GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 63-14

GEOLOGY OF TWEED, KALADAR AND BANNOCKBURN MAP-AREAS, ONTARIO

WITH SPECIAL EMPHASIS ON MIDDLE ORDOVICIAN STRATIGRAPHY

(31C/6, 11, AND 12)

(Report and Maps 24-,25-and 26-1963)

B. A. Liberty

Price 75 cents

1963

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GEOLOGY OF TWEED, KALADAR AND BANNOCKBURN MAP-AREAS, ONTARIO

With Special Emphasis on Middle Ordovician Stratigraphy

INTRODUCTION

The area mapped, about 1,200 square miles, comprises three 1-mile map-areas – Tweed (31 C/6), Kaladar (31 C/11), and Bannockburn (31 C/12) – lying between 44°15' and 44°45' lat. and 77° to 78° long. Surface features in the map-areas are largely bedrock controlled, but much of the Peterborough drumlin field and a part of the Dummer recessional moraines (Chapman and Putnam, 1951)[1] lie across the northern part. The nature of the bedrock surface is not as well known as in other areas to the west because of the extensive drift cover and the scarcity of quarries, pits, and outcrops. Outcrops are sparse except around the Palaeozoic-Precambrian contact where they appear in small escarpments and along creeks. Data on thickness of the glacial drift and the Palaeozoic rocks and on the lithology of the Palaeozoic rocks have been obtained from surface exposures and the few available diamond-drill holes. These data have necessitated modifications to the nomenclature used by Winder (1954, 1955) in the nearby Peterborough and Campbellford areas.

GEOLOGICAL SETTING

The Middle Ordovician rocks of the map-areas overlap the Canadian Shield to the north and are in turn covered by surficial deposits of Pleistocene age.

Precambrian rocks comprise the northernmost part of the Bannockburn and Kaladar map-areas. They have not been subdivided in this report. They include three main rock types: (1) sediments represented by paragneiss, conglomerate, crystalline dolomite, and crystalline limestone; (2) basic volcanic rocks, altered to hornblende and chlorite schists; and (3) the Deloro and Moira granites. Also present are small masses of gabbro, basalt, peridotite, rhyolite, aplite, argillite, andesite, and amphibolite. The various rock types have been well described by Satterly (1943) and M.E. Wilson (1940a, 1940b). Most of the Precambrian rocks that seemingly 'protrude' through the Palaeozoic cover are in Tweed map-area and consist of granite-gneiss, in contrast to those in the Belleville map-area, which are granite, conglomerate, or crystalline dolomite (Liberty, 1961). These monadnocks constitute inliers, which

[1]Names and/or dates in parentheses refer to publications listed in the Selected Bibliography.

vary in length from less than 100 feet to more than 1/2 mile, and exhibit visible relief up to 100 feet above the general Precambrian surface. Greater relief (up to 200 feet) on other concealed monadnocks has been inferred from stratigraphic data.

A veneer of glacial drift covers most of the bedrock surface within the map-area. Glacial striae are best preserved in strata of the Bobcaygeon (lower member) and Verulam Formations. Orientations of most glacial striae are between 210 and 220 degrees azimuth, but a second set of striae trending between 275 and 314 degrees azimuth has also been noted. Drift thicknesses range from about 200 feet within the Peterborough drumlin field (Chapman and Putnam, 1951) in most of Tweed map-area to 3 feet in other areas. The drumlins have typical shapes and are well displayed between Tweed and Foxboro. Two eskers occur within the area: a south-trending one through Tweed, and a southwest-trending one through Erinsville to Marlbank and Lime Lake. These eskers link up just northwest of Foxboro in the southwestern corner of Tweed map-area (Atlas of Canada, 1957, Map 14). The esker through Marlbank traverses Kaladar and Tweed map-areas for more than 40 miles. The esker through Tweed is at least 15 miles long.

Sand and gravel pits are moderately numerous throughout the three map-areas. Most of them occur within the Peterborough drumlin field, and in the area underlain by the Verulam Formation. A definite correlation exists between thickness of drift and bedrock distribution, thicker drift occurring in areas underlain by the more argillaceous or shaly bedrock formations, such as the Verulam. These rocks are considered to have impeded and slowed the forward movement of the ice more than did the massive, resistant and smoother strata of the Gull River (upper member) and Bobcaygeon (lower member) Formations.

MIDDLE ORDOVICIAN STRATIGRAPHY

All post-Precambrian bedrock strata in the map-areas are Middle Ordovician in age and lie within the Blackriveran and Trentonian stages (Kay, 1960). Map-units 2 to 5 on the accompanying maps correspond with certain stratigraphic units to the west (Caley and Liberty, 1950; Liberty, 1953a-d, and subsequent publications) as shown on Table I. The correlations inferred by the use (Caley and Liberty, 1950) of the older stratigraphic terms (i.e. Pamelia, Lowville, Leray, Rockland, Hull, Sherman Fall, and Cobourg) were not wholly accurate; the terms were used only tentatively, for they have biostratigraphic connotations. Moreover, the definitions of these units have different meanings to different investigators.

Many of the Middle Ordovician stratigraphic terms now in common use were named for places in central Ontario. Most of these terms, however, have been used for units that are essentially biostratigraphic. To complement these units and to clarify the

stratigraphy of the Ordovician rocks the writer has redefined and proposed new terms for the sequence of lithic units (Liberty, 1955; in press) in the region between Lake Huron and Lake Ontario. This releases the biostratigraphic terms to the biostratigrapher and the palaeontologist for correct usage. The rock units in Table I are of formational rank, are readily mapped, and are not encumbered by faunal connotations. The fourth column of the table gives the writer's interpretation as to the probable biostratigraphic units encompassed by the rock units.

By detailed mapping the writer has traced the rock units listed in Table I from the Lake Simcoe District (Liberty, in press) where he first recognized them, westward to the Bruce Peninsula, Manitoulin Island (Liberty, 1957), and Northern Peninsula of Michigan, and eastward to Kingston and state of New York.

Shadow Lake Formation

The Shadow Lake Formation (Okulitch, 1939) was redefined by the writer (Liberty, 1955) to conform to Johnston's (1911) "basal series". It consists of soft, red and green shales with some sandstone and arkose. In thickness it ranges from 50 feet down to zero in those localities over Precambrian topographic 'highs' where it is not present. Specific occurrences of this formation, at the base of map-unit 2, are indicated by symbol (SL) on the accompanying maps, so that the map-unit numbers on these maps coincide with those on the writer's adjacent published map-sheets. The Shadow Lake Formation is considered to be of Middle Ordovician age and in all probability is to be correlated palaeontologically with the Pamelia.

Simcoe Group.

The term "Simcoe Group" was proposed by Liberty (1955; and in press) for the carbonate sequence lying above the basal clastic sediments of the Shadow Lake Formation and below the black, brown and blue shales of the Whitby Formation (Liberty, in press), which contains the Collingwood, Gloucester, and Blue Mountain faunas of the Upper Ordovician.

The Simcoe Group contains four formations – the Gull River, Bobcaygeon, Verulam and Lindsay (in ascending order) – which have been traced from the Lake Simcoe District where they were defined, westward to Manitoulin Island and Northern Peninsula of Michigan and eastward to Kingston and state of New York. These formations include nine members: Gull River (three), Bobcaygeon (two), Verulam (two), and Lindsay (two). In turn, some of the members are subdivided into lithic units of less than member rank, here called submembers, which are the eastward extensions of units described as "beds" in the Lake Simcoe district by Caley and Liberty

Table I. Middle Ordovician Lithostratigraphic and Biostratigraphic Nomenclature, Southern Ontario.

Map-unit Nos. on Adjacent Map-sheets (Liberty, 1960, 1961)	Rock Unit (Formation Name)		Stratigraphic Term Formerly Used by Caley and Liberty, and Liberty (see Selected Biblio.)	Biostratigraphic Unit
6 and 7[1]	Simcoe Group	Lindsay	Cobourg	Cobourg
5	Simcoe Group	Verulam	Sherman Fall	Kirkfield-Sherman Fall-Cobourg
4	Simcoe Group	Bobcaygeon (upper member)	Rockland-Hull	Rockland-Kirkfield
3	Simcoe Group	Bobcaygeon (lower member)	Leray	Chaumont-(Leray)-Rockland
2	Simcoe Group	Gull River	Pamelia-Lowville	Pamelia-Lowville-Chaumont
2		Shadow Lake	Basals	Pamelia

[1] See under "Lindsay Formation".

(1950) and Liberty (1952 and subsequent publications). These distinctive lithologic units are known to thicken considerably across southern Ontario; for example one unit thickens from 1 foot to 35 feet, another from 8 to 150 feet. The writer in 1961 successfully mapped these submembers in Sydenham map-area (Liberty, unpublished manuscript), where the erosion surface permits more widespread areal distribution of these units. Recognition of these submembers has been of great value in revealing the existence (and throw) of faults, the presence of unconformities and the Peterborough structural arch (Liberty, in press), and in the logging of subsurface core and cuttings.

Within the present map-areas neither the Verulam Formation nor the Simcoe Group is completely represented. The average thicknesses of the lower two formations in the group are Gull River, 140 feet, and Bobcaygeon, 40 feet. It is believed that within the adjoining Belleville and Wellington map-areas the Verulam and Lindsay Formations each achieve a thickness of 300 feet. The Simcoe Group in these two map-areas is approximately 900 feet thick.

Gull River Formation

The Gull River Formation (Okulitch, 1939) was redefined by the writer (Liberty, 1955) to conform to Johnston's (1911) Lowville Formation, and to include Okulitch's Moore Hill Formation in its top. The formation is divisible into three members.

The lower member is composed of three lithic units of submember status. The lower submember consists of reddish mottled, green, fine-grained to very fine crystalline dolomitic limestone. Fresh surfaces present red mottling on a green background. It is 17 to 20 feet thick. The middle submember is a brown lithographic limestone with digits of yellow, fine-crystalline dolomite, presenting a mottled (digitate) appearance. It is only about 1.2 feet thick in the southeastern corner of Tweed map-area, the westernmost occurrence of this unit within the map-areas. The upper submember, present in all three map-areas, comprises an alternation of grey- and brown-weathering carbonates. These are generally grey, sublithographic to lithographic limestone and brown to yellowish brown, fine-grained to very fine crystalline dolomitic limestone and dolomite respectively. Bedding is generally even and 0.75 to 1.5 feet thick. This upper submember is a distinctive unit, about 40 feet thick, and lies on the lower submember throughout most of the three map-areas.

The middle member consists of two lithic units. The lower submember, 15 to 20 feet thick, is composed of thin-bedded (0.2 to 0.3 foot) 'shaly' (laminated) limestone. A profuse fauna, consisting of pelecypods, gastropods, cephalopods, ostracods, and other forms, is present in the lowest few feet. The upper submember, 25 to 30 feet thick, is massively bedded (1.5 to 3.0 feet) and consists predominantly of brown, grey and cream-coloured, lithographic and sublithographic limestone, but includes minor amounts of fine-grained,

argillaceous limestone, bioclastic limestone, and semi-crystalline limestone. It weathers to grey, dove, and tan colours, and contains some Leperditiid ostracods and Tetradium cellulosum.

The upper member of the Gull River Formation is divisible into three submembers. The lower is composed of grey, sublithographic and semi-crystalline limestone in massive beds (2.5 to 3.0 feet), which alternate cyclically with 5- to 10-foot-thick units of thin-bedded (0.1 foot) grey, lithographic limestone. Present in the base of this submember are minor amounts of fine-grained, argillaceous limestone and calcarenitic, bioclastic and oolitic limestone, in beds ranging from 0.4 to 0.8 foot thick. Thickness is somewhat more than 50 feet. Its fauna include a profusion of Tetradium cellulosum, T. fibratum, and pelecypods. The middle submember is composed of brown lithographic, sublithographic, admixed fine-crystalline and sublithographic, and admixed fine-granular and sublithographic limestones. This unit generally weathers to massive (2.0 to 2.5 feet thick) dark grey beds. It is about 20 feet thick and is richly fossiliferous. A list of the fossils would include:

Columnaria halli
Tetradium cellulosum
Tetradium fibratum
Fletcheria sinclairi
Streptelasma corniculum
Stromatocerium sp.
Rhynchotrema minnesotensis
Zygospira recurvirostris
Cyrtodonta huronensis
Hormotoma gracilis
Trochonema sp.
Bathyurus sp.
Ceraurus pleurexanthemus
Isotelus sp.
Leperditia sp.

The upper submember is composed of grey lithographic limestone and admixed fine-crystalline and lithographic limestone, in 0.5- to 0.6-foot beds. The submember is about 5 feet thick and carries a fauna similar to the middle submember. Both Tetradium cellulosum and Columnaria halli have been found.

The lower member and the lower submember of the middle member of the Gull River Formation are correlated palaeontologically with the Pamelia. The upper submember of the middle member and the lower submember of the upper member are correlated with the Lowville. The middle and upper submembers of the upper member are correlated with the Chaumont. The complete Gull River Formation correlates faunally with the Pamelia, Lowville, and Leray of the Ottawa Valley, and with the 'Lowville' of Manitoulin Island. Lithologically, the Gull River Formation has been traced westward into the 'Pamelia-Lowville' and Gull River (and Moore Hill) Formations (Johnston and Okulitch) of the Lake Simcoe district, thence to the Bruce Peninsula and into the beds between the 'basals' and Cloche Island strata on Manitoulin Island. It has also been traced eastward into the Pamelia, Lowville, and Chaumont beds of New York State. It is the lithological equivalent of the Pamelia-Lowville beds in the Ottawa Valley.

Bobcaygeon Formation

The term "Bobcaygeon" was introduced (Liberty, in press) for a lithogenetic unit that lies between the distinctive lithographic limestone of the Gull River Formation and the equally distinctive interbedded limestone and shale of the Verulam Formation. The name is from the town of Bobcaygeon, near which the stratigraphic relations and members can be seen to advantage at two localities — in a road-cut and quarry south of the town and in a road-cut northeast of the town, both on No. 36 highway.

Lower Member – Strata in the lower member were previously designated as Leray by Caley and Liberty (1950) and Liberty (1952) and as Coboconk by Liberty (1955).

The lower member consists of the following rock types: soft, brown, fine-grained, argillaceous limestone; grey, fine and medium calcarenitic limestone; brown, very fine crystalline limestone and brown, lithographic limestone; and a brownish grey and grey, sublithographic limestone which in the eastern part of Tweed map-area comprises almost half the member and is interbedded with the other rock types. Strata weather greyish blue to grey, smooth, and about 0.4 foot thick. Microcrossbedding is prominent on weathered surfaces of the clastic beds. Localities near Precambrian inliers show a thin-bedded (0.1 foot), crossbedded, blue, fine calcarenite and a very fine crystalline limestone (10 feet thick), which underlies (and may be interbedded with) light grey and pinkish grey, fine and medium calcarenitic limestone (11 feet thick). Thickness of the member is about 25 feet.

The lower member contains the following fossils: Tetradium cellulosum, T. fibratum, Columnaria halli, Streptelasma corniculum, S. profundum, Hesperorthis tricenaria, Triplesia cuspidata, Dalmanella rogata, Calapoecia canadensis, Receptaculites occidentalis, Maclurites logani, Solenopora compacta, and Doleroides ottawanus. Within the member, Dalmanella and echinoderm occurrences are known; these occur in the same member farther west and have not been noted by other workers before (Liberty, in press). The Black River - Trenton time boundary is considered to lie within this member, a substantiation of the work of Okulitch, 1939. The lower member is palaeontologically correlated with the Leray beds of the Ottawa Valley, with the Coboconk (as defined by Johnston, 1911) in the Lake Simcoe area and with the Napanee (at Napanee) as defined by Kay (1937). Lithologically the lower member has been traced west from the present map-areas into the Coboconk (which it includes) and south into the Selby member of the Rockland (Kay, 1937) in the Napanee area (see Liberty in Caley et al., 1962, p. 51). It has also been traced across the Bruce Peninsula into the lower part of the Cloche Island beds of Manitoulin Island, and into upper Bony Falls strata in Northern Peninsula of Michigan. It is the lithologic equivalent of the Leray beds of the Ottawa Valley and comprises only the lower beds of the unit named "Coboconk" by subsurface investigators (Sanford, 1961) in southwestern Ontario.

Upper Member – The upper member of the Bobcaygeon Formation comprises strata formerly described as Rockland-Hull by Caley and Liberty (1950) and Liberty (1952 and subsequent publications), as the "Dalmanella" and "Crinoid beds" only of the Kirkfield formation by Johnston (1911), and as Kirkfield Formation (in part) by Liberty (1955).

The upper member is predominantly a brown, evenly textured, very-fine- to fine-crystalline limestone with some brown, fine calcarenitic limestone alternating with brown, sublithographic limestone. Beds are from 0.3 to 0.5 foot thick as seen in unweathered sections. They weather into thin and medium beds of smooth bluish limestone. Prominent in the lowest 6 to 8 feet are thin (1/16- to 5/8-inch) partings of black 'shale' (highly calcareous shale) between 0.1-foot beds of brown to dark grey, sublithographic limestone. In weathered sections these strata always appear soft and fossiliferous, but may present a different, more resistant appearance in fresh sections in which the shale is barely evident. Fine calcarenite occurs in some parts of the member but is absent in some sections; it appears to decrease in coarseness and abundance eastward. The upper member of the Bobcaygeon Formation is only 15 to 18 feet thick in Tweed and Bannockburn map-areas and is not present in Kaladar map-area.

The upper member contains the following fossils: Dalmanella rogata, Triplesia cuspidata, Receptaculites occidentalis, Stromatopora sp., Stromatocerium sp., Columnaria halli, Solenopora compacta, Hesperorthis tricenaria, Phragmolites compressus, Dinorthis pectinella, Flexicalymene senaria, and Gonioceras groenlandicum. It also contains the second levels of Dalmanella and echinoderm profusions; these are the "Dalmanella" and "Crinoid beds" of Johnston (1911) in the Kirkfield area to the west. A first level of Prasopora occurrence is to be noted in this member also.

The upper member of the Bobcaygeon Formation is correlated palaeontologically with the Rockland (Raymond, 1914), with Kay's (1937) Kirkfield (in the base of the writer's Verulam Formation at Napanee), with the Rockland of the Ottawa Valley, and with the Cloche Island beds of Manitoulin Island. Lithologically this unit can be traced eastward into the Napanee member of Kay's (1937) Rockland and westward into the Kirkfield formation (Kay, 1943) as exposed in the face of the Kirkfield quarry (floor to 36-foot level only) where it encloses Johnston's "Dalmanella" and "Crinoid beds", and Kay's (1943) type Kirkfield.

Stratigraphic Interpretation and Time Transgression – The lower member of the Bobcaygeon Formation is the rock stratigraphic equivalent of the Coboconk beds (in the Coboconk east quarry in the Lake Simcoe district) and of the biostratigraphic Selby member of the biostratigraphic Rockland 'formation' in the type section in the Napanee area. The upper member of the Bobcaygeon Formation is the rock stratigraphic equivalent of the biostratigraphic Kirkfield 'formation' (in the Kirkfield quarry type section in the Lake Simcoe district) and

of the biostratigraphic Napanee member of the biostratigraphic Rockland 'formation' in the type section in the Napanee area.

The relationship of these units is shown below:

Lake Simcoe District (biostratigraphy)	Lithostratigraphy		Napanee area (biostratigraphy)	
Kirkfield	upper member	Bobcaygeon Formation	Napanee	Rockland Formation
Coboconk	lower member		Selby	

One plausible explanation is that the rock units transgress time lines and include older faunas as they are followed eastward from the Kirkfield area. For example, Kay (1937) correlated the Napanee with the Coboconk. Alternatively, however, the Kirkfield would equate with the Napanee (and the Coboconk with the Selby), which would mean that the Rockland would include the Kirkfield. But Kay (1937) stated that the Rockland underlay the Kirkfield. Liberty (present paper and in press) and Sinclair (1954) maintain that the Rockland should include the Kirkfield. The true biostratigraphic nature of most of these older terms was recognized (Kay, 1960) by the raising of their status to stages and substages from the dubious category of 'formation', i.e. Rocklandian.

Similarly the writer has found, in the Kirkfield-Coboconk area, that only the uppermost strata of the lower member of the Bobcaygeon Formation are within the biostratigraphic Rockland, thus corroborating the work of Okulitch (1939) and conclusions of Templeton and Willman (1963). Thus the lowermost strata in that area are not Trenton (or Napanee of the Rockland) but Black River in age (Chaumont fauna).

Verulam Formation

The Verulam Formation is by far the most distinctive lithologic unit of the Simcoe Group in central Ontario. The formation includes those strata previously referred to the Sherman Fall by Caley and Liberty (1950) and Liberty (1952 and subsequent publications). It was called the Verulam Formation by the writer (Liberty, 1955; and in press).

The formation is typified by the alternation of limestone and shale. The limestone is in the form of 'hardbands', 0.3 to 0.8 foot thick, of blue, fine- and medium-crystalline, very evenly textured limestone. The alternating beds of shale in weathered sections may be beds of calcareous claystone. Thin, friable, dark shale partings are present also and are interbedded in turn with bluish-weathering, dark grey and blue, sublithographic limestone, and brown, soft, argillaceous limestone. The lowest 30 feet of the formation contains soft, irregularly and regularly bedded claystone. Commonly included in this

lowest unit are thin beds of brown and dark grey, soft, sublithographic (claystone) limestone, chert nodules, and thin beds of bioclastic limestone in which silicified fossils and a profusion of Prasopora occur. In contrast, the uppermost 10 to 15 feet of the Verulam Formation contain thin-bedded 'ribbon' limestones (0.05 foot), which consist of blue, very fine crystalline limestone alternating with equally thin beds of shale and calcareous claystone. Thicker beds (0.4 foot) of brown and grey, medium- to coarse-crystalline limestone lie just below this uppermost unit and represent the unit described by the writer (Liberty, 1955) as the upper member of the Verulam Formation. The writer estimates the thickness of the formation to be about 300 feet in the Tweed-Belleville area.

The abundant and varied fauna in the Verulam Formation includes: Hemiarges paulianus, Cryptolithus tesselatus, Trematis ottawaensis, Encrinurus cybeleformis, Pasceolus globosus, Rafinesquina deltoidea, Hormotoma trentonensis, Fusispira subfusiformis, Columnaria halli, Receptaculites occidentalis, and Solenopora compacta. Additional profusion levels of Dalmanella, Prasopora and echinoderms (two) are known within the formation. These profusion levels have been traced into Tweed map-area from the Lake Simcoe district to the west, where the Verulam Formation constitutes the "Prasopora beds" of Johnston (1912).

The Verulam Formation is correlated faunally with the Sherman Fall and lowest Cobourg strata of New York State and the Ottawa Valley. The lowest few feet are correlated with the Kirkfield 'formation' as defined by Kay (1943). Lithologically the Verulam Formation has been traced westward across the Bruce Peninsula and into the "unnamed beds" on Manitoulin Island (Liberty, 1957) and into the Chandler Falls Formation in Northern Peninsula of Michigan.

The base of the Cobourg 'formation' (biostratigraphic) as mapped by Kay (1942) lies in the upper part of Liberty's Verulam Formation. Kay's Sherman Fall beds consistently lie well above the base of the Verulam Formation, and Kay's Kirkfield lies in the lowest Verulam strata within the present map-areas, although not at the reference section in Kirkfield quarry. Conceivably, the Verulam Formation may transgress time lines sufficiently, as it is traced eastward, to 'pick up' the Kirkfield fauna (see also Stratigraphic Interpretation and Time Transgression).

Lindsay Formation

The Lindsay Formation is not present within Tweed, Kaladar, and Bannockburn map-areas, but is mentioned both here and in Table I for easy reference to adjoining map-areas. Descriptive details of the Lindsay Formation appear under the heading "Map-units 6 and 7" in a paper on the adjoining Belleville and Wellington map-areas (Liberty, 1961). There, map-unit 6, which is the lower member of the formation, is a resistant, hard, brittle, blue, very fine

crystalline limestone (100 feet thick). Map-unit 7, the upper member of the formation, consists of soft, semi-nodular calcareous claystone (200 feet thick). The upper member only is the Cobourg of subsurface studies (Sanford, 1961). The type locality of the Lindsay Formation is a road-cut 4 miles north of Lindsay on Highway 35, in the Lake Simcoe District.

The term "Lindsay" was introduced by the writer (Liberty, in press). It groups map-units 6 and 7 (see Table I) in adjacent map-areas to the west (Liberty, 1960) and south (Liberty, 1961). The Lindsay Formation is the Cobourg of Caley and Liberty (1950) and Liberty (1952, and subsequent publications).

PALAEOZOIC OUTLIERS

One of the most striking features of the Bannockburn and Kaladar map-areas is the number of Palaeozoic outliers fringing the main mass of Ordovician sediments (Caley and Liberty, 1957; Liberty, 1959). The outliers range in size from a fraction of an acre to more than a square mile. Most of them appear in the form of low mesas but some occur as only a few feet of limestone in creek beds. The distribution of the outliers, both those in the map-areas and others in the Canadian Shield, implies that: (1) large areas of the Precambrian Shield were once covered by Palaeozoic sediments; (2) the Shield is presently more positive than it has been during other geological periods; and (3) the Shield has not been as stable a region structurally as was commonly believed.

STRUCTURAL GEOLOGY

The stratigraphic units in Tweed, Kaladar, and Bannockburn map-areas strike about east-west and dip southward at 15 to 18 feet per mile. Higher dips do occur, but they probably reflect drape of the Palaeozoic limestones over the underlying 'highs' or monadnocks on the Precambrian surface. Relief on the Precambrian rock surface may be judged from a road-cut on No. 37 highway, 7 1/2 miles south of Tweed, where the upper member of the Gull River Formation is overlain by basal strata of the Bobcaygeon Formation. Although closure on the dome is only about 50 feet, stratigraphic data suggest a Precambrian relief of about 200 feet. Similarly, Precambrian relief and drape of the overlying Ordovician sediments are believed responsible for the areal configuration of the formations near Halston, Blessington, and Foxboro, in the southern part of Tweed map-area.

Further evidence for the existence of a structural and topographic arch or platform in the Peterborough region, which was previously suspected by the writer (Liberty, in press), has been found

in the present map-areas. Stratigraphic information from the lower member of the Gull River Formation completely substantiates the presence of such an arch, whose existence had been suspected from the distribution of the Potsdam and Shadow Lake Formations. The lower submember of the Gull River's lower member lies completely across the platform; the middle submember lies on the east and west flanks only; and the upper submember extends completely across the arch, thickening eastward. No disconformities have been found yet within this lower member. Pamelia faunas in this member indicate the time during which the platform was effective. A minor disconformity exists at the top of the lower member of the Gull River Formation in this eastern area. From stratigraphic evidence in the Marmora area to the west and the Kingston area to the east, the writer suspects that a more important disconformity occurs at the base of the Bobcaygeon Formation. This disconformity, however, has not yet been recognized within the present map-areas owing to scarcity of sections.

A normal fault lies along Salmon River, its west side downthrown, about 100 feet. Detailed investigations indicate step-faulting and subsequent minor breaks in the strata. Movement along this fault is post-Blackriveran.

ECONOMIC GEOLOGY

Present economic activity in the three map-areas consists only of Roblindale Quarries Ltd., at Roblindale Station. There the lower member of the Bobcaygeon Formation and the middle and upper members of the Gull River Formation are being worked for railway ballast, concrete aggregate, and road metal. Other large quarries, now inactive, are the Crookston main quarry (Gull River Formation, upper member, and Bobcaygeon Formation, lower member) and Tweed quarry (Gull River Formation, upper member). Small inactive quarries are located as follows: (1)1.9 miles north of Eldorado (Gull River Formation, lower member); (2) 0.6 mile south of Eldorado (Gull River Formation, middle and upper members); (3) 3 miles northwest of Crookston (Gull River Formation, upper member, and Bobcaygeon Formation, lower member); (4) 2.3 miles north of Madoc (Gull River Formation, lower member); (5) 1/2 mile north of Roblin (Bobcaygeon Formation, lower member); and (6) at Sharps Corners (Gull River Formation, upper member, and Bobcaygeon Formation, lower member).

The Consolidated Sand and Gravel Co., about 10 miles southwest of Tweed, owns the only sand and gravel pit in operation in the three map-areas. There are many small sand and gravel pits, now abandoned, which have been worked periodically, primarily for road metal.

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