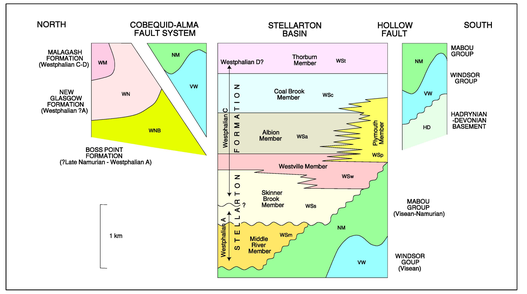
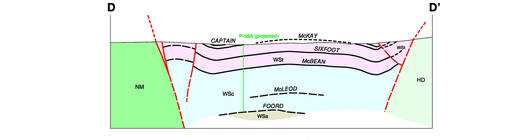
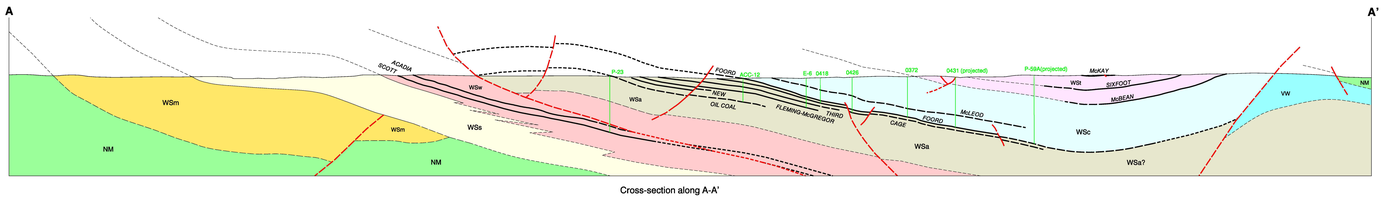


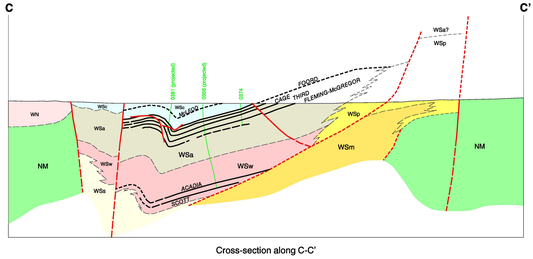
Figure 1. Legend to stratigraphic units



Cross-section along D-D'



Cross-section along A-A'



Cross-section along C-C'

Cross-section along B-B'

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GEOLOGICAL COMPILATION MAP OF THE STELLARTON BASIN

NOVA SCOTIA

Scale 1:25 000 - Échelle 1/25 000

Metres 500 0 500 1000 1500 2000 Metres

Universal Transverse Mercator Projection | Projection transverse universelle de Mercator
*Her Majesty the Queen in Right of Canada, 1999 | *Sa Majesté la Reine du chef du Canada, 1999

Geology by John W.F. Waldron[1], F.W. Chandler[2], P. Durling[3], K.S. Gillis[4], and R.D. Naylor[5], 1999

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Subsurface borehole data compiled by J.D. Hughes, Geological Survey of Canada

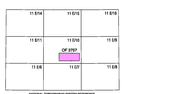
Digital cartography by R.L. Allard, Geoscience Information Division

Electrostatic plot produced by the Geoscience Information Division

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

Digital base map from data compiled by Geomatics Canada, modified by the Geoscience Information Division

Mean magnetic declination 1999, 31° 21' W, decreasing 12.9' annually



COOPERATION
CANADA-NOVA SCOTIA MINERAL DEVELOPMENT

ENTENTE DE COOPÉRATION NOUVELLE-ÉCOSSE CANADA SUR LE DÉVELOPPEMENT MINÉRAL

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