Ministry of
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Ontario Geological Survey
Open File Report 5856

Paleozoic Geology of the Central Bruce Peninsula

1993

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ONTARIO GEOLOGICAL SURVEY

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By

D.K. Armstrong

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ABSTRACT

The Paleozoic strata of the Bruce Peninsula form the defining physiographic feature of the region, the Niagara Escarpment, and host significant building stone and aggregate resources. In 1987, the Ontario Geological Survey initiated a multi-year project designed to map the exposed Paleozoic bedrock of the Bruce Peninsula at a scale of 1:50 000. In addition to surface mapping, a number of shallow to moderate depth drill holes (up to 123 m) were cored to provide subsurface data.

This report consists of the marginal notes for the preliminary map of the Paleozoic Geology of the Central Bruce Peninsula (P.map 3191). The map area encompasses the mainland part of the peninsula between latitudes 44°45' and 45°. Field work was carried out by the author during the summer of 1988, assisted by Ms. C. Czank.

Upper Ordovician shales and limestones through to lower Middle Silurian dolostones units are exposed along the east side of the Bruce Peninsula, beneath the Niagara Escarpment. The oldest exposed Paleozoic unit in the region comprises shales and minor limestones of the Upper Ordovician Georgian Bay Formation, observed along the shores of Cape Croker. Also well exposed on Cape Croker are unusual limestone beds within the typically red shales of the overlying Queenston Formation (Upper Ordovician). The dolostones of the Lower Silurian Manitoulin Formation form a discontinuous subordinate escarpment below the main Niagara Escarpment. This is overlain by shales and dolostones of the Cabot Head, Dyer Bay and Wingfield formations, which are less well exposed within the region. The contact between the Wingfield Formation and the overlying Fossil Hill Formation is a regionally angular unconformity, progressively cutting the Wingfield Formation to the south. The Fossil Hill Formation attains maximum thickness (7 m) at Sydney Bay. The overlying Amabel Formation, forming the main face of the Niagara Escarpment, is subdivided into two members, the lower Lions Head Member and upper Wiarton/Colpoy Bay Member. The latter member is subdivided into two lithofacies: biohermal, best developed near the top of the Amabel Formation; and non-biohermal. The Amabel Formation is overlain by the Guelph Formation consisting of biohermal, non-biohermal and inter-biohermal lithofacies. The bituminous and commonly laminated inter-biohermal lithofacies constitutes the Eramosa Member. The biohermal lithofacies is developed as stratigraphically low, northwest trending ridges in the central part of this map area and as large, stratigraphically thick, biohermal zones at the north and south ends of the map area.

The Wiarton/Colpoy Bay Member of the Amabel Formation and the Eramosa Member of the Guelph Formation are significant sources of dimension and building stone products in the map area. The distribution of the Eramosa Member is delineated on the accompanying map.

In the Bruce Peninsula, a number of zinc sulphide occurrences have been identified in the biohermal lithofacies of the Guelph and Amabel formations, as well as within the inter-biohermal Eramosa Member. The resource potential of most of these occurrences has been evaluated extensively.

Karstic features, including clint and grike topography, solution caves and pitted karstic pavement, are common in the dolostone bedrock of the Bruce Peninsula. The most extensive karst

development, the caves southeast of Mar, are developed in the biohermal lithofacies of the Guelph Formation.

Three bedrock stress release features, or pop-ups, were discovered in the map area. They range in orientation from 130° to 185° and occur at different stratigraphic levels.

Paleozoic Geology of the Central Bruce Peninsula

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PALEOZOIC GEOLOGY OF THE CENTRAL BRUCE PENINSULA

INTRODUCTION

Regional mapping by the Ontario Geological Survey (OGS) of the exposed Paleozoic strata on the Bruce Peninsula commenced in 1987 with mapping of the northern portion of the peninsula, north of latitude 45o00'N (Armstrong and Dubord 1992). This was followed, in subsequent years, with mapping of the central and southern portions of the peninsula (this map and Armstrong in press, respectively).

The central Bruce Peninsula map area is covered by 1:50,000 scale N.T.S. map sheets Cape Croker (41A/14) and White Cloud Island (41A/15). The Bruce Peninsula can be accessed by King's Highway 6, via Owen Sound and Wiarton. Public and private, paved and gravel roads provide good access in much of the map area. Access to some of the more remote regions in the map area are afforded by the Bruce Trail, numerous other trails and abandoned roads.

Subsurface information in the central Bruce Peninsula map area is afforded by drill cuttings and geophysical logs from a number of petroleum exploration wells drilled to Precambrian basement (see map for locations). In the 1980's the OGS drilled a series of deep regional drill holes in southern Ontario. These holes were continuously cored and geophysically logged through the Paleozoic succession to Precambrian basement (Johnson et al. 1985). One of these deep holes, drill hole OGS-82-4, is located within this map area, approximately 6 km northwest of Wiarton. In 1989 and 1990, the OGS cored a series of relatively shallow (35 to 123 m deep) drill holes on the Bruce Peninsula in support of the present mapping project. Preliminary results were reported by Armstrong (1989) and are incorporated in these marginal notes. Detailed core descriptions and geophysical logs will be published in a future open file report (Armstrong in prep.).

STRATIGRAPHY

The exposed Paleozoic strata of the Bruce Peninsula have been studied and mapped by a succession of geologists since the turn of this century. Although the resultant geological maps (Williams 1919; Caley 1945; Liberty 1966; Liberty and Bolton 1971) are generally consistent in their delineation of most formational contacts, there are significant exceptions, especially of the two youngest formations (the Amabel and Guelph formations). Additionally, numerous reports have been written on the stratigraphy, paleontology, and depositional histories of the Silurian strata of the Bruce Peninsula (Williams 1919; Bolton

1953; Bolton 1957; Sanford 1969; Liberty and Bolton 1971). Owing to its accessibility and relatively good bedrock exposure, the Silurian strata of the Bruce Peninsula have also been the subject of a number of geological field trips (e.g., Winder and Sanford 1972; Telford 1978; Armstrong and Goodman 1990).

The central Bruce Peninsula is underlain by up to 435 m of Paleozoic strata, however, less than 175 m (stratigraphic thickness) of these strata, ranging from Upper Ordovician to Middle Silurian in age, are exposed.

ORDOVICIAN

Georgian Bay Formation

The oldest strata exposed on the central Bruce Peninsula are the grey-green, siliciclastic shales, bioclastic limestones, and calcareous siltstones of the Upper Ordovician Georgian Bay Formation. This unit is exposed in a narrow outcrop belt along the eastern and northeastern shores of Cape Croker and Cape Commodore. Outcrops are typically small sections or bedding planes along the shore. The best exposure is along the eastern shore of North Bay where up to 7 m of strata are exposed in a 100 m long section. At this locality, the cores of large corals and stromatoporoids have been leached out and in-filled with coarse calcite, dolomite, celestite and fibrous gypsum. Commonly the limestone interbeds of this formation contain abundant bryozoans, brachiopods and orthoconic nautiloids, as well as rare corals and stromatoporoids. Sedimentary structures such as ripple marks and gutter casts are common in the limestone and siltstone interbeds. Locally, bioclastic limestone interbeds are capped by ripple-laminated calcisiltites.

The Georgian Bay Formation is approximately 100 m thick in drill hole OGS-82-4 (Johnson et al. 1985). In this map area, the uppermost approximately 10 m of this formation is exposed.

Queenston Formation

The Upper Ordovician Queenston Formation conformably overlies the Georgian Bay Formation. In addition to its characteristic red siliciclastic shales, the Queenston Formation, in the central Bruce Peninsula, contains significant interbeds of grey-green shale, siltstone, and fossiliferous and non-fossiliferous limestone.

Queenston Formation strata are widely exposed on Cape Croker and in the Big Bay area, where the limestone interbeds form ledges. Upper Queenston Formation strata, mostly red shales capped by 2 to 5 m of grey-green shales, are well exposed beneath dolostones of the Manitoulin Formation along the shores of Cape Dundas, Cape Paulett, and Colpoy's Bay.

The limestone interbeds range from non-fossiliferous, very fine-grained, dark grey beds up to 10 cm thick, to very fossiliferous, grey, argillaceous beds up to 1 m thick. Fauna include abundant brachiopods, bivalves and bryozoans, as well as sparse corals and nautiloids. In addition to limestone interbeds, very thin- to thin-bedded, calcareous and non-calcareous, fine-grained, green-grey to grey-brown siltstone interbeds are locally significant. These siltstone interbeds are commonly either planar or ripple-laminated. Siltstone interbeds are common in outcrops near Benjamin's Point and Kings Point on Cape Croker.

The basal contact of the Queenston Formation with the Georgian Bay Formation is traditionally placed at the base of the lowest significant red shale bed (Liberty and Bolton 1971). Aside from the grey-green shales which occur in its uppermost few metres, the Queenston Formation typically contains only minor, thin grey-green shale beds and rare carbonate beds. However, the Queenston Formation interval intersected in drill hole OGS-82-4 (Johnson et al. 1985) indicates that, in the central Bruce Peninsula area, at least 10 m of interbedded grey-green shale and limestone overlies a basal, approximately 10 m thick interval of predominantly red shale. The thickness and stratigraphic position of this interval is consistent with outcrops of similar rock types on Cape Croker and in the Big Bay-Cape Commodore area. The best exposure of the Queenston Formation/Georgian Bay Formation contact is at Benjamin's Point (or Montresor Point) on Cape Croker. The contact is placed at the base of the maroon and olive shales and occurs at the base of the cliff; grey-green, fossiliferous limestone beds which occur at the shoreline, below these reddish shales, are assigned to the Georgian Bay Formation.

Almost 60 m of strata assigned to the Queenston Formation were intersected in drill hole OGS-82-4 (Johnson et al. 1985). The thickest exposed sections in the map area are 8 m at Cape Dundas, 26 m at Benjamin's Point, 10 m at Mallory Beach, and 18.5 m east of Big Bay. The upper contact of the Queenston Formation is exposed at Cape Dundas, Cape Paulett and the south shore of Colpoy's Bay.

SILURIAN

Manitoulin Formation

The Lower Silurian Manitoulin Formation is exposed discontinuously along the eastern shore of the Bruce Peninsula, as a subordinate escarpment beneath the Niagara Escarpment. This formation consists generally of thin- to thick-bedded, light grey-brown to blue-grey, buff-brown weathering dolostones and calcareous dolostones.

The Manitoulin Formation can be grossly subdivided into 2 informal units: a lower medium- to thick-bedded, fine- to coarse-crystalline dolostone which is commonly planar laminated or cross-stratified and an upper, thin-bedded, bioturbated, fossiliferous, fine- to medium-crystalline dolostone (Anastas 1992). In the map area, the basal 0.5 to 2 m of the lower unit is commonly finer crystalline, slightly calcareous, bioturbated and argillaceous. Very thin shale beds and partings occur in these basal beds. Silicified fossils (brachiopods, crinoids and corals) are common in the upper unit and thin, discontinuous, silicified, fossil-fragment grainstone beds are common in the lower unit. Chert nodules and lenses are common throughout the Manitoulin Formation and gypsum nodules (up to 10 in diameter) occur locally (e.g., east of Rush Cove) in the lower part of the formation.

The Manitoulin Formation dolostones sharply overlie the shales of the Queenston Formation. This contact is exposed in extensive outcrops along the shores of Cape Dundas and Cape Paulett. It is also discontinuously exposed along the south shore of Colpoy's Bay.

The upper contact of the Manitoulin Formation is not exposed in the map area; however, it is very gradational in drill core (Johnson et al. 1985). The thickest exposures of the formation in the map area, approximately 8 m, are located at Cape Dundas, Cape Paulett and along the south shore of Colpoy's Bay. In drill hole OGS-82-4, Johnson et al. (1985) reported a thickness of 12.5 m.

Cabot Head Formation

In the central Bruce Peninsula, the Lower Silurian Cabot Head Formation (the Cabot Head (restricted) Member of Liberty and Bolton, 1971) consists primarily of red, siliciclastic shales. This formation is poorly exposed in the map area. Because of its shaly nature the Cabot Head Formation weathers recessively and generally occurs under talus covered and vegetated slopes. Owing to its poor exposure, narrow outcrop belt and the scale of this map, this unit is generally combined with one or more of the relatively thin overlying units.

The best exposures of the Cabot Head Formation in the map area are in a road cut above and south of Rush Cove (on the north shore of Cape Dundas) and in a ditch outcrop on the hillside, 3 km south of Big Bay. In both locations less than 3 m of this formation are exposed beneath dolostones of the Dyer Bay Formation. Although predominantly a red shale in this area, the uppermost 1 to 2 m of this formation is also commonly green. In a small outcrop on the north shore of Hope Bay, thin, irregular beds of bryozoan-rich, argillaceous dolostone occur in red and blue-green shale assigned to the Cabot Head Formation. Minor, thin, sparsely fossiliferous dolostone beds are known in thicker outcrops of this formation in the northern Bruce Peninsula area (Armstrong and Dubord 1992).

The lower contact of the Cabot Head Formation is not exposed in this map area. In drill hole OGS-82-4 approximately 25 m of strata were assigned to this formation (Johnson et al. 1985). This formation is reported to be up to 30 m thick in petroleum exploration wells in the map area.

Dyer Bay Formation

The dolostones of the Middle Silurian Dyer Bay Formation are not well exposed in the map area. This formation is exposed in three significant outcrops: in a road cut above and immediately south of Rush Cove; in Gleason Creek at Oxenden; and in a ditch outcrop on a hillside south of Big Bay. In all three locations its sharp basal contact with the Cabot Head Formation is exposed. This formation is also exposed in small outcrops along the shore of Barrow Bay.

The Dyer Bay Formation consists of thin- to medium-bedded, light grey to dark grey-brown, microcrystalline to coarse-crystalline dolostone. The basal 1 m is commonly microcrystalline. This formation typically exhibits platy, planar to slightly irregular parting and very regular, vertical jointing. The Dyer Bay Formation is sparsely to moderately fossiliferous, with its fauna dominated by bryozoans; the fauna also includes corals, brachiopods, and gastropods. Trace fossils are abundant. The formation also contains various non-biogenic sedimentary structures such as soft-sediment slumps, scour marks, ripple marks, and ripped-up lithoclasts.

In outcrop, the lower contact of the Dyer Bay Formation with the Cabot Head Formation is sharp and appears disconformable. However, in drill hole OGS-90-4, load casts of Dyer Bay Formation dolostone occur in the underlying Cabot Head Formation shale. The gradational upper contact of the Dyer Bay Formation with the Wingfield Formation is exposed in the outcrop 6 km south of Big Bay. Shaly dolostone beds at the top of the Rush Cove outcrop may also represent the transitional contact into the overlying Wingfield Formation.

In outcrop, the Dyer Bay Formation ranges from 4.7 m thick at Rush Cove to 3.2 m thick at Big Bay. In the subsurface, cored thicknesses range from 4.78 m in drill hole OGS-90-4 to 4.88 m in OGS-82-4 (Armstrong in prep.; Johnson et al. 1985). Thicknesses of up to 11 m for the Dyer Bay Formation in the subsurface are reported from petroleum exploration wells in the map area.

Wingfield Formation

The Middle Silurian Wingfield Formation consists of interbedded dolostone and shale. Although dominantly dolostone, its thin shale interbeds predispose this unit to recessive weathering. In this map area it is typically poorly exposed beneath dolostone outcrops of the Fossil Hill Formation.

The Wingfield Formation consists of grey-green shale interbedded with thin beds of grey-brown, fine- to medium-crystalline dolostone and argillaceous dolostone, with grey-green shale lithoclasts and partings. The dolostone interbeds are locally laminated, and ripple marks and mudcracks are common.

The lower gradational contact of the Wingfield Formation with the Dyer Bay Formation, exposed in a ditch outcrop south of Big Bay, is placed at the base of the lowermost significant occurrence of grey-green shale. In drill core, this contact is also marked by a change in colour of dolostone interbeds, from olive in the Wingfield Formation to blue-grey in the Dyer Bay Formation. The sharp, disconformable, upper contact of the Wingfield Formation with the Fossil Hill Formation is best exposed along the shore at Isthmus Bay, at Lion's Head.

The Wingfield Formation thins towards the south, as it is progressively cut by a regional unconformity at the base of the Fossil Hill Formation (Armstrong in prep.). Thicknesses of the Wingfield Formation in the subsurface range from 5.2 m in drill hole OGS-89-1 to 4.1 m in OGS-82-4. It is less than 2 m thick (with top and bottom contacts) in an outcrop south of Big Bay, near the southern boundary of this map area.

Fossil Hill Formation

The Middle Silurian Fossil Hill Formation, consisting primarily of thin- to medium-bedded fossiliferous dolostone, commonly occurs in the central Bruce Peninsula map area as a subordinate escarpment below the main Niagara Escarpment. This formation is well exposed in extensive bedding plane outcrops along the shore of Isthmus Bay, and in low escarpment outcrops at Isthmus Bay, Hope Bay, Barrow Bay, Sydney Bay, Jones Bluff, Coveney's Hill and Malcolm Bluff. Other significant outcrops occur at Colpoy's Bay, Skinner's Bluff and south of Big Bay.

The Fossil Hill Formation consists of thin- to medium-bedded, light to dark brown, fine- to coarse-crystalline, fossiliferous dolostone with an abundant and commonly silicified fauna. The fauna is dominated by pentamerid brachiopods and includes, locally, significant coral (syringoporid, halysitid, and favositid types) and stromatoporoid concentrations (Johnson 1979). In the northern part of the map area, the middle third of the formation consists of very fine- to microcrystalline, bioturbated, non-fossiliferous dolostone which is informally referred to as the "barren beds" or "barren zone". This "barren zone" thins from approximately 2 m at Isthmus Bay to less than 20 cm at Cape Croker and it does not appear to be present in outcrops south of Cape Croker. In the subsurface the "barren zone" ranges from 2.74 m thick in drill hole OGS-89-1, near Pike Bay, to less than 20 cm thick in OGS-90-4, near Hope Bay.

Regionally, the basal contact of the Fossil Hill Formation is an angular unconformity cutting progressively older units in a southwardly direction. In its outcrop belt, this formation sharply overlies grey-green shales and interbedded dolostones of the Wingfield Formation at Isthmus Bay, in a number of outcrops on and near Cape Croker, at Lake Charles, Skinner's Bluff, and south of Big Bay.

The Fossil Hill Formation ranges from approximately 5 m thick in the Lion's Head area, to over 7 m thick in the escarpment south of Sydney Bay and approximately 4 m thick in the Big Bay area. In the subsurface of the map area this formation thins southwardly from 7.57 m thick in drill hole OGS-89-1 to 3.54 m thick in OGS-82-4.

Amabel Formation

On the Bruce Peninsula the Amabel Formation is stratigraphically subdivided into a lower unit, the Lions Head Member and an upper unit, the Wiarton/Colpoy Bay Member. In this study the Amabel Formation is subdivided into three lithofacies: lithofacies A_a corresponds directly to the Lions Head Member, and lithofacies A_b and A_c correspond to the non-biohermal and biohermal lithofacies of the Wiarton/Colpoy Bay Member, respectively. In the map area, lithofacies A_a constitutes the lowest few metres of the formation. Lithofacies A_b makes up most of the remainder of the formation, that is, the Wiarton/Colpoy Bay Member. Lithofacies A_c occurs discontinuously in the upper part of the Wiarton/Colpoy Bay Member.

The **Lions Head Member**, or **lithofacies A_a**, consists of light grey-tan, thin- to thick-bedded, platy to blocky parted, fine-crystalline, dense, non- to sparsely fossiliferous dolostone with locally significant blue to purple mottles, chert nodules and microstylolites. The sparse fossils, which include corals, stromatoporoids, and crinoids, are commonly broken and silicified. Mottles are typically distinct and range from sparse, small, burrow-like shapes to more intense swirly forms. Thin blue beds with sharp upper contacts (possibly hardgrounds) occur locally near the base of this member.

The basal contact of the Lions Head Member with the underlying Fossil Hill Formation is generally not well exposed. It commonly weathers recessively and is covered. Two clean exposures of this contact were discovered in the map area: at the western end of King's Point Bluff and at Malcolm Bluff. This contact is partly covered in outcrops at Isthmus Bay, Colpoy's Bay, Jones Bluff, above Mallory Beach, at Skinner's Bluff and south of Big Bay. This sharp contact is typically marked by a dramatic increase in fossil content into the Fossil Hill Formation and the appearance of mottles in the Lions Head Member. In drill core this contact is sharp and appears to be disconformable, locally marked by the presence of glauconite, pyrite, and/or possible hardgrounds (Armstrong in prep.).

Despite intense dolomitization which obscures fossil content and primary sedimentary structures in the **Wiarton/Colpoy Bay Member**, 2 gross lithofacies have been identified: the non-biohermal lithofacies A_b and the biohermal lithofacies A_c. Both of these lithofacies are very thick-bedded, white-weathering dolostones which form the main cliffs of the Niagara Escarpment. They are differentiated on the basis of apparent fossil content and related porosity, bedding morphology, weathering characteristic and, locally, mottling style and intensity.

Lithofacies A_b consists of white to light grey-tan, blue-grey mottled, fine- to medium-crystalline, thick- to massive-bedded, sparsely to very fossiliferous dolostone. Porosity in this lithofacies ranges from nonexistent to local fossil moldic or vuggy porosity. A moderately to well developed, fine, inter-crystalline porosity is common to this lithofacies. Lithofacies A_b appears to consist mainly of dolomitized sand-sized echinoderm fragments. Locally identifiable fossils include echinoderms, corals (rugose and tabulate), cephalopods and brachiopods. The characteristic streaky, diffuse, blue-grey mottling and related(?) ribbed pattern, exhibited on weathered vertical faces (i.e., on dissolution enhanced joint surfaces), appear to indicate primary bedding and locally is suggestive of cross-stratification.

Generally, lithofacies A_b gradationally overlies lithofacies A_a. Locally, however, coarser lithofacies A_b beds sharply overlie lithofacies A_a or interbeds of one of the lithofacies occur within the other. In the northern Bruce Peninsula lithofacies A_b grades laterally, to the north and northwest, into lithofacies A_a (Armstrong and Dubord 1992).

Lithofacies A_c is lithologically similar to lithofacies A_b except that the former is commonly more intensely and irregularly blue-grey mottled and coarser crystalline. In addition, the fauna, which is essentially the same as in lithofacies A_b, is generally more obvious, larger and rimmed by blue-grey colouration in lithofacies A_c. Also, bedding is more lensoidal or undulatory than in lithofacies A_b. Lithofacies A_c tends to weather more ruggedly than lithofacies A_b which weathers into relatively smooth, large, jointed blocks. These characteristics are consistent with a biohermal origin for lithofacies A_c. Small lenses, a few metres across, of lithofacies A_c occur locally in lithofacies A_b and are not indicated on the map. Small zones of dense, fine-crystalline, locally vuggy, irregularly blue-mottled dolostone, observed at the Adair Marble Quarry, south of Hope Bay, may be small mud-dominated lenses of lithofacies A_c.

Large, northwest trending dolostone ridges occur within the middle to upper part of the Amabel Formation on the Bruce Peninsula. In this map area, these ridges are well developed on the Lion's Head, Cape Dundas, and Sydney Bay Bluff promontories and in the area from approximately 5 km southwest of Hope Bay to north of Berford Lake. These bedrock ridges are in the order of

10's of metres wide by 100's of metres long and up to a few metres high. Although they commonly contain undulatory bedding, other lithofacies A_c characteristics (e.g., high fossil content) are not always obvious in outcrop and a biohermal origin is speculative. An alternate explanation for the origin of these ridges is that they are large, current-formed sand bodies, composed of lithofacies A_b. They possibly formed the foundation for lithofacies A_c bioherms or younger Guelph Formation bioherms.

The lithofacies A_c ridges which occur from southwest of Hope Bay to north of Berford Lake, directly underlie similarly oriented bioherms of the Guelph Formation. Lithofacies A_c dolostone is commonly similar in appearance to the biohermal lithofacies of the Guelph Formation (lithofacies G_d), so the contact between the Guelph and Amabel formations in this biohermal zone is placed where flanking and laterally equivalent beds of non-biohermal Guelph Formation lithofacies (lithofacies G_b and G_c) occur.

Although not well exposed in outcrop, the upper contact of the Amabel Formation with the Guelph Formation appears gradational, in both biohermal and non-biohermal situations. In drill core (e.g., OGS-89-1) the top of the Amabel Formation (Wiarton/Colpoy Bay Member) is commonly sharp and stylolitized (Armstrong in prep.).

A complete section through the Amabel Formation is not exposed in a single outcrop in the map area. An almost complete section of the Amabel Formation, approximately 25 m thick (Bolton 1957), is exposed immediately south of the map area, in the large road cut north of Wiarton. In the subsurface of the central Bruce Peninsula this formation ranges from approximately 24 m in drill hole OGS-82-4 to over 30 m in drill hole OGS-89-1 (Armstrong in prep.).

<u>Guelph Formation</u>

In this study, 4 lithofacies are identified which constitute the Guelph Formation. Two lithofacies, G_a and G_b, correspond to the strata assigned to the Eramosa Member (previously of the Amabel Formation). The remainder of the Guelph Formation consists of the non-biohermal lithofacies G_c and the biohermal lithofacies G_d. Lithofacies G_a and G_b (i.e. the Eramosa Member) occupy an inter-biohermal position in the lower part of the formation. The bioherms of lithofacies G_d occur at various stratigraphic horizons in the formation: underlying, overlying and lateral to the Eramosa Member lithofacies. Lithofacies G_c occurs throughout the Guelph Formation, overlying and grading laterally into lithofacies G_d and gradationally overlying lithofacies G_a and G_b.

The **Eramosa Member**, consisting generally of thin-bedded, bituminous dolostone, can be subdivided into two lithofacies, G_a and G_b. **Lithofacies G_a** consists of tan-grey to black, very fine- to medium-crystalline, thin- to medium-bedded, sparsely fossiliferous, moderately to very bituminous, laminated dolostone. Chert nodules occur locally, especially in very bituminous, black beds. Sphalerite concretions occur in lithofacies G_a in at least two locations in the map area: just east of Highway 6, approximately 12 km south of Ferndale (Sangster and Liberty 1971; Tworo 1985); and at the north end of Owen Sound Ledgerock Ltd.'s Wiarton Quarry. Interbeds of non-laminated, slightly bituminous lithofacies G_b dolostone are common. Fauna, including brachiopods and corals, are typically small and sparse. Laminae occurring towards the base of the lowest lithofacies G_a beds are stromatolitic.

Lithofacies G_b consists of light tan to grey-tan, thin- to thick-bedded, sparsely fossiliferous, slightly to moderately bituminous dolostone with sparse to abundant microstylolites and local chert. This lithofacies is commonly interbedded with lithofacies G_a and is transitional in character between lithofacies G_a and lithofacies G_c. The contact between lithofacies G_b and G_c is gradational. Locally, lithofacies G_b is moderately fossiliferous, typically containing fragmented corals and shells. Locally, such as in the road cut immediately north of Wiarton, this lithofacies is vuggy and contains fine needle-like molds, probably after gypsum.

In the southern and central Bruce Peninsula, the lithofacies which constitute the Eramosa Member occur in three informal units: 1) a basal unit consisting of lithofacies G_b; 2) a middle unit consisting of the laminated lithofacies G_a (informally termed the "Marble Bed"); and 3) an upper unit consisting of interbedded lithofacies G_a and G_b. This internal stratigraphy of the Eramosa Member is generally best exposed in and around the building stone quarries located along Oliphant Road, a few kilometres northwest of Wiarton (Armstrong and Meadows 1988). Liberty and Bolton's (1971) reference section for the Eramosa Member on the Bruce Peninsula, located at the southwest end of Sky Lake, exposes only the upper unit of the Eramosa Member. The middle unit is typically 3 to 4 m thick and is plotted with lithofacies G_b on this map; individual outcrops of lithofacies G_a are noted on the map.

Up to 12 m of Eramosa Member strata are exposed in the Oliphant Road quarries. In OGS drill hole OGS-89-1, a complete interval of this member, approximately 24 m thick, was intersected (Armstrong in prep.).

Lithofacies G_c comprises the bulk of the Guelph Formation on the Bruce Peninsula. This lithofacies consists of light grey-tan to brown, fine- to medium-crystalline, thin- to thick-bedded, sparsely to very fossiliferous dolostone. It is typically tabular bedded and beds are horizontally oriented, except where they drape over bioherms of lithofacies G_d. Locally, lithofacies G_c exhibits minor blue-grey mottling. Lithofacies G_c fauna includes bivalves, gastropods, brachiopods, cephalopods, corals, stromatoporoids, and echinoderms. These fossils are locally concentrated into biostromal horizons or into small (less than 3 m diameter) biohermal mounds; both of which are included within this lithofacies.

On a weathered surface, lithofacies G_c commonly exhibits a course subhorizontal ribbing (centimetre to decimetre scale) which corresponds to interbeds of softer, more porous (and more fossiliferous?) dolostone and more resistant, less porous beds. Locally the non-porous beds appear laminated. As with the Amabel Formation, dolomitization has obscured much of the primary structures and fossil content in the Guelph Formation.

Generally, lithofacies G_c gradationally overlies lithofacies G_b or Amabel Formation lithofacies A_b. Lithofacies G_c also grades laterally into the flank beds of lithofacies G_d bioherms. Non-horizontal (up to 20^o) beds of lithofacies G_c, G_b and G_a are interpreted as draping over lithofacies G_d bioherms.

Lithofacies G_d consists of light grey-tan to tan, locally blue-grey mottled, medium- to very coarse-crystalline, thin- to thick-bedded, irregular to lensoidal bedded, fossiliferous dolostone. This lithofacies is interpreted to be biohermal in origin. The contained fauna is essentially the same as in lithofacies G_c, however, the more abundant and larger frame-builders (corals and stromatoporoids) predominate. Fossils are commonly concentrated in type-specific zones. Very coarse encrinitic grainstones are common in the lower and flanking parts of these bioherms.

Blue-grey colouration, either as mottles or rimming fossils, is similar to that seen exhibited by the Amabel Formation biohermal lithofacies A_c. In addition, the commonly thick and lensoidal bedding of lithofacies G_d is also similar to that of the Amabel Formation. Where Guelph Formation bioherms directly overlie Amabel Formation lithofacies A_c, such as in the area 5 km west of Hope Bay, the similarities in lithologic character complicate the placement of the formational contact. Outcrops of biohermal dolostone which occur in isolation (i.e. without associated flanking beds) and stratigraphically in vicinity of the Guelph Formation-Amabel Formation contact are commonly difficult to assign to one formation or the other.

Areas designated on the map as being underlain by lithofacies G_d commonly include a number of individual bioherms and intervening areas with outcrops of lithofacies G_b or G_c. Beds of these latter lithofacies are commonly oriented sub-horizontal, as they drape or flank the bioherms.

In the central Bruce Peninsula, lithofacies G_d occurs in an almost continuous unit at the base of the Guelph Formation. Thicker biohermal developments occur at the north end of the map area, from east of Stokes Bay to Myles Bay, and near the south end of the map area, in the Berford Lake area. Small bioherms also occur near the top of the Guelph Formation strata, along the west shore of the peninsula, in the Howdenvale to Rocky Point areas.

The lower Guelph Formation bioherms appear to be gradational with the underlying Amabel Formation lithofacies A_c biohermal strata. Both of these biohermal strata form northwest oriented ridges, discernable on topographic maps and in aerial photographs (Armstrong and Goodman 1990). These biohermal ridges are best exposed in the area along Highway 6, south of the Eastnor Swamp, approximately 7 km southwest of Hope Bay. Ridges, formed in overlying and draping lithofacies G_c strata, persist for a number of kilometres west of the lithofacies G_d outcrop belt.

The lithofacies G_d outcrops along the north shore of Myles Bay are among the most fossiliferous in the map area and exhibit zonation of fossil types. The lower Guelph Formation bioherms are not exceptionally fossiliferous. Typical fauna and the relationship of this lithofacies to flanking lithofacies G_b and G_c beds are well exposed in glacially fluted outcrops in a gravel pit 5 km south of Ferndale.

There is no single outcrop in the map area which exposes a complete section through the Guelph Formation. The thickest Guelph Formation interval intersected in OGS drill holes in the map area is approximately 32 m, in OGS-89-1, just north of Pike Bay. The lowest 24 m of this interval is assigned to the Eramosa Member (Armstrong in prep.).

ECONOMIC GEOLOGY

Building stone has been quarried from the Amabel and Guelph formations on the Bruce Peninsula since before the turn of the century (Parks 1912; Goudge 1938). The Wiarton/Colpoy Bay Member of the Amabel Formation is currently quarried for aggregate and related products at quarries in the southern Bruce Peninsula and for dimension stone at the Adair Marble Quarry, south of Hope Bay (Derry Michener Booth and Wahl and Ontario Geological Survey 1989). Lithofacies A_b dolostone from this quarry was recently used in the construction of the Canadian Chancery in Washington D.C.

The Eramosa Member of the Guelph Formation is currently quarried for a variety of building stone products from numerous quarries in the central and southern Bruce Peninsula (Armstrong and Meadows 1987; Derry Michener Booth and Wahl and Ontario Geological Survey 1989). The laminated nature of lithofacies G_a in the middle unit of this member, commonly called the "Marble Bed", produces a decorative polished dimension stone. The Eramosa Member directly underlies Quaternary drift in two areas in the central Bruce Peninsula map area: 1) in the vicinity of the two quarries located approximately 12 km south of Ferndale; and 2) in a large belt from north of Beattie Lake to the Oliphant Road quarries, located at the south end of the map area, a few kilometres northwest of Wiarton. This large belt appears to have more of the Eramosa Member stratigraphy preserved (i.e., the upper unit). It is, however, covered by surficial sediments over much of its areal extent. In the smaller area, to the north, the upper unit appears to consist entirely of lithofacies G_b and does not contain significant bituminous interbeds as is the case in the larger belt.

Eramosa Member and Guelph Formation lithofacies (G_a, G_b and G_c) may locally yield thicker-bedded blocks suitable for dimension stone. Lithofacies A_b is a proven source of dimension stone and essentially underlies the eastern half of the central Bruce Peninsula, from north of Wiarton to Lion's Head. This unit also has good potential as a source of aggregate in its outcrop belt. The Ontario Geological Survey recently conducted an evaluation of aggregate resources in St. Edmund and Lindsay townships (OGS, in prep). Aggregate quality tests conducted by the Ministry of Transportation of Ontario (MTO) yielded generally favourable results for outcrop samples of the Guelph and Amabel formations. Development is controlled, on the eastern side of the peninsula, by the Niagara Escarpment Plan.

During the mid-1960's Dow Chemical of Canada Ltd. conducted a shallow drilling program on the Cape Dundas promontory, between Hope Bay and Barrow Bay, in search of chemical-grade dolostone.

In the central Bruce Peninsula, potential shale resources are limited to a narrow outcrop belt along the base of the Niagara Escarpment and to the Cape Croker Indian Reserve. Although extensively exposed on Cape Croker, the significant limestone and siltstone interbeds in the Queenston Formation in this area may limit development potential of this shale.

The Guelph and Amabel formations are host to a number of zinc sulphide (sphalerite) occurrences on the Bruce Peninsula which have been extensively investigated since the early part of this century (Williams 1919; Guillet 1967; Liberty and Bolton 1971; Sangster and Liberty 1971; Tworo 1985). Despite intensive mapping, trenching, geochemical sampling, and diamond drilling, none of these occurrences were proven to be economic deposits. Coarse-crystalline sphalerite occurs as: 1) open space fillings (in fossil molds, vugs and fractures) in the biohermal lithofacies of the Guelph and/or Amabel formations; and 2) as nodules in lithofacies G_a of the Eramosa Member with haloes of very fine-crystalline sphalerite replacing the host dolostone. The largest occurrence of the first style of mineralization is the former Albemarle Zinc or Bruce Peninsula Zinc occurrence, located southwest of Berford Lake. Sphalerite occurs in outcrops of lithofacies G_d up to 1 km northwest of this showing. This style of mineralization is also present in lithofacies G_d bioherms at the McLay Farm occurrence, located approximately 12 km south of Ferndale. The second style of mineralization also occurs at the McLay Farm locality. Similar sphalerite nodules with replacement haloes were discovered in lithofacies G_a at the north end of the Owen Sound Ledgerock Ltd.'s Wiarton Quarry, northwest of Wiarton. A number of other properties in the central Bruce Peninsula have been investigated for zinc mineralization by exploration companies as late as the mid-1960's (MNDM Mineral Deposit Inventory). Their investigations appear to have commenced as soil geochemical anomalies which led, in many cases, to diamond drilling.

The only hydrocarbon-producing field on the Bruce Peninsula is the now-abandoned natural gas field at Hepworth, in the southern part of the peninsula. This field produced gas from the Ordovician Simcoe Group (or Trenton-Black River) at a depth of approximately 427 m, from 1901 to approximately 1935 (Bailey and Cochrane 1984). Six hydrocarbon exploration wells have been drilled in the central Bruce Peninsula map area. Of these only 1, drilled in 1924, encountered a show of natural gas. A seventh well drilled into potential hydrocarbon-bearing strata in the map area, drill hole OGS-82-4, encountered two oil shows in Ordovician strata at depths greater than 400 m.

KARST

The carbonate bedrock surface of the Bruce Peninsula has been exposed to the dissolution action of water owing to the relatively thin drift cover. Karst features and processes on the Bruce Peninsula were described by Cowell (1976) and Cowell and Ford (1980). Karst pavement has developed on the exposed bedrock surfaces and karstic dissolution has progressed through joints, fractures and other porous zones into the subsurface. In general, dissolution seems most intense in lithofacies with a higher fossil content and associated higher initial porosity (i.e. lithofacies A_c and G_d and the biostromal zones in lithofacies G_c). Pitted karstic pavement is typically well developed on the bedding plane outcrops of Guelph Formation on the western shore of the peninsula.

Dissolution-enhanced joints characterize karst development in the thick-bedded Amabel Formation dolostones on the topographically higher eastern side of the peninsula. In both the Amabel and Guelph formations, extensive clint and grike systems are developed. Within 1 to 2 km west of the edge of the Niagara Escarpment, joint patterns are recognizable on 1:10,000 scale aerial photographs in open fields with thin drift cover. These joint patterns are well developed in fields underlain by either the Fossil Hill or Amabel formations and are particularly evident in the area southwest of Cape Croker.

The Mar Caves, located on the northwestern shore of Berford Lake, are karstic caves developed in the biohermal lithofacies G_d of the Guelph Formation (Cowell 1976). Sinkholes are commonly developed in the biohermal dolostones which cap the promontories on the east side of the peninsula. Greig's Caves, located on the southern side of Barrow Bay, are "sea caves", developed near the base of the Amabel Formation primarily by waves of a post-glacial lake.

STRUCTURAL GEOLOGY

Liberty and Bolton (1971) report the regional dip of Paleozoic strata on the Bruce Peninsula to range from 4.8 to 7.6 m/km to the southwest. The regional strike and dip, determined for this map area using the base of the Fossil Hill Formation as encountered in OGS drill holes as a datum, are 164^{o} and 6.5 m/km to the southwest, respectively. A strike and dip of 162.5^{o} and 6.4 m/km, respectively, were determined using the base of the Manitoulin Formation as encountered OGS-82-4, a petroleum exploration well and an outcrop elevation.

A well developed joint system is evident in the dolostone strata of the Bruce Peninsula. Locally, especially in the topographically higher and thick-bedded units on the eastern and northern parts of the peninsula, joints are preferential sites for karstic dissolution. Joint orientations, systematically measured in this map area, revealed major orientation concentrations clustered at 45 to 80^{o} and 145 to 185^{o}. A smaller clustering was noted at 90 to 100^{o}. Generally, joints were less well developed in biohermal strata.

Recent (neotectonic?) bedrock stress release features, or pop-ups, were discovered at 3 locations in the central Bruce Peninsula map area: 1) in interbedded shales, siltstones and limestones of the Queenston Formation, less than 1 km west of Benjamin's Point on Cape Croker; 2) in dolostones of the Fossil Hill Formation, approximately 1.5 km south of Coveney's Hill, southwest of Cape Croker; and 3) in dolostones of the Lions Head Member (Amabel Formation), 1.2 km east of Lake Charles. Although the Benjamin's Point pop-up is only visible in cross section, a linear feature which extends offshore from the pop-up into shallow water, and is visible on a 1:10,000 scale aerial photograph, is oriented at approximately 154^{o}. South of Coveney's Hill, up to 4 bare bedrock and earth covered (bedrock cored?) ridges are oriented from 340^{o} to 5^{o}. The Lake Charles pop-up is exposed in a low road cut through a bedrock-cored ridge which is oriented approximately 135^{o}. All of these features appear to have amplitudes of no more than 1 m.

ACKNOWLEDGEMENTS

The assistance of the owners and operators of the quarries in the central Bruce Peninsula is much appreciated. Permission, granted by the Chippewas of Nawash Band, to enter and examine the geology of the Cape Croker Indian Reserve (I.R. 27) is appreciated. Mr. R. Pasarich, of Owen Sound, is thanked for permission he granted to examine his zinc occurrence south of Berford Lake.

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CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

3268
ISSN 0826-9580
ISBN 0-7778-1472-2

Ministry of Northern Development and Mines

Ontario

Mines and Minerals Division
Ontario Geological Survey

MAP P.3191

PALEOZOIC GEOLOGY

CENTRAL BRUCE PENINSULA

SOUTHERN ONTARIO

Scale 1:50 000

1000 m 0 1 2 km

NTS References: 41 A/14, 15

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LEGEND

PALEOZOIC

SILURIAN

10	**Guelph Formation**
	10d Lithofacies G_d: Biohermal dolostone; light grey-tan to tan, fossiliferous, irregularly to lensoidal bedded; may include outcrops of other Guelph Formation lithofacies
	10c Lithofacies G_c: Dolostone; light grey-tan to brown, tabular bedded; locally biostromal
	Eramosa Member
	10b Lithofacies G_b: Dolostone; slightly to moderately bituminous, light tan to grey-tan, microstylolites, local chert
	10a Lithofacies G_a: Dolostone; laminated, moderately to very bituminous, local minor chert; interbeds of lithofacies G_b are common
9	**Amabel Formation**
	Wiarton/Colpoy Bay Member
	9c Lithofacies A_c: Biohermal dolostone; fossiliferous, white to light grey-tan, irregular blue-grey mottles, thick- to massive-bedded, undulatory to lensoidal bedding
	9b Lithofacies A_b: Dolostone; white to light grey-tan, streaky blue-grey mottles, thick- to massive-bedded
	Lions Head Member
	9a Lithofacies A_a: Dolostone; light grey-tan, thin- to thick-bedded, dense, sparsely fossiliferous; local blue to purple mottles, chert nodules and microstylolites
8	**Fossil Hill Formation:** Dolostone; fossiliferous; fauna commonly silicified; local chert nodules; microcrystalline, non-fossiliferous beds in middle
7	**St. Edmund Formation**[a]: Dolostone
6	**Wingfield Formation:** Interbedded dolostone and shale; dolostone is thin-bedded; shale is grey-green
5	**Dyer Bay Formation:** Dolostone; light grey to dark grey-brown, thin- to medium-bedded, moderately fossiliferous, abundant sedimentary structures
4	**Cabot Head Formation:** Shale; red and minor grey-green, siliciclastic; with minor dolostone interbeds
3	**Manitoulin Formation:** Dolostone and calcareous dolostone; thin- to thick-bedded, fine- to coarse-crystalline

ORDOVICIAN

2	**Queenston Formation:** Shale with interbeds of siltstone and limestone; red and grey-green, siliciclastic shale and siltstone; non- to very fossiliferous, light to dark grey, generally argillaceous limestone
1	**Georgian Bay Formation:** Interbedded grey-green shale, fossiliferous limestone and calcareous siltstone

[a] *Not present in this map area.*

SYMBOLS

X	Bedrock outcrop		Geological boundary, observed
	Quarry location		Geological boundary, approximate
	Drill hole site		Geological boundary, interpreted
Zn	Zinc sulphide (sphalerite) occurrence		

SOURCES OF INFORMATION

Topography from Map 41 A/14, 15 of the National Topographic System.

Records of petroleum exploration wells from the Ministry of Natural Resources, Petroleum Resources Laboratory, London.

Mineral Deposit Inventory Index of the Ministry of Northern Development and Mines.

Metric conversion factor: 1 foot = 0.3048 m

CREDITS

Geology by D.K. Armstrong and C.A. Czank, 1988. Additional geological information from OGS drill holes OGS-89-1, OGS-90-4, and OGS-82-4.

To enable the rapid dissemination of information, this map is **unedited**. Discrepancies may occur for which the Ontario Geological Survey does not assume liability. Users should verify critical information.

Issued 1993.

Information from this map may be quoted if credit is given. It is recommended that reference be made in the following form:

Armstrong, D.K. 1993. Paleozoic geology, central Bruce Peninsula, southern Ontario; Ontario Geological Survey, Preliminary Map P.3191, scale 1:50 000.