Overview of the Geology and Mineral Resources of the Western Part of the Windsor (Kennetcook) Basin, Wolfville - Windsor Area (NTS 21H/01 and part of 21A/16), Hants and Kings Counties, Nova Scotia

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Wolfville - Windsor Geological Map

A preliminary geological map (1:50 000 scale) of the Wolfville - Windsor area (NTS 21H/01 and part of 21A/16) was displayed at Mining Matters '99 in November 1999. This geological map (Figs. 1 and 2) will be an update of work by Crosby (1962). The new map is a compilation of recent geological mapping work (1980s to 1990s), undertaken at a variety of scales, by Dr. R. G. Moore, L. Ham and the late Dr. S. Ferguson. The map will accompany a report on the geology of the western part of the Windsor (Kennetcook) Basin in preparation by Dr. R. G. Moore. The report will further contribute to documenting and understanding the Carboniferous basin infill, especially the Windsor Group and Horton Group strata, as well as, to varying degrees, paleogeographic, tectonic and sedimentary settings. These data are fundamental in understanding the distribution of base metal deposits and other potential mineral, petroleum and water resources within the area.

The Wolfville - Windsor map area (Figs. 1 and 2) uniquely includes most of the major rock units constituting southern mainland Nova Scotia. These include the following (Fig. 3): Cambrian to Devonian metavolcanic rocks of the Meguma Terrane; late Devonian peraluminous granitoid rocks of the South Mountain Batholith; sedimentary rocks of the Carboniferous Windsor Basin; Mesozoic (Late Triassic to Early Jurassic) Fundy Basin sedimentary and volcanic rocks; and locally, rare Early Cretaceous unconsolidated sand and clay. Unconformities of successive upper Paleozoic and lower Mesozoic basin fills are well represented. The map area also contains type and reference sections for many rock units including: the lower to middle Paleozoic White Rock, Kentville and New Canaan formations (stratigraphically above the Goldenville and Halifax formations of the Meguma Group); the Carboniferous Horton and Windsor Groups (Bell, 1929, 1958); and the Wolfville, Blomidon, North Mountain and Scots Bay formations of the Mesozoic Fundy Group. The area has had a long history of mineral exploration and mining as well as petroleum exploration. Exploration for metallic minerals, industrial minerals and petroleum continues in this prospective area. Currently, the utilization of geology in water resource evaluation and management is a developing application in this intensive agricultural and municipal growth region. Some recent references related to the geology of the western part of the Windsor Basin include Moore (1996), Martel and Gibling (1996) and Boehner (1994).

Windsor Basin

The Windsor (Kennetcook) Basin is a northeasterly elongated structural basin in central mainland Nova Scotia (Fig. 1). The Windsor Basin together with the adjacent Shubenacadie and Musquodoboit basins comprise the Minas Sub-basin (depositional) of Bell (1958). The prominent northeast-southwest structural trend merges and converges with a well-developed east-west orientation in the Cobequid-Chedabucto Fault System, which extends along the northern part of the Windsor and Shubenacadie basins. Early Cretaceous strata occur locally as fault-controlled erosional remnants in the nearby Musquodoboit and Shubenacadie basins and similar outliers may be discovered in the Windsor Basin. The Windsor Basin, like the Shubenacadie and Musquodoboit basins, is a small structural element of the late Paleozoic basin system in Atlantic Canada referred to as the Maritimes Basin. The basins are depositionally and structurally related and represent the present day erosional remnants of late Paleozoic overstep to the south onto the Meguma Platform with original depositional limits unknown.

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Deformation and structural complexity ranges from generally undeformed, gently folded rocks in the Musquodoboit Basin on the southeast, through to severely deformed rocks toward the northwest in the Windsor Basin (Fig. 1). This structural zonation reflects proximity to the Cobequid - Chedabucto Fault System and is important in controlling the location, limits and structural configuration of the Carboniferous strata and mineral deposits in the area.

The Windsor Basin contains up to 2000 m (stratigraphic thickness) of upper Paleozoic, primarily Carboniferous continental and marine sedimentary rocks. The basin underlies approximately 1500 km$^2$ of northeastern Kings County and western Hants County. The western part of the basin is included on the Wolfville - Windsor geological map (Figs. 1 and 2) and contains the type areas and type sections for the Carboniferous Horton and Windsor groups (Bell, 1929, 1960). The basin fill ranges in age from mainly Early Carboniferous (Tourainian) with very minor Late Devonian, to Late Carboniferous (Westphalian B-C). The basin strata overlie, with angular unconformity, the Cambrian to Ordovician metasedimentary rocks, or nonconformably overlie the Late Devonian peraluminous granitoid rocks (Fig. 3). Contacts with the bounding basement blocks are complicated by syn- and post-Carboniferous fault movements. Age relationships between the South Mountain Batholith granitoids and the overlying Horton Bluff Formation in the western part of the basin, based on palynology and geochronology, indicate an apparently short time interval (10-15 million years in the Famennian) for batholith unroofing and erosion to provide sediment for the overlying Horton Bluff Formation.

The earliest basin fill (up to 1000 m in the east-central part of the basin) is dominated by coarse-to fine-
Figure 2. Simplified geological map of the Wolfville - Windsor map area, including the western part of the Windsor Basin.
grained alluvial strata of the Horton Bluff and Cheverie formations of the predominantly Tournaisian - Viséan age Horton Group (rare Late Devonian). The Horton Group is sourced from and onlaps the basement metasedimentary and granitoid rocks along parts of the southern and western borders of the Windsor Basin. The Viséan Windsor Group disconformably overlies the Horton Group and comprises an interstratified sequence (up to 800 m) of marine evaporites, carbonates and continental redbeds. The Windsor Group and part of the Horton Group contain numerous industrial mineral occurrences, including barite, gypsum, anhydrite, salt, dolomite and limestone, as well as base metals including Pb, Zn and Cu, Mn, and locally Ag and U.

The Watering Brook Formation of the Mabou (Canso) Group generally conformably (local disconformities) overlies the Windsor Group and comprises up to 150 m of late Viséan grey and red mudrocks, gypsum, anhydrite and locally halite. Basin fill of the Horton, Windsor and Mabou groups is unconformably overlain by the Namurian-Westphalian Scotch Village Formation. The Scotch Village Formation has previously been included as part of the Pictou Group, but is now re-assigned to the Cumberland Group. It comprises more than 300 m of fluvial grey sandstone and red mudrocks in the central area of the basin, and regionally overlies an eroded landscape of variably deformed Windsor and Mabou group strata.

### Stratigraphy and Depositional History

The stratigraphic succession within the Windsor Basin is similar to that occurring in many of the late Paleozoic basins in Nova Scotia and has elements of both evaporitic marine and nonmarine deposition. The initial basin-fill of the Horton Group (Fig. 3) comprises a three part succession of upper and lower coarse-grained facies and a medial fine-grained facies. In general, the coarse-grained facies are primarily fluvial and alluvial deposits of the lower and uppermost parts of the Horton Bluff Formation (lower and upper units on Fig. 3), and the Cheverie Formation. The fine facies constitute the middle part of the Horton Bluff Formation and are dominated by lacustrine deposits (including carbonates).

The Horton Bluff Formation is approximately 350-525 m thick in the type area and may exceed 1000 m in the central part of the basin. It generally displays fining upward and basinward trends. The Horton Bluff Formation is overlain conformably (and locally disconformably) by the coarse-grained Cheverie Formation, which is approximately 100-260 m thick in the type area. The coarse alluvial fan facies, including red and green conglomerate, form part of the Coldstream Formation (50-90 m thick) in the Shubenacadie Basin near the southeasterly pinchout limits of the Horton
Group on the Meguma Platform. These conglomeratic facies are not well represented in the Windsor Basin, except locally along the southern and southeastern border of the basin adjacent to the Rawdon Fault zone. Very little is known about the thickness, stratigraphy and lithology of the Horton Group in most of the western central part of the Windsor Basin.

The continental alluvial fluvial-lacustrine sedimentation phase of basin development was suddenly succeeded by a regional marine invasion of the Windsor seas in the early Viséan. Catastrophic flooding of a subsurface basin landscape with nearly instantaneous transgression is inferred. Locally, for example in the Cheverie area, there is a thin, sparsely fossiliferous quartzose sandstone associated with the transgression at the contact between the Cheverie and Macaum formations. This marine sandstone is included in the basal part of the Windsor Group. The basal unit of the Windsor Group is a marine carbonate which occurs regionally in several distinctive facies. The dominant facies is the Macaum Formation, which comprises laminated limestone 1-17 m thick. It is generally present in outcrop in the northern part of the basin (its type area) and is inferred to extend throughout much of the subsurface of the basin (Figs. 1, 2, 3). The correlative buildup (biothermal) facies is called the Gays River Formation, which ranges in thickness from 15-30 m and has limited areal extent. It is not known to be developed in the Windsor Basin, but is well represented in the type area in the southern part of the Shubenacadie Basin and in much of the Musquodoboit Basin. The Gays River Formation buildups are generally developed on pre-Carboniferous basement rock beyond the Horton Group pinchout (e.g. Shubenacadie Basin, Fig. 3). Buildups were particularly well developed on or around basement topographic highs within and peripheral to the depositional basin margins. Suitable basement highs may not have been present or carbonate buildups not preserved in the present day erosional limits of the Windsor Basin.

The typical anhydrite- and salt-dominated evaporite sequence of the lowermost Windsor Group is well represented in the area. Although there are no complete basinial sections through the White Quarry (Carrolls Corner Formation correlative) and Stewiacke formations, these units together are typically up to 400 m thick. They are inferred to extend throughout the basin, but the present distribution of saline evaporites of the Stewiacke Formation is limited by structure and subsurface dissolution.

Strata typical of the middle part of the Windsor Group (B Subzone of Bell, 1929) are included in the Miller Creek, Wentworth Station, and Pesqueid Lake formations, which have a total thickness of approximately 120 m. Due to the extensive deformation in their type areas near Windsor, the contacts between these units are generally faults. The upper contact of the Pesqueid Lake Formation with the Murphy Road Formation is conformable. These units are characterized by a major change in depositional style and are distinctive in comprising numerous thinner transgressive and regressive cycles (minicycles) of marine carbonates, evaporites and redbeds. Regionally, this represents repeated marine transgression and regression, individually recorded by fossiliferous marine carbonate, overlain by progressively saline marine evaporites (anhydrite and salt) and capped by continental redbed siliciclastics. The Miller Creek, Wentworth Station and Pesqueid Lake formations are distinctive in their constituent carbonate members and correlate with the MacDonald Road Formation in the adjoining Shubenacadie Basin and Musquodoboit Basin. The absence of coarse-grained siliciclastics and no apparent onlap of basement rocks indicates that the marine invasions in the Windsor Basin were similar to those in the Shubenacadie and Musquodoboit basins: they occurred over a terrain with very subdued paleotopographic relief, and were accompanied during regressions by input of fine-grained siliciclastics.

Carbonate rocks of the Miller Creek, Wentworth Station and Pesqueid Lake formations are typically shallow water deposits, ranging from intertidal/ supratidal to subtidal below wave base environments. They include algalstromatolites, oncolitic and argillaceous micritic packstone, wackestone and mudstone (rarely oolitic), with variable shelly biota of brachiopods, gastropods and bivalves. The nodular sulphate and fine redbeds represent regressions with the development of sabkha-type hypersaline mudflats and the massive mosaic anhydrite and stratified salt deposited on hypersaline lagoonal (subaqueous) evaporites in basinward sections.

The Miller Creek, Wentworth Station and Pesqueid Lake formations are overlain by a lithologically similar package of interstratified red siltstone, marine carbonate and minor evaporite comprising the Murphy Road Formation. The Murphy Road Formation constitutes the upper part of the Windsor Group (Subzones C, D and E of Bell, 1929) and is approximately 185-200 m thick. The lower contact is conformable with the underlying Pesqueid Lake Formation. The Murphy Road Formation is the uppermost formation of the Windsor Group and records the last marine carbonate deposition in the area. With the exception of the variation in lithologic component proportion (e.g. an overall
decreased evaporite and greater redbed content) the depositional environment for the carbonates, sulphate evaporites and red beds is generally similar to that described for the underlying Miller Creek, Wentworth Station and Pesaquid Lake formations. The Murphy Road Formation correlates with the Green Oaks Formation in the adjoining Shubenacadie Basin and the Musquodoboit Basin (Figs. 1 and 3).

The Watering Brook Formation of the Mabou Group comprises grey and red mudrocks, gypsum, anhydrite and locally halite. It is approximately 130 m or more in thickness and conformably overlies the Murphy Road Formation at the top of the Windsor Group in the Windsor Basin. These deposits represent the transitional return to continental (initially saline) lacustrine and fluvial deposition with the retreat of the Windsor seas. Evaporite deposits present in this interval indicate a residual connection to the parent marine environment.

Overall, paleotopography and tectonism appear to have had a diminishing influence on sedimentation in the Lower Carboniferous comprising the Horton, Windsor and Mabou groups in the Windsor Basin. The importance and influence of topography decreased with time, as erosion and successive deposition of onlapping strata buried the basement relief within and around the perimeter of the Windsor Basin. The depositional sequence to the top of the Mabou Group (late Viséan) displays a general pattern of fining upwards. Regional uplift to the north of the basin, near the end of deposition of the Miller Creek, Wentworth Station and Pesaquid Lake formations (B Subzone), probably significantly restricted the areal extent of marine deposition to the north.

Windsor and Mabou group strata in the Windsor Basin are unconformably overlain by a sequence of interstratified fine- to medium-grained, grey sandstone and red to grey mudrocks assigned to the Scotch Village Formation. These strata are known to exceed 300 m in thickness and occur throughout the Windsor Basin and parts of the adjacent Shubenacadie Basin (Figs. 1, 2 and 3). The stratigraphy, age and contact relationships of rocks included in the Scotch Village Formation initially appeared simple; however, further palynological work indicates they are complicated. The Scotch Village Formation was formerly understood to be dominantly mid- to late-Westphalian in age, but it includes a substantial section of Namurian strata. Further seismic surveys and drilling will be required to clarify this because these strata have very limited subsurface data and very poor outcrop representation. The major unconformable contact with the underlying early Carboniferous basin fill is locally revealed by significant erosion and reworking, including the inclusion of upper Windsor Group marine fossil detritus in the Scotch Village Formation. For example, the unconformable contact of the Scotch Village Formation with the lower part of the Green Oaks (Murphy Road) Formation at Riverside Corner (e.g. drillhole NSDME RC85-1; Boehler, 1994), near the southeastern border of the Windsor Basin (Fig. 1), indicates the locally substantial erosion of Lower Carboniferous strata. The braided fluvial mudflat strata of the unconformably overlying Scotch Village Formation record a substantial change in the sedimentation pattern in the Windsor Basin and adjacent Shubenacadie Basin. This follows the general pattern in the regional Maritimes Basin, especially in the late Namurian to Westphalian, with the return to sustained fluvial and alluvial deposition typical of the Late Carboniferous.

Carboniferous basin fill on the northern boundary of the Windsor Basin is proximal to the regional Cobequid-Chedabucto Fault System and is variably to intensely deformed (Fig. 1). These rocks comprise the Walton Block and are unconformably overlain by the southern outcrop margins of the Mesozoic rift basin fill. The basal units are represented by Late Triassic, medium-grained, redbed siliciclastics of the Fundy Group (Wolffeville Formation). Carbonate breccias of tectonic and karst origin (multigeneration?) are commonly associated with the Macumber Formation outcrops in this area. These rocks are referred to as Pembroke breccia and are part of the host for base metal and barite mineralization.

Remnants of early Cretaceous silica sand and clay are locally present on top of the Carboniferous rocks (Fig. 3); however, their stratigraphy and distribution in the Windsor Basin are poorly known. These unconsolidated Cretaceous deposits are probably correlative with the Chaswood Formation in the adjoining Shubenacadie and Musquodoboit basins. Recent mapping, drilling and seismic surveys have significantly expanded the known distribution, detailed stratigraphy and structure. Faults locally offset both the Cretaceous and Carboniferous strata. Small Cretaceous occurrences have also been reported in the southern part of the Windsor Basin near McKay Section and in the Fundy Gypsum Miller Creek Quarry (Fig. 1). A thick section of unconsolidated sand (potentially Cretaceous) was recently intersected in mineral exploration drilling to a depth of 150 m at Wade Lake near Goshen (Fig. 1) in the northwestern part of the basin.

Mafic sills and dykes associated with periods of intrusive and extrusive activities occur throughout the geological column in the Wolfville - Windsor map area.
In the post-Cambrian to Silurian, mafic dykes and sills intruded Halifax Formation rocks and locally, post-Halifax Formation strata. Within the Windsor Basin, mafic dykes and sills locally intruded Early Carboniferous Horton Group strata. The Horton Bluff Formation has small, intensely altered mafic dyke and sill intrusions at Johnson Cove near Cheverie where there are six localities at three stratigraphic levels. Similar intrusions occur near Cheverie (New Cheverie Road) and Grey Mountain.

Structure

The Windsor Basin is the most structurally disturbed of the Carboniferous overstep basins in the Meguma Zone. This is primarily due to its proximity to the regional Cobequid-Chedabucto Fault System (CCFS), as well as the related Mesozoic Fundy Basin (Figs. 1, 2 and 3). The Windsor Basin has the basic configuration of a synclinorium with northeastward- to eastward-trending synclines and anticlines. The basin is truncated on the southeast by the Rawdon Hills Block and Rawden Fault, on the northwest in the Walton Block by the onlap unconformity of the early Mesozoic Fundy Basin, and on the west by the onlap unconformity of the Meguma (Zone) Platform. The extension and continuity of basin rocks beneath the Mesozoic Fundy Basin (mainly submerged beneath the Minas Basin) to the north is not defined in drilling or seismic surveys. Fault blocks of Lower Carboniferous rocks in the complex CCFS along the northern shore of the Minas Basin, however, are geologically similar to rock units exposed in the Windsor - Wolfville map area (e.g. outcrops of Murphy Road, White Quarry and Macumber formations).

Complex structure pervades the middle part of the Windsor Group and parts of the Horton Group (e.g. Horton Bluff Formation in the Walton Block) including recumbent folding related to the thrust and decollement. Substantial dip-slip (and potentially strike-slip) movement, postdating the Windsor Group, is indicated on these faults. The movement history includes episodes that postdate the Westphalian B-C and postdate the Early Cretaceous. There are numerous minor and major folds in the basin, including the Walton, Melanson Mountain and Grey Mountain anticlines. These folds are defined primarily by Lower Carboniferous strata. The faults are generally open and asymmetric, with gentle and steep to locally overturned dips near the faults.

The dominant structural features of the western part of the Windsor Basin are prominent northeastward- and northwestward-trending faults including the Rawdon, Avon River, Pesaquid Lake and Kennebecook Thrust faults. The Rawdon Fault is a high-angle reverse fault clearly related to the underlying basement rocks and probably extends through the Meguma Group and South Mountain Batholith basement to the southwest. The Kennebecook Thrust is a complicated fault zone along the northwestern border of the basin. In this area, Horton Group and locally lowermost Windsor Group strata (Macumber and White Quarry formations) occur as a steep to overturned southern limb to the major Walton Anticline structure which dominates much of the structurally complicated Walton Block. These units are typically juxtaposed with upper Windsor (e.g. Murphy Road Formation) or younger Carboniferous units to the south and east in the basin. This includes the locally very complicated folding and faulting as well as thrust movement at different scales within the Horton and Windsor groups.

Seismic surveys in the east-central part of the basin have been interpreted to indicate southerly directed thrust movement of the Walton Block over the Windsor Basin rocks to the south. The magnitude and depth of the inferred thrust, both towards the north and south, are unknown. Complex, recumbent isoclinal folds in the Wentworth Station and Miller Creek formations and in the Dark Quarry Fault Zone near Windsor are known to occur in other parts of the basin and may extend as a basinwide decollement zone. A genetic connection to the Kennebecook Thrust is also possible. Further seismic surveys and drilling will be required to clarify the geology and structure of the central and deep basin areas.

The Kennebecook Thrust and Rawdon Fault are part of an extensive northeastward-trending fault system extending from the Meguma Zone into the east-west Cobequid-Chedabucto Fault Zone, which extends through central Nova Scotia from the Bay of Fundy to Chedabucto Bay and offshore. The Avon River and Pesaquid Lake faults appear to be primarily related to strata above a decollement (related to the Kennebecook Thrust?) at the top of the White Quarry Formation (and within the Stewiacke Formation). Regional magnetic field patterns are defined by the typical higher magnetic response of the Halifax Formation and lower response of the Goldenville Formation in regional scale northeastward-trending folds. This pattern can be traced from the outcrop areas beyond the basin into the basin (with attenuation due to the basin fill). Significant strike-slip offsets (1 km or more) of the Avon River or Pesaquid Lake faults are not evident in the western part of the basin.

The present basin configuration reflects a two-part structural system with local block faulting, folding-
tilting and erosion of the Mabou Group and older rocks, followed by deposition of the Namurian to Westphalian Scotch Village Formation above the unconformity. Local faulting, such as along the Rawdon Fault, has disturbed the Scotch Village Formation, indicating a movement event after the Westphalian B-C. Subsequently, there was structural disturbance, including faulting, associated with the Late Triassic. In addition, there may have been post-Early Cretaceous faulting and folding similar to that evident in the Chaswood Formation of the Musquodoboit Basin. The structural history of the basin is locally very complex, due in part to the proximity to the regional Cobequid-Chedabucto Fault System. Tectonism occurred throughout the development of the Carboniferous and Mesozoic basin fills, especially during the late Namurian to early Westphalian, post-Westphalian, and post-Triassic.

There is a close paleogeographic relationship between the Musquodoboit, Shubenacadie and Windsor (Kennetcook) basins. These structural basins appear to have only modest dislocation and disruption on the northeastward-trending faults linked to the Cobequid-Chedabucto Fault System to the north. The general and detailed stratigraphy, structure and facies patterns are very similar, indicating close spatial and temporal relations throughout their history.

**Mineral Resources and Mining**

Mining activity in the western part of the Windsor Basin has concentrated on the extensive industrial mineral resources over the past 200 years. Limited, but economically significant, mining of base metals and silver occurred at the Walton deposit. Mineral exploration has historically focused on base metals and barite in the basal Windsor Group (e.g., Walton, Gays River, Smithfield, Upper Brookfield, Fig. 1) as well as industrial minerals including sulphur, salt, potash and gypsum in the Windsor Group. A special issue of the journal *Economic Geology* was published recently (see Sangster and Savard, 1998, for current papers and contained references) which documented the geology of base metal mineralization in the Carboniferous basins of Nova Scotia. Significant lode gold was produced from deposits in the Meguma Group in the Rawdon Hills area and minor placer gold has been recovered from surficial drainage basins. The Walton barite deposit was a major carbonate-hosted barite and base metal/silver deposit discovered in the 1950s and in production until the 1970s. Substantial mining problems related to weakly consolidated host rocks, fracturing and water influx were encountered and continued throughout the life of the mine.

Gypsum mining has been continuously active in the Windsor Basin for over 200 years. Gypsum and anhydrite occur in extensive deposits in the area. Early production was characterized by a large number of small, independent producers. Larger operations were rare in the early history; however, this evolved in more recent times with the consolidation of deposits and production by large producers. Major production has occurred for more than 40 years at the Miller Creek and Wentworth quarries operated by Fundy Gypsum Company. A smaller gypsum quarry near McKay Section and a gypsum products plant in Windsor were recently closed by Domtar after many years of operation. Recently there has been substantial (multi-million dollar) investment by Fundy Gypsum to upgrade their production and processing operations at Wentworth and Miller Creek. Limestone has also been produced locally on a limited basis for agricultural applications.

The Windsor Basin has been extensively explored for base metal and barite deposits. This exploration is, in part, related to the discovery and development of the Walton barite deposit and the subsequent discovery of a significant base metal sulphide and silver ore body in its lower part. Exploration has focused primarily on the Horton Group-Windsor Group contact, especially the prospective basal carbonates of the Windsor Group. This exploration activity stimulated the discovery of significant tonnages of these metals at Gays River, as well as other similar prospects. In addition to base metal and barite deposits, exploration has been undertaken in several less intensive phases for celestite, sulphur, salt, potash and uranium.

Petroleum exploration drilling was undertaken in the Cheveric, Falmouth and Kennetcook areas in several exploration plays beginning in the early 1900s. Exploration interest continues in the region as a result of hydrocarbon shows and favourable geology. Most of this hydrocarbon exploration has focused on plays in the Horton Group and the lowermost part of the Windsor Group because of potential reservoirs in the Horton and evaporite seals in the Windsor.

**Metallic Minerals**

Exploration for base metals in the Windsor Basin has focused on the Horton-Windsor contact zone, especially the basal carbonate of the Windsor Group. One of the most prospective exploration areas is in the Walton Block, extending along the northern border of the basin, especially between the Avon River and Upper
Brookfield. The numerous Pb, Zn, Cu, Mn, Ag (trace Co, Ni) mineral occurrences and prospects in the area commonly occur where the basal carbonate (Macumber Formation) overlies Horton Group continental siliciclastics (e.g. Walton, Upper Brookfield, Smithfield). Mineral deposits are also associated with basal carbonate buildups on Meguma Group basement beyond the Horton Group pinchout (Gays River Formation at Gays River). The Windsor Group basal carbonate and base metal-silver mineral association has been long recognized and investigated. Barite and siderite are commonly associated with these base metal deposits and in some cases are the dominant economic minerals.

Carbonate buildups of the Gays River Formation at the base of the Windsor Group are major exploration targets as potential hosts for base metal deposits of the Gays River Zn-Pb type. Many of these were discovered and explored throughout the 1970s, and although the host buildups are locally well developed, only a few were significantly mineralized. Although these buildups are not known to be present in the basin margin areas, they may occur in the deeper, unexplored parts of the Windsor Basin.

Significant lode gold was produced from various fold related quartz vein deposits in the Meguma Group in the Rawdon Hills. Minor placer gold has been prospecting and recovered from surficial drainage basins in the southern part of the Windsor Basin. This gold is inferred to have originated locally from lode gold mineralization in the underlying Meguma Group. Similar potential exists for paleoplacer deposits associated with the lower part of the Horton Group because it has a substantial source area in the surrounding Meguma Group metasedimentary rocks.

Non-metallic (Industrial) Minerals

Barite-Siderite

Discordant, stratiform and stratabound barite deposits, with or without associated siderite, base metals and silver, are well documented in the Windsor Group in the Windsor Basin and in the adjacent Shubenacadie Basin. The structurally controlled barite and siderite mineralization occurs primarily in association with faulted Macumber Formation and related Pembroke breccia carbonates along the structurally complicated Walton Block on the northern side of the Windsor Basin (e.g. Lower Burlington, Cheverie, Walton and Goshen). This mineral zone extends eastward into the northern side of the Shubenacadie Basin and includes the high-grade barite at Upper Brookfield (Nystone - Division of E-Z-EM Canada Inc., producer of high-grade medical barite) and occurrences at Middle Stewiacke, Southvale and Hidden.

Limestone and Dolostone

Limestone and dolomite occur throughout the Windsor Basin and are described in a report by Murray and Luke (in prep.). The most important occurrences of high quality limestone are located within the Windsor Group including, for example, small biothermal buildups associated with certain carbonate members of the MacDonald Road Formation. There has been minor previous production from carbonates of this type in the Windsor area. There are also known occurrences near Avondale and in the Miller Creek Quarry. There is currently no significant production at these locations.

Gypsum and Anhydrite

Gypsum and anhydrite outcrops are very widespread in the Windsor Basin area and the nature of these deposits is closely related to the stratigraphy, structural history, erosion and exposure to groundwater. The evaporitic sections dominating the Wentworth Station and Miller Creek formations and the underlying White Quarry (Carrolls Corner) and Stewiacke formations have undergone (and continue to vary degrees of dissolution in the near-surface and subsurface environments. Karstification features, including dolines, hummocky topography, sinkholes, cavities and other solution structures, are locally well developed in the near-surface environment. The penetration of groundwater has dissolved at least some and probably much of the periphery of the Stewiacke Formation salt in the Windsor Basin. Salt springs are locally very abundant. This dissolution process, together with accompanying hydration of most parts of the disturbed Wentworth Station and Miller Creek formations and the upper part of the White Quarry Formation, has produced very large gypsum deposits in the area.

There are very thick economic sections of gypsum (60 m or more) associated with extensively hydrated zones of the Windsor Group evaporite section. Historically, gypsum exploration, development and mining occurs near the contact between, and within, the White Quarry Formation (the A Subzone, basal anhydrite) and the overlying Wentworth Station and Miller Creek formations (B Subzone). This geology occurs extensively along the southern border of the Windsor Basin near Windsor, as well as near Cheverie and Walton along the northern border of the map area. The White Quarry Formation is generally less structurally disturbed than the overlying Wentworth
Station and Miller Creek formations, which are typically escavally/recumbently folded and faulted. These units, in their type areas in the Fundy Gypsum Company quarries along the southern border of the basin, are separated by a structurally disturbed contact zone (the Dark Quarry Fault Zone) near the top of the White Quarry Formation. Regionally, a major stratigraphic unit named the Siewiacke Formation occurs at this position. It is very distinctive, known only in subsurface sections and dominated by stratified halite with subordinate anhydrite and mudrock. Near-surface dissolution processes have invariably removed the soluble evaporites from these sections, especially near permeable fault zones and basin margins. Stratified halite is known to occur in correlatable sections of the Wentworth Station and Miller Creek formations (B Subzone) in the eastern part of the basin near Riverside Corner and Upper Walton River. The presence of halite has a potentially major role in the structural discontinuity, complex folding and faulting at the top of the White Quarry Formation, both locally and regionally (major decollement zone).

These units and the structurally disturbed contact zone have the greatest potential for gypsum development due to the balance of appropriate rock types, stratigraphy and structure. Fractures, natural rock permeability and associated groundwater penetration are essential to fully hydrate the parent anhydrite beds. This situation has been identified both locally and regionally (e.g. Musquodoboit and Shubenacadie basins) where exceptionally thick and extensive hydration occurs. A contributory component (locally dominant) is an association of gypsum with residual material from the dissolution of a major stratified salt unit (with subordinate anhydrite interbeds) in the Siewiacke Formation, which occurs (formerly occurred) at this exact stratigraphic level.

Salt and Potash

The first exploration for potash deposits in the Windsor Basin was undertaken in 1974, as a consequence of the previous discovery of large potash deposits associated with gravity anomalies in the lower part of the Windsor Group in New Brunswick. Exploration drilling was carried out on the large Kennebecook gravity anomaly at Clarksville (near Riverside Corner, Fig. 1) along the southeastern border of the basin immediately east of the Wolfville-Windsor map area. This drilling encountered deformed stratified salt deposits in the Watering Brook Formation above the Windsor Group. Although potash salts were not intersected, substantial salt deposits are documented here and throughout the Windsor Basin (eight deposits and occurrences), as well as in the adjacent Shubenacadie Basin. Deep petroleum exploration wells and mineral exploration drillholes intersecting significant salt sections include: Anthony No. 1 near Kennebecook, Noel No. 1 near Noel Road, and Riverside Corner RC 85-1 near Riverside Corner (Boehner, 1994). The Windsor Basin has numerous occurrences of salt springs and seeps, indicating the wide distribution of salt-bearing Windsor Group rocks. There is significant potential for large, stratified salt resources and potentially potash in the central region of the basin.

Native Sulphur

The occurrence of native sulphur in the Windsor Group has been investigated since the 1960s. The Hilden area, located at the far eastern extremity of the Windsor Basin (Fig. 1), has interesting occurrences of native sulphur both in outcrop and in exploration drill core. The sulphur occurs with calcite, fluorite and trace hydrocarbons in fracture-fill within evaporites of the lower part of the Windsor Group (Carrolls Corner Formation). It is interesting to note that there is an unusual anhydrite/flourite vein association without sulphur in the White Quarry Formation (Carrolls Corner Formation correlative) anhydrite at White Head near Cheverie. Hydrocarbon occurrences are abundant in the Windsor Group at this locality. The association of native sulphur and hydrocarbons is a well known connection in commercial developments.

Petroleum and Natural Gas

Interest in hydrocarbon exploration (including exploration well drilling) began in the early 1900s near Cheverie and Falmouth (Windsor). Drilling and seismic programs have operated from the mid-1940s (e.g. Kennetcook) to the early 1980s (e.g. Noel), with several wells drilled in the Kennetcook area. Most of this hydrocarbon exploration focused on plays in the Horton Group and the lowermost part of the Windsor Group. The prospective rocks in this interval are noted for hydrocarbon shows and occurrences (e.g. Cheverie, Walton Barite Mine, Soquip et al. Noel No. 1 etc.); however, commercial discovery and development has yet to occur. In the adjacent Shubenacadie Basin, drillhole NSDME Alton 87-1 intersected a high pressure flow of natural gas (methane) near the top of the Carrolls Corner Formation anhydrite where it is overlain by salt of the Siewiacke Formation. Small gas seeps and gas shows are frequently associated with mineral exploration diamond-drill holes intersecting Windsor Group evaporites. Minor natural gas occurrences were detected in the Soquip et al. Noel No. 1 well and oil seeps were common in mine workings intersecting the Windsor-
Group. Outcrops of evaporite and carbonate rocks are locally very petrolierous, especially the White Quarry Formation anhydrite near Cheverie in the northwestern part of the Windsor Basin. Liquid hydrocarbon was a commonly encountered in the underground workings of the Walton barite mine and is often associated with the ore zones. The potential for hydrocarbon resources in the deeper parts of the Windsor Basin and adjacent Shubenacadie and Musquodoboit basins is virtually unknown at this time because the lack of geological information. This hydrocarbon potential requires additional exploration and drilling for assessment.

Coal

Minor, fissile coaly shales occur in association with the Scotch Village Formation in the Windsor and Shubenacadie basins. Similar centimetre-scale coaly shales have been intersected in drillholes in the Windsor Basin, but do not appear to be of economic significance.

References


