GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 67-8

PRELIMINARY ACCOUNT OF THE GOULBURN GROUP, NORTHWEST TERRITORIES, CANADA

L. P. Tremblay

CANADA

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ABSTRACT

The Goulburn Group outcrops over an area 5,000 square miles extending from east of Bathurst Inlet in the east to west of Contwoyto Lake the west, a distance of more than 100 miles. In general the area is rugge(and highly dissected with relief up to 1,500 feet. The rock succession is more than 15,000 feet thick in the east and less than 3,000 feet in the west It has been subdivided into five conformable formations from bottom to top the Western River Formation which is predominantly thinly bedded argillit the Burnside River Formation (pink quartzite), the Peacock Hills Formati(which is mainly thinly bedded argillites, the Kuuvik Formation (dolomite a: limestone), and the Brown Sound Formation (first named in this paper) of thinly bedded argillites, siltstones, and buff sandstones. The Group rests unconformably on Archean granites and gneisses dated at 2,490 m.y. and i overlain unconformably by the Tinney Cove Formation (sandstone and conglomerate) which is correlated with the Thelon Formation of the Dubawnt Group to the east. It is not known if the Goulburn Group is cut by the Hudsonian granite but it is traversed by gabbro sill and dykes dated at fron 1,550 to 1,050 m.y. The source rocks for this succession are not known b the source area is probably to the southeast. Quiet environment and shallc water deposition are indicated.

PRELIMINARY ACCOUNT OF THE GOULBURN GROUP, NORTHWEST TERRITORIES, CANADA

INTRODUCTION

The purpose of this paper is to present a preliminary account of the Goulburn Group. The writer spent parts of the summers of 1962 and 1963 in the Beechey Lake area (Fig. 1) where about 300 square miles of Goulburn Group rocks were mapped on the scale of 1 mile to 1 inch, and in 1965 about 100 square miles of similar rocks were mapped on the same scale in the Contwoyto Lake area (Fig. 2). Both areas are south of latitude 66° and are about 100 miles apart. As a result of this work the Goulburn Group is more precisely defined: its lower limits are more carefully described, its stratigraphy is known in greater detail, its subdivisions are more definitely established and their limits are indicated and described. The mutual relationships of several newly named formations (Tremblay, 1967) are discussed, and the main rock types of these and other important units are described in detail. The name Brown Sound Formation is proposed for the uppermost unit of the Goulburn Group and its lithology as outlined by Fraser (1964) is discussed in the light of the group as a whole.

EXTENT

As mapped by Fraser (1964), the outcrop area of Goulburn rocks (Fig. 3) extends continuously along Bathurst Inlet from the Arctic coast in the north, to the source area of Ellice and Western Rivers in the south. To the west Goulburn rocks are found as far as the northwest end of Contwoyto Lake, and also occur east of Bathurst Inlet. The area west of the Bathurst Inlet is the main block of Goulburn rocks. A small area of related rocks mapped by Bostock (1965) in the Rocking Horse Lake area (Fig. 3) is believed to represent the westernmost extension of definitely known Goulburn rocks. Altogether these areas cover approximately 5,000 square miles.

PHYSICAL FEATURES

The area underlain by the Goulburn rocks is very rugged. Although it stands at about the same elevation as the adjoining areas of granites and gneisses it is much more closely dissected, and changes in elevation are not only more common but also much more abrupt and steeper. Dissection is particularly intense along the Burnside, Booth and Mara Rivers (Fig. 3)

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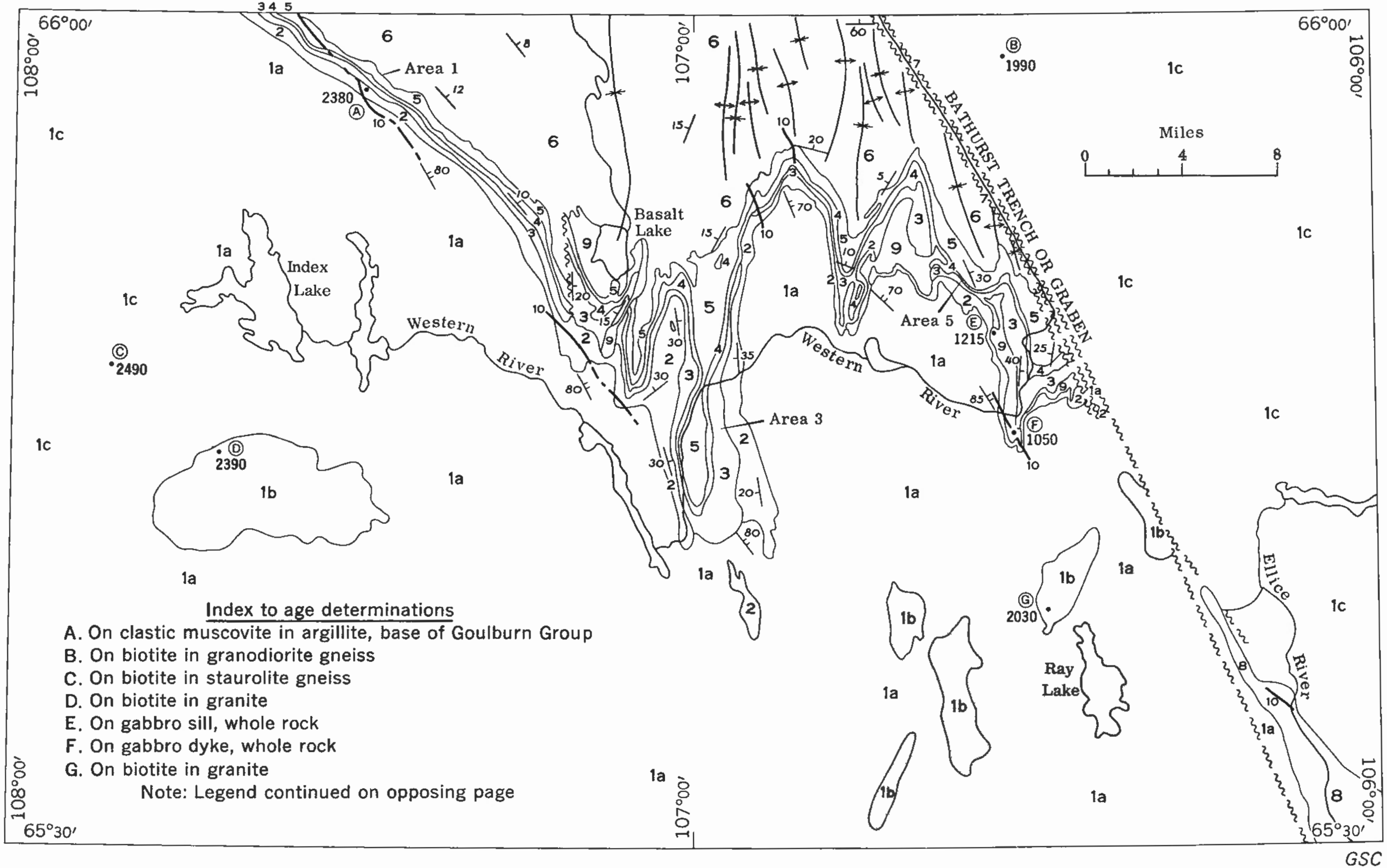

Figure 1. Distribution of Goulburn rocks in the Beechy Lake map-area.

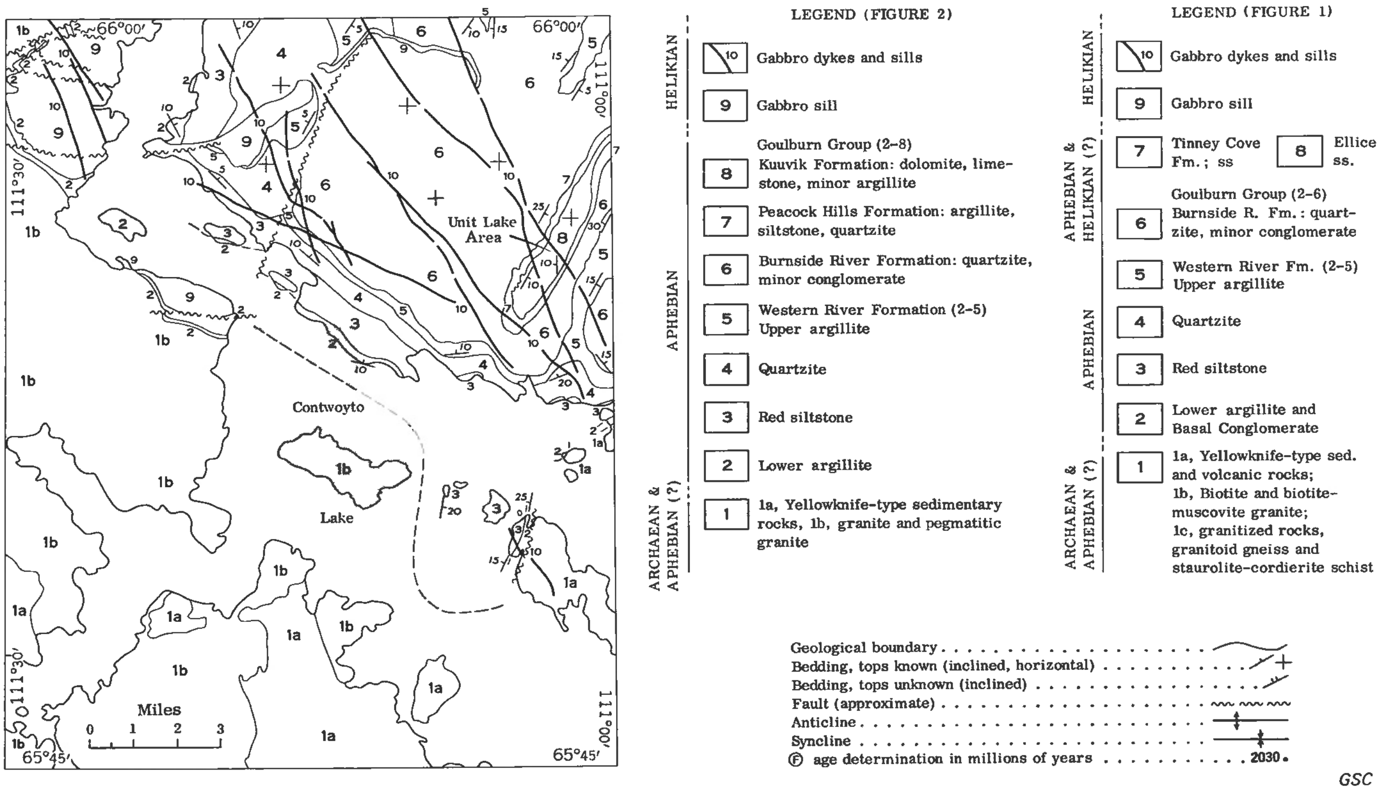

Figure 2. Distribution of Goulburn rocks in the north half of Contwoyto Lake map-area.

where relief reaches about 1,000 feet along Booth River, 1,200 feet along Mara River and 1,500 feet along Burnside River. In the vicinity of Bathurst Inlet and along Western River the dissection is as intense or even more so and locally relief reaches 1,500 feet. The area is approximately delineated on the north by Burnside and Booth Rivers and on the south by Mara River and its tributaries. The highest hills are formed of or capped with quartzite or gabbro whereas the lowest areas are underlain by argillite, siltstone and carbonate rocks, and thus topography roughly reflects the local geology and structure of the area.

In the two widely spaced areas that have been traversed extensively by the writer, Beechey Lake area (Fig. 1) and Contwoyto Lake area (Fig. 2) Goulburn rocks are represented by abundant rock outcrops and large chaotic accumulations of frost-heaved blocks. Valleys or depressions are generally covered with moss and grass but locally they are areas of great accumulations of glacial erratics of all sizes.

GENERAL GEOLOGY OF THE GOULBURN GROUP

HISTORY AND DEFINITION

The term Goulburn was first used in 1924 by J.J. O'Neill as a formational name for a succession of about 4,000 feet of quartzites and conglomerates that outcrop on Goulburn Peninsula on the western side of Bathurst Inlet. If other rocks were included by O'Neill in his Goulburn Formation it is not stated in the text (1924, pp. 23A and 47A-51A). Wright (1957) correlated quartzite found near Western River with O'Neill's Goulburn quartzite because he regarded this quartzite as the southern extension of O'Neill's Goulburn quartzite. Fraser in 1962 established the continuity of outcrops between O'Neill's original area and Wright's quartzite and this continuity was found to extend as far as Contwoyto Lake in the west (Fraser, 1964). Wright elevated the term Goulburn from that of formation to that of group and included another map-unit with the quartzite that is exposed near Western River. This additional unit conformably underlies that quartzite and is mainly composed of argillite, slate, dolomite and sandstone. In 1962, Fraser (1964) observed great thicknesses of conformable slates, argillites and dolomite not only below but also above O'Neill's quartzite. These he regarded as parts of the Goulburn Group, and by so doing he extended the definition of the Goulburn Group. In this paper, the Goulburn Group is used in Fraser's sense. It includes not only the original quartzite of O'Neill, but also great thicknesses of conformable argillite, slate, quartzite and dolomite above and below it. The lower limit of the Goulburn Group is marked by a pronounced unconformity; the upper limit as mapped by Fraser (1964) is marked by the base of a sandstone unit (the Tinney Cove Formation) which lies unconformably over the uppermost map-unit (the Brown Sound Formation) of the Goulburn Group. The Tinney Cove sandstone was mapped by the writer in 1963 within the Bathurst Trench in Beechey Lake area where it is in faulted contact with Goulburn rocks on the west and with gneisses on the east.

SUBDIVISIONS

When Fraser mapped the Goulburn Group in 1962 on the scale of 8 miles to 1 inch (Fraser, 1964), he subdivided it into six map-units. These outcrop in the area extending east from Mara River to the junction of Western River and Bathurst Inlet. This seems to be the only area where the six map-units occur in complete succession. In the Kuuvik Lake area the lower four map-units are apparently present and the four map-units mapped by the writer in the Contwoyto Lake area (Fig. 2) are also probably the same succession. Only the lowermost map-unit is present in the Rocking Horse Lake area (Bostock, 1965).

Because the writer has neither mapped the entire area of Goulburn rocks nor measured a complete section of the group, the detailed stratigraphy of the group is not yet fully known. In the two small areas examined the lower two map-units of Fraser were studied in detail. The middle two map-units were studied only in the Contwoyto Lake area as they do not occur in the Beechey Lake area. The upper two map-units have not been seen by the writer, and therefore information on these is taken directly from Fraser (1964), but their relationship has been reinterpreted.

In this paper the map-units used by Fraser are retained except that the two uppermost are grouped together as one unit. The map-units studied by the writer were regarded as formations and were named for clarity of description and ease of reference. They were further subdivided into members where possible and practical. In a previous paper (Tremblay, 1967) the following names were given to the lower four formations, from bottom to top: Western River Formation, Burnside River Formation, Peacock Hills Formation and Kuuvik Formation. In addition, the Western River Formation was subdivided in the same paper into five members from bottom to top as follows: Basal Conglomerate, Lower Argillite, Red Siltstone, Quartzite and Upper Argillite. Although not mapped by the writer, the two uppermost map-units are here named the Brown Sound Formation as they are regarded as parts of the same formation.

THICKNESS

With minor variations the thickness of the Goulburn Group gradually increases from west to east and from southwest to northeast. Thus the Goulburn rocks are 900 feet thick in the Rocking Horse Lake area, 2,300 feet thick in the Contwoyto Lake area and from 16,000 to 20,000 feet thick in the vicinity of the Bathurst Trench. This increase in thickness from west to east is clearly indicated by a few of the map-units. The pink quartzite of the

Table 1

Sections of Goulburn Rocks
as measured in the field and as estimated from Fraser's map (G.S.C. Map 45-1963)

Formation	West of Bathurst Inlet										East of Bathurst Inlet			
	Rocking Horse Lake (Bostock, 1965)	Thickness in feet	Contwoyto Lake (Tremblay, 1967)	Thickness in feet	Kuuvik Lake (estimated from Fraser's map)	Thickness in feet	Beechey Lake West	Thickness in feet	Beechey Lake East	Thickness in feet	Tinney Cove (Fraser, personal communications)	Thickness in feet	Composite Section (Fraser, 1964)	Thickness in feet
Brown Sound	Missing		Missing				Missing				Siltstone and argillite, sandstone	?	Siltstone and argillite, sandstone, conglomerate	1000
Kuuvik			Dolomite, limestone, minor argillite	140+	Dolomite, limestone	?					Dolomite, Limestone	?	Dolomite, limestone	800
Peacock Hills			Argillite, siltstone, pink quartzite	160	Argillite, argillite with interlaminated limestone	3000					Argillite, argillite with interlaminated limestone	?	Argillite argillite with interlaminated limestone	2000
Burnside River			Pink to red quartzite, minor conglomerate	600+	Quartzite, minor conglomerate	3000	Pink and red quartzite, minor conglomerate	9000+			Pink and red quartzite, minor conglomerate		Quartzite, orthoquartzite, minor arkose, conglomerate	7500
Western River	Greywacke	128	Grey argillite and greywacke, some red argillite	125	Argillite, concretionary argillite, dolomite, quartzite, minor conglomerate	?	Grey argillite, some red argillite and quartzite	160	Argillite and quartzite in the ratio of 5 to 1	1700	Mainly argillite and quartzite; ratio of argillite to quartzite is 3 to 1	3000	Argillite, concretionary argillite, dolomite, quartzite, conglomerate	3500
	Pink quartzite, conglomerate, limy beds	310	Pink quartzite, white quartzite, some conglomerate	450			White quartzite, dolomite (stromatolitic)	130	Dolomite (stromatolitic) and quartzite	550	Quartzite, red, purple, grey, and white	900		
	Argillite, grey purple, green; 20-foot section contains abundant limy concretions	300	Concretionary red argillite, red and grey argillites	475			Red argillite and siltstone, grey argillite, dolomite	300	Red argillite and siltstone	450	Argillite, red, grey, and green; dolomite concretions and beds near bottom	1500		
	Quartzite, yellow, green; argillite; some carbonate beds	170	Argillite, some quartzite; a few carbonate beds	285			Argillite, white quartzite, minor dolomite (stromatolitic)	300	White quartzite	800	Argillite, quartzite, dolomite (stromatolitic)	1900		
	Conglomerate; local carbonate cement	?	Conglomerate locally	0-2			Regolith and some conglomerate	0-20	Conglomerate	20				

Burnside River Formation is more than 600 feet thick in the Contwoyto Lake area, about 3,000 feet thick as measured on Fraser's map in the Kuuvik Lake area, and more than 9,000 feet thick in the Beechey Lake area. The lowest map-unit, the Western River Formation, exhibits the same trend but its thickness is much more variable and seems to be controlled in part by relief of the old erosional surface on which it was deposited, but it is definitely much thicker near the Bathurst Trench than in the west, away from the trench. The other three map-units probably follow the same pattern, but their general variation is not known as they were not mapped in the east near the Bathurst Trench by the writer and are not present everywhere.

SECTIONS

Sections were measured at several places in the two areas mapped by the writer, and composite sections prepared from the measured sections are given in Table 1. Sections presented by Fraser (1964) and Bostock (1965) plus a section estimated from Fraser's map, are also included in the same table. All sections, particularly those measured in the field, give information on the types of rocks, show stratigraphic variations in the types of rocks, present thicknesses of the various rock types and mappable units and indicate lateral variations in composition, thicknesses, and colour of the rocks.

From the composite section of Fraser (last column in Table 1) the Goulburn Group is at least 15,000 feet thick, and the work done in Beechey Lake area indicates that it may be even thicker. Because no complete section was measured by the writer, a more accurate figure cannot be presented at this stage.

NATURE OF BASAL UNCONFORMITY

The Goulburn rocks rest unconformably on Yellowknife-type sediments, granite, granitic rocks and gabbro. The mapping of the unconformity in Beechey Lake area (Fig. 1) and in Contwoyto Lake area (Fig. 2) suggests that there is no overlapping of the formations, but overlapping of the members within a formation is indicated. Some slight variations in the nature of the rocks within a particular formation in passing from east to west is also indicated.

The unconformity is a definite and sharp feature except where there is a regolith along it. Where it is sharp the unconformity on a broad scale appears to dip gently north and northeasterly. In detail, however, it seems to be very irregular as it represents a rough old erosional surface. Where there is a regolith the direction of dip was not determined. From the Bathurst Trench almost to Basalt Lake the unconformity is sharp and is overlain by quartz-pebble conglomerate. In the Contwoyto Lake area it also is sharp but overlain by argillite, white quartzite or rarely by conglomerate. In the area between Beechey and Contwoyto Lakes the unconformity is probably marked all the way by a regolithic zone up to 20 feet thick. This zone is along the old erosional surface and is made up of blocks of steeply dipping Yellowknife-type sediments and granite, still in their original positions or slightly moved and bound together with light brown-weathering dolomitic cement.

WESTERN RIVER FORMATION

Definition

The Western River Formation is the lowest formation of the Goulburn Group and was named after Western River where it is well exposed and good sections can be studied. It is conformable with the Burnside River Formation which marks its upper limit and the unconformity at the base of the group marks its lower limit. There is a distinct difference in lithology in passing from the argillites and white to buff quartzites of the Western River Formation to the pink quartzite of the overlying Burnside River Formation. The upper contact is marked locally by a narrow layer of quartz-pebble conglomerate, and elsewhere by the base of the pink quartzite, but in general is indicated by a thin layer of thinly bedded red argillite. In general, both the bottom and top of the Western River Formation are well defined and can be located readily and accurately.

Extent

The Western River Formation is moderately well exposed around most of the outside edge of the area underlain by the rocks of the Goulburn Group. Good sections were observed at several places, particularly in those areas for which sections are given in Tables 1 and 2. Most of these sections are composite, and represent data collected at many places within areas of several thousand square feet. It appears from the sections that the formation increases in thickness easterly and northerly, that there are local variations in thickness of some of the lower members of the formation, and that there is a certain amount of lateral variation along strike, not only in thickness but also in the nature of the rocks.

Subdivisions

The Western River Formation has been subdivided for mapping purposes into five members. Each member, except the basal conglomerate, includes several rock types, and was traced across the areas mapped. Although they were investigated only where traced in these two areas, the

Table 2

Section of Western River Formation from west to east
in Beechey Lake area

Location of Sections	Along western contact of area to Goulburn rocks near north boundary of map-area Area 1*		Near southernmost part of area of Goulburn rocks, east of Western River Area 3*		A short distance west of Bathurst Trench and north of Western River Area 5*	
Member	Lithology	Thickness in feet	Lithology	Thickness in feet	Lithology	Thickness in feet
Upper Argillite	Red siltstone Quartzite Argillite Buff quartzite Grey argillite Red siltstone	60 100	Argillite and red siltstone Argillite, quartzite Pink quartzite Argillite	700	Red siltstone Argillite Red slate Pink quartzite Argillite White quartzite Gabbro Argillite	10 940 10 240 150 100 450 250
Quartzite	White quartzite Dolomite Quartzite (white, blue, and green)	60 40 30	Dolomite and quartzite	300	Dolomite and quartzite	550
Red Siltstone	Argillite Dolomite Red siltstone Argillite	30 5 250 5	Red siltstone Argillite, quartzite and dolomite Red siltstone	200 200 300	Red siltstone	450
Lower Argillite	Dolomite White quartzite Grey argillite	5 30 250	Argillite and quartzite Red siltstone White quartzite	700 200 200	White quartzite	800
Basal Conglomerate	Regolith (dolomitic)	5	Conglomerate	5	Conglomerate	5
Angle of dip of beds at section site	10°E		15°W		30°E	
Total thickness of section		870 feet		2800+ feet		4000 feet

*See Figure 1 for location of Areas 1, 3, and 5.

members may extend all around the area of Goulburn rocks outlined by Fraser. The descriptions given below are drawn only from the two areas studied by the writer but may apply to all the areas of Goulburn rocks. The members can be distinguished from each other fairly readily and their respective lower and upper limits can be relatively accurately located. The basal conglomerate is generally too thin to be mapped and was included on the map in the lowest of the other four members. The members mapped are, from bottom to top: Basal Conglomerate, Lower Argillite, Red Siltstone, Quartzite, and Upper Argillite.

Regolith and Basal Conglomerate

A regolith was noted on the unconformity at the base of the Goulburn Group along the southern edge of the main mass of Goulburn rocks south and west of Basalt Lake, and west for an unknown distance toward Contwoyto Lake. East of Basalt Lake to Bathurst Inlet it is missing, and in the Contwoyto Lake area it is missing or rare and patchy. This regolith resembles a breccia, and is made up of fragments of Yellowknife-type sediments and granite in a dolomitic cement. The fragments are angular and of various sizes, and in most places they have been moved only slightly from their original positions. The dolomitic cement envelops the fragments, fills joints, fractures and openings in the blocks and fills depressions that were originally present along the unconformity. Some of the larger fractures or depressions are locally filled with a mixture of dolomitic cement and occasional well-rounded white quartz pebbles or patches of quartz-pebble conglomerate. These patches may rest on the dolomitic material or may be mixed with it. Where these patches are missing the regolith is overlain directly by quartzite or grey to green argillite and slate. In general where there is a regolithic zone there is no basal conglomerate layer, and conversely, where there is a conglomerate there is no regolith. The association of uncommon conglomerate patches with dolomitic material of the regolith near the place where the basal conglomerate occurs in a continuous layer seem to suggest that this association may represent a transition zone from a true regolith west of Basalt Lake to a true conglomerate layer east of it. In the Contwoyto Lake area, near the extreme west end of the area underlain by the Goulburn Group, both regolith and conglomerate are present only locally.

The basal conglomerate forms a continuous layer up to 20 feet thick east of Basalt Lake, but west of the lake it is only in patches or pockets or is missing entirely. It is a quartz-pebble conglomerate made up of about 98 per cent white quartz fragments, plus a few fragments of glassy grey quartz and rare red quartzose rocks, all in a sandy matrix. The fragments are well rounded, but are relatively unsorted as to size (they range from 2 feet to less than 1/4 inch, although most of them are between 1 inch and 2 inches in diameter). The matrix resembles a fine-grained quartzite or sandstone and is made up mainly of quartz grains, less than 1 mm in diameter, in a sericitic or clayish cement. Where the amount of sericitic cement is high, the conglomerate is crudely schistose. The ratio of fragments to matrix is about 3 to 1. Magnetite is the only metallic mineral noted. The conglomerate is generally massive and homogeneous but locally includes thin white quartzite beds.

Lower Argillite

In Beechey Lake area the Lower Argillite rests on the basal conglomerate east of Basalt Lake and on the regolithic zone west of it. For a long distance west of Beechey Lake area it probably also rests on the regolith. In Contwoyto Lake area it is found directly on Yellowknife-type sedimentary rocks and granite, and its lower contact thus is well defined. Its upper contact is generally marked by the appearance of red siltstone in the Beechey Lake area and of concretionary red argillite in the Contwoyto Lake area. This member is made up mainly of argillites in the west, contains much white quartzite in the east, and near the Bathurst Trench it also includes some dolomite.

The Lower Argillite shows some lateral variation and overlap. Overlap is particularly apparent in the Beechey Lake area where the member becomes very thick. In the area northwest of Basalt Lake it is made up mainly of argillites with minor amounts of white quartzite toward the top. East of Basalt Lake it is made up almost entirely of white quartzite, and minor argillite is present near the top rather than at the bottom. Other rock types such as a layer of red argillite near the window of older rocks southeast of Basalt Lake also suggest overlap. Lateral variation is also indicated in the Contwoyto Lake area, where the white quartzite is much thicker in the west than in the east, and probably pinches out farther east.

The argillites are grey, red, and green, and some in the Beechey Lake area are buff or peppery buff. In general these variations of colour reflect variations of composition. In Beechey Lake area the argillites are mainly grey whereas in Contwoyto Lake area they are of all colours. The argillites are dense to fine grained and massive to faintly slaty. They are thinly bedded, varve-like, and interlamination of colours accentuates the interbedding. In some localities near the base of this member, chlorite and large muscovite flakes are abundant along some bedding planes. They are probably clastic grains, although some of the smaller grains may be recrystallized material. The origin of these flakes is discussed later under Metamorphism. A K/Ar age on a concentrate of large flakes of muscovite gave 2,380 m.y. which represents the age of the basement, and therefore is regarded as a maximum age for the Goulburn rocks.

Thin sections show that the argillite is distinctly layered, clastic, and partly recrystallized. Some of the layers are only a few millimetres thick, and many have poorly defined boundaries. Some layers are made up mainly of clastic grains (averaging 0.1 mm) cemented with sericite and chlorite flakes. Alternate layers are made up of sparse clastic grains (averaging 0.04 mm) in a dense felt-like mass of sericite and chlorite. Other layers have only sericite and chlorite in a somewhat finer grained felted mass. Most grains are subangular to subrounded, but a few are long and slender. The grains are mainly undulatory quartz and the matrix or cement is a mixture of sericite and chlorite which represents recrystallized clay material. About 15 per cent of the grains are feldspar, but locally this percentage may be even greater. Rare tiny grains of sphene and zircon and a few granules of iron oxides were observed. Biotite is present locally in very small quantity, and some of the chlorite contains zircon grains with haloes as in biotite and seems to be pseudomorphic after biotite. There are rare large flakes of green biotite or chlorite. Clastic grains of muscovite lying parallel to bedding in some of the layers correspond to the grains used for the 2,380 m.y. K/Ar age. Iron oxide granules are much more abundant in some of the dark grey layers particularly where a chlorite-sericite aggregate is the main constituent. A few grains of bluish green, possibly detrital, tourmaline were noted. A little carbonate was recognized locally.

The quartzite is a massive to thick-bedded, well-jointed, fine-grained rock. Bedding is faint. The rock is commonly white but parts of the succession in the Beechey Lake area are greenish, bluish, buff and faintly pink. The bluish and greenish colours are due to disseminated chlorite, the buff to carbonate, and the pink to iron oxide. Carbonate specks appear locally as tiny rusty brown dots that give weathered surfaces a peppery appearance.

In thin sections the quartzites display a clastic texture, are made up of clastic grains closely packed and cemented together with a little chloritic-sericitic material. In general there is very little matrix and where present its grain size is less than 0.05 mm. Most grains in the quartzites are well rounded to subrounded and average 0.5 mm, ranging in size from 2.0 mm down to matrix size. The respective amounts of grains and matrix are about 85 and 15 per cent. Most of the grains are undulatory quartz and many show a slight silica overgrowth. Feldspars, both plagioclase and potassic feldspar (microcline and perthite), represent about 15 per cent of the grains. There are also a few chert grains and rock fragments. Other minerals noted only in trace amounts are zircon, magnetite, biotite, muscovite, leucoxene, limonite, sphene, and tourmaline.

Dolomitic rocks and calcareous argillite were noted at various levels in this member. In the Beechey Lake area these lithologies seem to be more common near the base, whereas in the Contwoyto Lake area they are more common toward the top. The carbonate-rich rocks occur mainly as beds or layers, but some form boudins cemented with grey argillite, and some form concretions in red argillite. In the Beechey Lake area near the Bathurst Trench, mapping revealed a great thickness of thinly bedded carbonate rocks mixed with some argillite, contorted and brecciated, that is quite different from the carbonate rock mapped higher in the succession. Domical structures resembling stromatolites were noted in these thinly bedded carbonate rocks.

Red Siltstone

The base of the Red Siltstone member is marked by the appearance of abundant red argillite in the succession. The contact is generally transitional in places where the grey argillite of the Lower Argillite member and the red argillite of the Red Siltstone member are thinly interbedded over a few feet. In the Contwoyto Lake area, because there is much red argillite in the Lower Argillite member, the contact was placed at the first appearance of limy concretions in the concretionary red argillite. Mapping of this contact from Contwoyto Lake to Beechey Lake would show if these two members are truly correlatable.

The Red Siltstone is generally in sharp contact with quartzite of the Quartzite member above. This is the case in Contwoyto Lake area. In Beechey Lake area, however, it is overlain in many places by grey argillite or calcareous, red to white sandstones, the contact being transitional over a few feet. In such instances the contact was placed at the disappearance of abundant red argillite in the succession.

The Red Siltstone member outcrops as a continuous belt along the north shore of Contwoyto Lake and as a belt outlining the area of Goulburn rocks in the Beechey Lake area. The belt was not recognized over a short distance at a place about five miles east of Basalt Lake in the Beechey Lake area, where quartzite of the Lower Argillite member appears to be in direct contact with rocks of the Quartzite member above.

The Red Siltstone member is about 500 feet thick in the Contwoyto Lake area where it is almost entirely concretionary red argillite. Near the top in this area it includes about 50 feet of grey argillite and rare beds of grey and reddish white sandstones. In the western part of Beechey Lake area it is 250 feet thick and includes minor scattered beds of greenish grey argillite and rare thin dolomite beds. In the east near the Bathurst Trench the thickness is also about 250 feet but the member there is represented by about 50 per cent red argillite and 50 per cent sandstone. In the central part of the Beechey Lake area, it is about 700 feet thick and was subdivided into two red siltstone zones, lower and upper, separated by a thick succession of bedded grey argillite and white quartzite.

The exposures are generally good and characteristic, particularly those in the Contwoyto Lake area that are concretionary and those in the west half of Beechey Lake area that are thinly bedded and dark chocolate red.

The main rock type is a red argillite or siltstone. It is deep red to dark chocolate red, fine grained and generally thinly bedded. Dark and light red beds alternate and account for the interbedding so characteristic of this rock. In many instances, a bed seems to be made up of two fractions, a lighter red, somewhat coarser grained and thicker basal part, and a darker red, much finer grained upper fraction. Most beds are less than 1 inch thick and commonly are varve-like in appearance. Mud-cracks were noted on many loose slabs but were rarely seen in outcrops.

The argillite of this member in the Contwoyto Lake area is of the same colour but is somewhat more massive than the red argillite of the Beechey Lake area. It commonly contains light to dark brown concretions, and therefore the name concretionary red argillite is applied in the Contwoyto Lake area. The concretions are dolomitic to limy, lenticular to elliptical, and in general are less than 4 inches long by 1 inch to 2 inches wide. The concretions constitute 40 per cent of the rock toward the centre of the concretionary red argillite succession, but their abundance decreases towards the bottom and top of the member. The concretions occur along beds and in a few instances are so large that they resemble beds. Their distribution suggests that they originally were continuous beds, that the beds were broken into fragments as in mud-cracks, and that later the fragments were separated from each other following filling of the cracks with red argillite.

Chemical analyses of the Red Siltstones (free of limy concretions) from the Beechey (analysis 1) and Contwoyto (analysis 2) Lake areas are presented in Table 3. These analyses, compared to the average composition of 33 Precambrian slates (Nanz, 1953) show some striking resemblances but are slightly lower in Al_2O_3 and total iron. The Fe_2O_3 content, however, is about the same in these analyses. There is a marked difference in comparison with the greywacke of the Yellowknife-type sediment (analysis 9).

The interbedded quartzite and sandstone near the top of the member are similar to those of the overlying Quartzite member. The grey argillite beds at many levels in the succession are similar to argillites of the Lower Argillite member which has already been described.

In thin section the red siltstone or argillite is seen to be stratified due to variations in composition and grain size. Some layers are sandstones as their grains average 0.5 mm and are never greater than 1 mm in diameter. Other layers have only a few sparse clastic grains in a similar felted mass, and still others are made up entirely of a felted mass of sericite and chlorite. The latter are really shale because their grains average less than 0.005 mm. The sericite and chlorite flakes are generally oriented parallel with the layered structure or deviate only slightly from it. Rare flakes at right angles to the main trend may be related to a crude cleavage visible locally. Tiny specks of an opaque substance, carbon and iron oxides, form about 5 per cent of the rock. Other minerals present in small amounts are carbonate, biotite and limonite.

Table 3

Chemical Analyses
of rocks of the Goulburn Group

(in comparison with other analyses)

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	63.5	58.2	60.9	60.4	88.9	64.5	66.2	65.4	64.19	93.9	92.5
Al_2O_3	15.4	17.3	16.4	18.5	1.6	15.9	15.7	15.8	17.29	2.5	1.4
FeO	1.8	0.8	1.3	6.7	0.3	2.8	2.6	2.7	5.25	0.2	0.3
Fe_2O_3	4.2	6.4	5.3	4.1	1.7	2.1	2.3	2.2	0.35	1.5	0.2
MgO	2.7	3.3	3.0	2.7	1.2	2.9	2.5	2.7	2.98	<0.5	0.1
CaO	0.7	0.9	0.8	1.1	0.1	<0.1	0.2	0.1	2.35	<0.1	3.0
Na_2O	0.6	1.5	1.1	1.3	0.3	1.6	0.2	0.9	4.14	0.1	0.1
K_2O	5.3	4.5	4.9	4.1	2.5	4.6	6.0	5.3	1.16	1.6	0.1
H_2O	2.9	3.0	3.0		1.0	2.9	2.9	2.9	1.97	0.5	0.2
TiO_2	0.69	0.75	0.72	0.8	0.13	0.66	0.75	0.71	0.60	0.11	
MnO	0.05	0.08	0.07	0.1	<0.02	0.02	0.02	0.02		<0.02	
P_2O_5	0.13	0.12	0.12	0.2	<0.02	0.09	0.07	0.08		<0.02	
CO_2	1.0	1.0	1.0		0.2	0.01	0.01	0.01		0.1	2.3
Total	99.0	97.9			97.9	98.2	99.5			100.5	

For the Goulburn rocks, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, and MnO were determined by X-ray fluorescence using the fusion method, and Na_2O, P_2O_5, CO_2, H_2O, and FeO were determined by rapid chemical analysis and Fe_2O_3 by difference. Analyses by the staff of Chemical Laboratory of the Geological Survey of Canada, Ottawa.

1. Composite sample, Red Siltstone, Beechey Lake area.
2. Composite sample, Red concretionary Argillite and Siltstone, Contwoyto Lake area.
3. Average of Nos. 1 and 2 above.
4. Average of 33 Precambrian slates (Nanz, 1953; p. 57).
5. Composite sample, Quartzite member, Contwoyto Lake area.
6. Composite sample, Upper Argillite, Beechey Lake area.
7. Composite sample, Upper Argillite, Contwoyto Lake area.
8. Average of Nos. 6 and 7 above.
9. Average of two greywackes, Yellowknife area (Maxwell, 1965; Nos. 508 and 514).
10. Composite sample, Quartzite, Burnside River Formation, Beechey Lake area.
11. Average of 7 orthoquartzites (Pettijohn, 1949; p. 241).

Quartzite

The Quartzite member occurs immediately above the Red Siltstone. It is about 450 feet thick in Contwoyto Lake area where it is composed of about 300 feet of pink quartzite overlain by about 150 feet of white quartzite. Grey and pink argillites are also present in thin seams. In Beechey Lake area the member is about 150 feet thick west of Basalt Lake, and about 600 feet thick immediately east of the Bathurst Trench. The member in this area is characterized by large amounts of interbedded dolomite and limestone. Near the Bathurst Trench, the quartzite is poorly indurated whereas west of Basalt Lake, it is well indurated.

This member is a good marker in the Beechey Lake area where it is readily recognized by its position above the Red Siltstone and by the fact that brown weathering carbonate occurs as large lenses within it. In the Contwoyto Lake area, its position immediately above the concretionary red argillite makes recognition possible, but the absence of brown weathering dolomitic rocks and the lithological resemblance to the Burnside River Formation makes recognition there somewhat difficult.

Contacts with the Red Siltstone member range from sharp to gradational. The upper contact also is sharp to gradational depending on the amount of interbedding between white quartzite and the grey argillite at the base of the overlying Upper Argillite. The disappearance of quartzite generally marks the contact.

In addition to abundant quartzites and dolomitic rocks some grey argillite and a few narrow lenses of quartz-pebble conglomerate were also noted. Two sections of the Quartzite member from the Beechey Lake area, one measured near the Bathurst Trench, and the other measured east of area 5 shown on Figure 1, are presented in Table 4 and show that quartzite is generally more abundant than dolomite. Quartzite is eight times more abundant near the Bathurst Trench and twice as abundant in the western part of Beechey Lake area. The carbonate rocks are missing entirely in the Contwoyto Lake area. In the east near the Bathurst Trench, the succession dolomite-quartzite is repeated four times, whereas in the west there is only one layer of dolomite separating two quartzite layers. Argillite occurs abundantly in this member only in the area southeast of Basalt Lake. In Contwoyto Lake area the quartzites were subdivided into a lower pink quartzite unit and an upper white quartzite unit.

The quartzites of Beechey Lake area are much more variable in composition than those of Contwoyto Lake area. In Contwoyto Lake area only two varieties were recognized, a pink and a white quartzite. In Beechey Lake area, although the quartzite is generally a well consolidated, homogeneous, white to grey, medium-grained, massive and closely jointed rock, it is locally pink to red and is ferruginous. In places its weathered surface is pitted and speckled light to dark rusty brown due to the weathering of

Table 4

Sections of the Quartzite member
Beechey Lake area

Area 5 Figure 1	Thickness in feet	About 1 mile west of Bathurst Trench	Thickness in feet
Dolomite, pink sandstone	50	Dolomite	15+
		Sandstone	20
Dolomite, purple calcareous sandstone, limestone	360	Dolomite, in part arenaceous	10
Calcareous sandstone, dolomite	50	Sandstone	110
		Dolomite	20
Purple sandstone	40		
		Sandstone	180
Calcareous sandstone, siliceous dolomite	55	Dolomite, in part arenaceous	10
Purple sandstone, dolomite	45	Sandstone	200+

disseminated carbonate in a white sandy mass. Other quartzites have tiny disseminated grains of white kaolinized feldspar in a mass of quartz. Others have concentrations of tiny green grains such as chlorite, hornblende and epidote. Most quartzites have tiny black grains of iron oxide. Some quartzites have dark rusty brown dolomitic pockets and layers and locally these pockets and layers are so abundant that the rock is a dolomitic quartzite.

The pink quartzite in Contwoyto Lake area is massive, fine-grained, coarsely bedded, and well jointed, and much resembles the pink quartzite of the Burnside River Formation, although it is somewhat finer grained and not crossbedded. The white quartzite is well crossbedded (see Fig. 4), coarse grained, and typically rusty white on weathered surfaces.

A chemical analysis of pink quartzite is given in Table 3. The average of seven orthoquartzites (analysis 11) is also included. Both show some similarities. However, the pink quartzite is low in Al_2O_3 and CaO and high in MgO and K_2O compared to the average orthoquartzite. There is also a slight difference in the silica content.

The dolomite and dolomitic rocks vary greatly in composition and texture. The main type is fine grained, gritty and massive and has a characteristic, light chocolate brown, muddy, weathered surface. On most outcrops it exhibits tiny, irregular, siliceous blebs and seams. Where massive and almost silica-free it has a conchoidal appearance. On the surface of many outcrops it exhibits pronounced spherical markings which are regarded as stromatolites. The siliceous blebs and seams are missing from some outcrop areas but are a major constituent in others. In the field, all gradations from an almost silica-free dolomite to a siliceous dolomite were noted. The silica is either cherty or sandy and generally is pink or purple. On weathered surfaces it stands out as ridges of irregular shape and form. Much of the silica is probably sedimentary but some, at least that which occurs along the cleavage planes, is probably later.

Various types of breccia also occur, generally made up of dolomitic fragments in a sandy matrix with a carbonate cement, or of argillaceous and sandy siliceous fragments in a dolomitic base. Thin beds and small lenses of dark brown weathering, grey to white and fine- to medium-grained limestone were also observed.

In thin sections all gradations were seen from a clastic rock with about 5 per cent carbonate cement to a carbonate rock with about 5 per cent clastic grains or siliceous material filling holes. The clastic rocks are sandstones or quartzites as some of the rocks show some silica overgrowth on quartz grains. The sandstones or quartzites are composed of about 80 per cent quartz grains, 15 per cent feldspar grains, some chert or rock grains, and about 5 per cent carbonate cement. In Contwoyto Lake area the matrix is sericitic and in some pink quartzites comprises as much as 30 per cent of the rock. Iron oxide, sphene, and tourmaline occur in trace amounts. Where

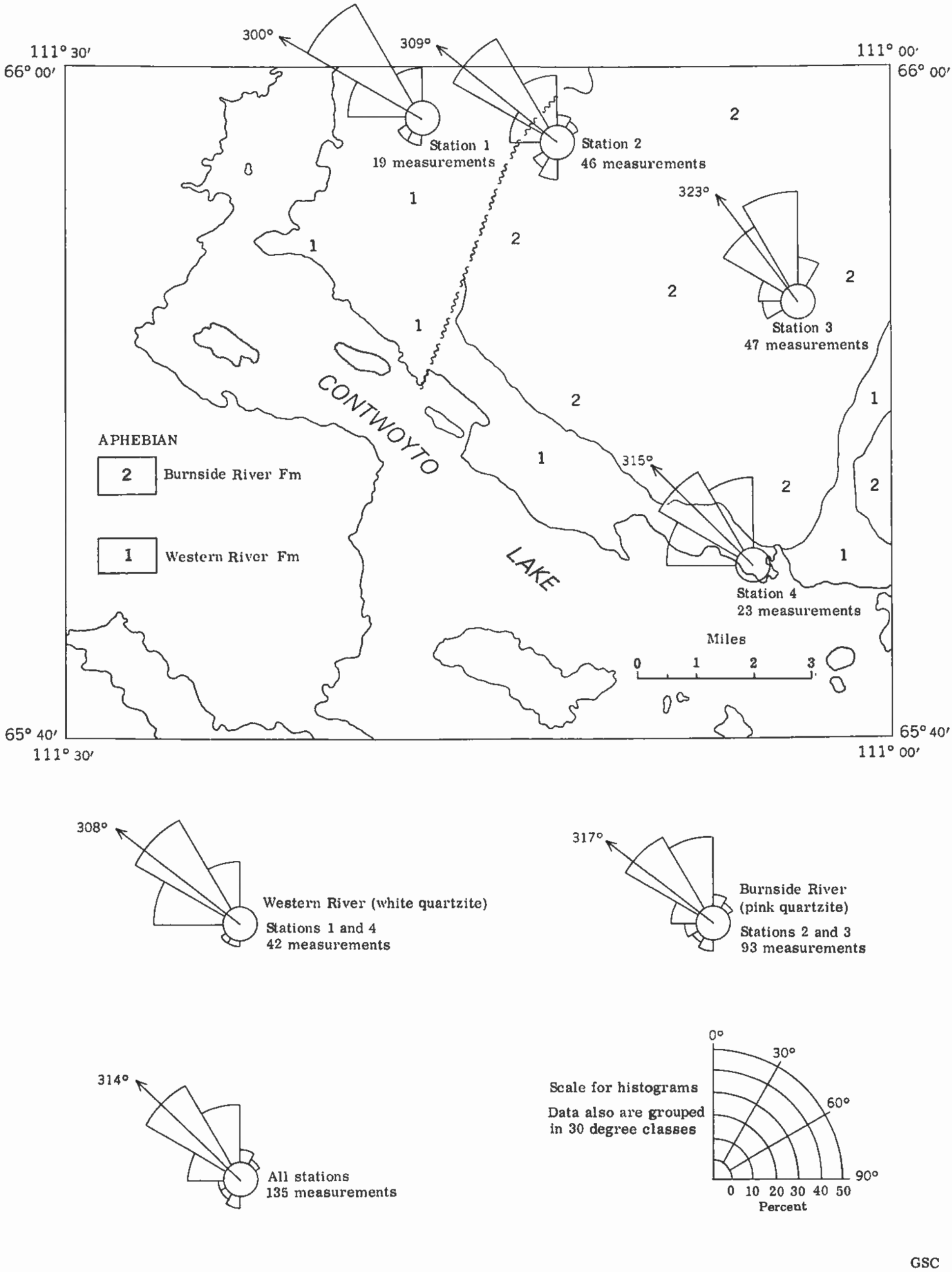

Figure 4. Histograms summarizing known crossbedding information on Goulburn rocks in Contwoyto Lake area

the cement is carbonate there are also trace amounts of sericite and chlorite. The grains are subrounded to rounded and average about 0.5 mm in diameter, although they vary between 0.2 mm and 2.0 mm. The quartzites in Contwoyto Lake area are somewhat finer grained. The grains of the pink quartzite average about 0.08 mm and those of the white quartzite 0.2 mm. The grains of the matrix are somewhat smaller. A few grains are altered, and some are stained red. Quartz shows undulatory extinction and some of the feldspar is perthitic. Where the carbonate represents more than 5 per cent of the rock, the clastic grains average 0.01 mm and are found in varying amounts amongst the carbonate. The carbonate shows a rough layering which may be of sedimentary origin. Some quartz in the carbonate may be later, i.e. the result of percolating or circulating solutions, because it seems to fill cracks and cavities in the carbonate.

Upper Argillite

The Upper Argillite, immediately above the Quartzite member, is the uppermost member of the Western River Formation. Lithologically it much resembles the Lower Argillite and in general cannot be distinguished from it unless its position in the succession is known. The Quartzite member generally serves to separate the Upper and Lower Argillite members, because the Quartzite member, at least in Beechey Lake area, is readily recognized by its brown-weathering dolomitic rocks.

The lower contact of the Upper Argillite member is generally placed at the disappearance of quartzite of the Quartzite member and at the increased abundance of grey argillite in the succession. This contact is sharp to gradational. The upper contact is sharp and readily located because it is between grey or red argillite of the Upper Argillite and pink quartzite or quartz-pebble conglomerate of the Burnside River Formation.

In Contwoyto Lake area the Upper Argillite is about 125 feet thick and was subdivided in two units, the lower comprising about 100 feet of mainly grey argillite and greywacke and the upper comprising about 25 feet of mainly red argillite. In Beechey Lake area it comprises argillite, quartzite and red argillite, all interbedded. Argillite is the most abundant and characteristic rock type and is mainly grey. Quartzite constitutes up to about 20 per cent of the member in this area and is more abundant in the east than in the west. Red argillite occurs normally as thin layers but in some parts of the member it is the main rock type, generally within limited thicknesses.

The Upper Argillite outcrops in Contwoyto Lake area as a belt near the north shore of Contwoyto Lake and as inliers in the pink quartzite of the Burnside River Formation. In Beechey Lake area, it forms a belt of variable thickness that is very wide near the Bathurst Trench and east of Basalt Lake but is very narrow west of Basalt Lake.

Argillite, the most common rock type, is usually grey, massive, fine grained or dense and well jointed. Some is locally red, buff or light green, and a few beds are slaty. Most argillite occurs in thin beds that form great thicknesses and resemble varves. Most beds are less than 1 inch thick, but a few reach 2 feet. The red and green argillites generally are sparingly interbedded with the grey argillite except in Contwoyto Lake area where red argillite occurs in abundance near the top of the member. There are also some quartzites, represented by greywacke and impure quartzite in Contwoyto Lake area, and by quartzite similar to quartzite of the Quartzite member in Beechey Lake area.

Two chemical analyses of the grey argillite of this member, one from Beechey Lake area, the other from Contwoyto Lake area, are given in Table 3. Analysis 8, their average, differs from the average of the Lower Argillite (analysis 3) in its higher silica content and its different FeO and Fe_2O_3 contents, although the total iron contents are about the same. The average Precambrian slates of Nanz (analysis 4) is much lower in SiO_2 and much higher in total iron, Al_2O_3, and CaO, than is the Upper Argillite average. The average analysis of two greywackes (analysis 9) from the Yellowknife area is added for comparison and indicates that the Upper Argillite and the greywackes are quite different chemically except for their silica, total iron, and MgO contents.

In thin section the argillite is crudely layered due to a varying concentration of clastic grains in adjoining layers, to the varying composition of alternate layers, and to the sorting of clastic grains of slightly different grain size in adjoining layers. Some layers are a felted mass of sericite flakes or of sericite and chlorite flakes. Others have various amounts of clastic grains in a felted mass of sericite and chlorite. The clastic grains average 0.02 mm but larger ones up to about 0.4 mm were also noted. Other layers are composed almost entirely of clastic grains cemented together with very little sericite and chlorite. Some flakes of sericite and chlorite are locally oriented, and may represent recrystallized clay material. The clastic grains are subangular to subrounded and most are quartz, about 15 per cent are feldspar, and there are also a few chert grains. The felted mass varies in amount from place to place and may form up to 35 per cent of the slide. Opaque material is present everywhere in small quantity, but locally, particularly in the purple argillite, it accounts for as much as 15 per cent of the rock.

The quartzite of this member is massive, fine grained and typically is clastic in hand specimens. It is white, buff and pink and some of the thicker beds much resemble the pink quartzite of the Burnside River Formation. Beds are fairly thick and bedding is hard to recognize. In thin sections it is made up of abundant closely packed clastic grains set in a matrix of smaller grains and a chlorite-sericite cement. The grains are rounded to subrounded. The largest average 0.3 mm and compose about 65 per cent of the rock; the smallest average about 0.02 mm. Most grains are quartz, a few are feldspar, and rare ones are chert. In general, no silica overgrowth can be seen on quartz grains except in Contwoyto Lake area where the quartz and feldspar grains show some overgrowth. Magnetite is a common opaque, and tourmaline was also noted.

The red argillite is very similar to the red argillite of the Red Siltstone member. It is dense, massive and dark chocolate red. Thin sections show that it is made up of closely packed clastic grains in very little matrix. Iron oxide cement fills the space between. The grains are subangular to subrounded, are mainly quartz with no silica overgrowth, and average about 0.05 mm. Some of the grains are red-stained altered feldspar. Opaque substances represent 3 per cent of the rock, and although some is pyrite most is probably carbon and iron oxides.

BURNSIDE RIVER FORMATION

The Burnside River Formation, a thick succession of pink quartzites and quartz-pebble conglomerate, overlies the Western River Formation. The name is derived from Burnside River which traverses the largest outcrop area of this formation and which probably provides good and complete sections. This formation is probably the pink quartzite referred to by O'Neill as the Goulburn quartzite. Its lower and upper contacts are sharp and easily determined because they are indicated respectively by pink quartzites in contact with thinly bedded red and grey argillites below, and by a mixture of red, grey, green and buff argillites above.

Its outcrop areas include large tracts of angular frost-heaved blocks and flat to gently sloping rock surfaces which commonly reflect the dip of the bedding. This formation covers about 75 per cent of the exposed area of Goulburn rocks (Fig. 3) and extends from Contwoyto Lake in the west to the Bathurst Trench in the east where it is truncated by the trench. Small areas of it have been mapped by Fraser (1964) east of the trench.

The thickness of the formation as measured in Contwoyto Lake area where both lower and upper contacts were mapped was determined at between 600 and 800 feet. In Beechey Lake area, the upper limit was not mapped but from the information available it is at least 9,000 feet thick. The sections along Burnside River may provide more accurate estimates of the thickness for the area of Goulburn rocks near and on the west side of the Bathurst Trench. The above estimates of the thickness suggest that the Burnside River Formation thins out to the west, and possibly it eventually dies out before reaching the area underlain by rocks of the Epworth Group.

Pink quartzites and sandstones comprise about 90 per cent of the total succession. Quartz-pebble conglomerate is next in abundance, and minor amounts of grey, green and red argillites and slate were noted locally.

The quartzites are mostly various shades of pink and red, but locally they are almost white. In general the quartzites are massive, well consolidated, closely jointed rocks. Bedding was recognized everywhere, but with some difficulty, possibly because it is too coarse for the size of the outcrops seen, not distinct enough to be readily noted, or because the outcrops are dirty and extensively covered with lichen. Crossbedding is abundant locally, but except where the exposures are good, it is hard to recognize crossbeds and use them for determining direction of transport. Fairly accurate determinations in the Contwoyto Lake area suggest a northwesterly direction of transport (see Fig. 4). Ripple-marks of the symmetrical type were noted at a few places. The rocks are fine- to coarse-grained and in general each bed is fairly uniform in grain size. Grains are generally between 1 mm and 0.1 mm, averaging about 0.4-0.5 mm. White quartz pebbles up to 2 inches across were locally noted. Where the grain is very fine the rock resembles an argillite and the rock has a conchoidal fracture.

Hand specimens of the quartzites are characterized by a clastic texture and seem to be composed mainly of glassy quartz. A few deep red grains are probably also quartz although some may be feldspar, and other rare black grains are probably magnetite.

A chemical analysis of this quartzite from Beechey Lake area is given in Table 3, and like all other chemical analyses of Goulburn rocks presented in the same table it is somewhat K_2O-rich in comparison to the orthoquartzite of Pettijohn (analysis 11).

In thin section the quartzite is seen to be composed almost entirely of quartz grains cemented together with a small quantity of sericite, chlorite, and/or carbonate. Feldspar, chert and lithic grains were also recognized and generally constitute less than 5 per cent of the rock. There is practically no matrix. Locally, and particularly in Contwoyto Lake area, grains other than quartz form about 10 to 15 per cent of the rock; the amount of matrix also is highly variable, locally representing about 30 per cent of a representative thin section. Some specimens are sufficiently high in feldspar grains to be called arkose. The grains are generally rounded and subrounded, rarely subangular, fairly well sorted as to grain size, and closely packed. Some slides show silica overgrowth on quartz and even locally some feldspar grains show overgrowth at their margins.

Trace amounts of bluish green tourmaline, zircon in tiny grains, and minor opaque minerals were noted in all thin sections examined.

Quartz-pebble conglomerates represent about 10 per cent of the succession and occur as layers intercalated in the quartzites. These layers may be up to 10 feet thick but generally are about 1 foot to 2 feet thick. They are true beds and some of them are lenticular. This conglomerate is made up of about 25 to 50 per cent pebbles in a sandy matrix. The pebbles are more than 95 per cent white quartz and grey glassy quartz. There are also rare pebbles of red jasper, dark grey to black chert, buff feldspar and variegated quartz and quartzite. Other less common fragments are fine-grained granulose quartz-biotite gneiss, thinly layered quartzite, smoky quartz, grey-buff argillite, fine-grained clear quartzite, and deep red hematitic quartzite. The pebbles are well sorted as they are mainly less than 2 inches but range up to 6 inches in size. They show some orientation in their elongation and also some crude depositional layering. Some of the pebbles probably were derived from the Western River Formation. The matrix is generally pink and has an average grain size of about 1 mm.

The argillite occurs as seams less than an inch thick and locally as zones of thinly bedded rocks less than 2 feet thick. It represents only a small part of the quartzite succession. The seams show up best on flat weathered surfaces where they form a thin veneer covering most of the exposed surface, and they appear to be more common toward the top of the succession. They were used to determine the bedding attitudes in the pink quartzites.

PEACOCK HILLS FORMATION

The Peacock Hills Formation, named after the Peacock Hills located at the northwest end of Contwoyto Lake is a succession of argillites and quartzites that form a northeasterly elongated basin in the Unit Lake area in the southeast part of the Peacock Hills. This basin contains the only area of these rocks visited and mapped by the writer. The section measured is continuous and well exposed in a gulley on the west shore of Unit Lake. This section is presented in Table 3. Other areas correlatable with this formation are Fraser's unit 12 (1964) outcropping in the Kuuvik Lake area, and the area along, and a short distance west of, the Bathurst Trench. Other small areas of this unit are also shown on Fraser's map east of the trench.

The lower contact of the formation is marked by pink quartzite of the Burnside River Formation, and the upper contact by a 10-foot zone of interbedded carbonate rocks and argillites. This 10-foot zone is the boundary between the Peacock Hills Formation and the overlying Kuuvik Formation. The measured section at Unit Lake (Table 5) is 160 feet thick, and the correlatable unit mapped by Fraser to the east is 2,000 feet thick, suggesting much lateral variation.

In the Unit Lake area this formation is made up of about 80 per cent argillites and 20 per cent pink quartzites (Table 5). The argillites and/or siltstones are predominantly black and purple to pink near the bottom and pink to grey near the top. They all are fine grained, and thinly interbedded as shown by an interlamination of various colours. In general they much resemble the argillites and siltstones of the Western River Formation, and for this reason no detailed description is given here. The quartzite is more coarsely bedded than the argillites and siltstones and is interbedded with them.

Table 5

Peacock Hills Formation. Detailed section measured on the west shore of Unit Lake.

Rock types	Thickness in feet
Gradational upper contact	
Thinly bedded mixture of light brown dolomite and red, green, and grey argillites.	5-10
Thinly bedded purple argillite; ripple-marked.	10
Fine-grained pink quartzite (about 90% of unit) interbedded with minor purple argillite.	25
Thinly bedded, green limy argillite interbedded with minor green siltstone.	6
Thinly bedded purple and black argillites with some coarser clastic material grading downward into thinly bedded green and grey argillites and siltstones.	50
Thinly bedded fine-grained pink quartzite	4
Thinly bedded pink and purple argillites with minor sandstone beds and occasional grey argillite laminae.	15
Fine-grained pink quartzite.	2.5
Thinly bedded grey argillite and siltstone grading upward into coarser grained clastic material; ripple-marked.	10
Fine-grained dirty pink quartzite with minor thin argillite laminae.	4
Thinly bedded black and purple argillites with rare pink quartzite laminae.	7.5
Thinly bedded black argillite and purple siltstone interbedded with minor dirty pink quartzite and green argillite.	21
Sharp lower contact	

Total 160 feet

It resembles the pink quartzites of the Burnside River Formation and where outcrops of both quartzites are close to one another they cannot be distinguished. Near the top of the section all these rocks become somewhat carbonate-bearing. In the Unit Lake area where the rocks of this formation were examined, most of the argillites are schistose and display a cleavage parallel to the trend of the main structure. This cleavage is locally so strong that it has obscured the bedding.

Fraser's unit corresponding to this formation was described as follows: "argillite comprises purplish, green, and grey argillite, and slate, and buff weathering, recessive layers of light grey limestone, dolomite, and calcareous siltstone, which constitute from 20 to 50 per cent of the rock. Soft sediment deformation, graded bedding, and crossbedding are typical of these strata" (Fraser, 1964, p. 12).

KUUVIK FORMATION

The Kuuvik Formation conformably overlies the Peacock Hills Formation. Its name is derived from the Kuuvik Lake area where rocks related to this formation are better and more extensively exposed than those mapped by the writer in the Unit Lake area. The Kuuvik Formation and rocks correlatable with it have the same distribution as the Peacock Hills Formation. It is found in the Unit Lake area, in the Kuuvik Lake area, along and slightly west of the Bathurst Trench, and as small scattered areas at some distance east of the Bathurst Trench (Fig. 3). A measured section in the Unit Lake area is only 140 feet thick (Table 6), but this section is not complete because its upper limit was not seen. Fraser (1964, p. 12) from more extensive information, regards the formation as about 800 feet thick.

The lower contact of the formation is placed at the appearance of carbonate rocks in the argillite of the Peacock Hills Formation, and it generally is indicated by a transitional zone 10 feet wide where rocks of both formations are thinly interlayered and above which mainly carbonate rock is found. Its upper limit was not mapped by the writer but, from Fraser's information, may be taken as the horizon at which carbonate rocks disappear from the succession and are replaced by argillites and siltstones.

In the Unit Lake area, this formation is made up mainly of light brown-weathering dolomitic rocks that are interbedded toward the bottom with green and red argillites, and toward the top with thin beds of buff-weathering limestone. The dolomite is thinly layered to massive, dense and muddy looking, and is locally stromatolitic. It locally includes much argillaceous material in irregular seams, and small patches. Some of the argillites are slaty, and like argillites in the Western River Formation, they commonly are dense, shaly, thinly bedded, and variable in colour from layer to layer. Fraser describes the unit correlatable with this formation as follows: "Weathered surfaces of the dolomite are light grey, buff, or pink, and are very commonly ribbed by paper-thin, wedge-like laminae of silica.

Table 6

Kuuvik Formation. Detailed section measured at the north end of Unit Lake.

Rock types	Thickness in feet
Upper contact not exposed	
Light brown, thinly layered dolomite.	10
Light brown, thinly layered dolomite, interbedded with massive buff limestone.	5
Light brown, thinly layered dolomite, interbedded with rare beds of massive buff limestone.	50
Light brown, thinly layered dolomite, interbedded with beds and seams of green argillite and slate.	20
Light brown, thinly layered dolomite, interbedded with minor red and green argillites and slates.	40
Thinly bedded mixture of light brown dolomite and red, green, and grey argillites.	10-15
Gradational lower contact	

Total 140 feet

In the uppermost and lowermost parts of the unit are argillite and siltstone interbeds that exhibit ripple marks and crossbedding ... . Stromotolites are abundant in the dolomite, especially in the upper parts." (Fraser, 1964, p. 12).

BROWN SOUND FORMATION

A formation made up mainly of "interlaminated, deep red, grey, maroon, and brown siltstone and argillite" outcrops in Bathurst Inlet area between Western River and Brown Sound. These rocks are "fine to very fine grained, locally arkosic and micaceous, and break with a hackly fracture. Characteristically they contain granules of specularite and joint surfaces coated with specularite. Red, crossbedded sandstone is abundant in the upper half of the unit. The total thickness of the unit is unknown but may be in the order of 1,000 feet" (Fraser, 1964, p. 12).

The name Brown Sound Formation is proposed for this succession. The Brown Sound Formation conformably overlies the Kuuvik Formation. This formation was not mapped or visited by the writer because it does not occur in the areas he mapped, and its description is taken directly from Fraser's paper.

Fraser's map-unit 15 is his uppermost part of the Goulburn Group (Fraser, 1964). Amagok Creek traverses the northern exposures of this map-unit and provides information on the relationship of this formation with sandstones of the Tinney Cove Formation above and on its lithology.

West of Bathurst Inlet, map-unit 15 occurs only near the mouth of Western River. There the map-unit is in faulted contact on the east and west with the Brown Sound Formation, and its contact with the overlying Tinney Cove Formation is an unconformity. Because this area was not visited or studied by the writer, the information presented below is taken directly from Fraser's map and paper.

This map-unit is "a mottled, cream-coloured, red and buff, crossbedded sandstone of unknown thickness. In some localities the matrix ... is kaolinitic. Conglomerate beds in the basal part of the sandstone contain pebbles of buff sandstone, quartzite, quartz, and granite" (Fraser, 1964, p. 12).

The similarity of lithology of both this map-unit and the upper part of the Brown Sound Formation (Fraser, personal communication) and their occurrence in the same general vicinity suggest that the two are probably the same unit repeated by faulting and folding. The overlying unconformity becomes a feature of major stratigraphic significance as it marks the top of the Goulburn Group and separates it from the Tinney Cove Formation above.

STRUCTURAL GEOLOGY

Structural information on the Goulburn Group is scanty. A certain amount of data were collected by the writer in the two areas studied. These define the structure of the areas, but, because the areas are so small compared to the total area of Goulburn rocks and so far apart (they are 100 miles apart and at the extreme east and west end of the outcrop area of Goulburn rocks) the data may not be characteristic of the Goulburn rocks as a whole. However, they may at least be characteristic of the southern part of the area of Goulburn rocks, because both small map-areas are near its southern edge.

PRIMARY STRUCTURES

Bedding or stratification is striking and well defined in argillites and siltstones of the Goulburn Group. Beds in these rocks are varve-like, that is generally less than an inch thick with sharp boundaries. In carbonate rocks bedding is poor and generally is only distinct where represented by paper-thin laminae, lenses, and irregular masses of siliceous material in parallel orientation. In quartzites it is faint, thick, and in general is difficult to see in outcrops. In the two areas studied overturning of beds was not observed and their dips are generally less than 60 degrees.

Minor structures such as mud-cracks, ripple-marks, and cross-beds were recognized in the two small areas of Goulburn rocks studied by the writer. They were also reported by Fraser. In general they all suggest that the beds are in their normal position. Mud-cracks were seen only rarely on the outcrops but were noted at several places on loose slabs of the Lower Argillite and Red Siltstone members of the Western River Formation. Ripple-marks are common features on sandy beds of a few horizons over large areas of the Lower Argillite member in the Beechey Lake area. In size they are small to large, and locally, very large. Crossbeds occur in abundance in the pink quartzites of the Burnside River Formation, in the sandstones of the Brown Sound Formation and of Fraser's map-unit 15 and also in the white quartzites of the Western River Formation. Measurements (see Fig. 4) in Contwoyto Lake area indicate a northwesterly direction of transport for both the white and pink quartzites of the two lower formations. A few measurements on the Burnside River pink quartzite in the Beechey Lake area suggest the same direction of transport. No measurements were made in the other formations. Variation of grain size is a common feature in some beds but is irregular rather than of the type of grain gradation characterized by coarse grains at the bottom and fine grains at the top.

SECONDARY STRUCTURES

A cleavage was noted in parts of both areas studied. It is generally weak and widely spaced in the Western River Formation, rare in the

Burnside River Formation, but is a prominent feature in the Peacock Hills Formation, at least where this formation was mapped by the writer in Contwoyto Lake area.

In Contwoyto Lake area a cleavage is well developed in the region extending from north of Unit Lake to the islands in Contwoyto Lake in the south. In Unit Lake area it occurs in the Peacock Hills Formation where it affects only the argillites and is parallel to the main syncline or trace of the fold axis passing by Unit Lake. On the islands in Contwoyto Lake it is found in the concretionary red argillite (Red Siltstone member) of the Western River Formation and seems to be restricted to the projected southern extension of the Unit Lake area. It may be related to deformation that has affected the Peacock Hills Formation but its direction and dip suggest that it may be in part a load effect or may represent slippage on planes parallel to the unconformity between Goulburn rocks and older rocks below. This cleavage is locally very prominent as the limy concretions have been reoriented in the cleavage plane.

In the Beechey Lake area cleavage was recognized only in argillite and in general is faint and in most instances it is impossible to measure it with any accuracy. It is most apparent in the argillites of the Lower Argillite member of the Western River Formation that outcrop in the area extending east of Basalt Lake to the Bathurst Trench. In this area it is best developed where the rocks are more intensely folded and at places near the base of the succession. Its strike is north, about parallel to the few folds recognized in this area, and its dip is steeply east. Most of this cleavage is probably related to folding, but some, particularly the cleavage near the base of the succession, may be a load effect as locally it is almost parallel to the beds. In the Burnside River Formation the cleavage is restricted to rare thin beds of argillite intercalated with massive, thick, pink quartzite beds. This cleavage is also faint, parallel to the bedding and is responsible for the schistose appearance of some of the argillite beds. It is probably due to movement along these beds between thick beds of pink quartzite or it may be merely a load effect.

All the rocks of the Goulburn Group have been folded. Some are gently deformed and have dips less than 15 degrees, others are steeply inclined and have dips of 60 degrees or more. The argillites and siltstones generally are more intensely deformed than the quartzites. Thus in an area about 15 miles wide extending from Basalt Lake east to the Bathurst Trench, eight major synclines separated by anticlines were mapped in the Burnside River quartzite. On the other hand detailed mapping of the underlying argillites of the Western River Formation have indicated much tighter folds as a section, 1 mile long, measured at a place about 6 miles south and east of Basalt Lake has revealed six fold axes. In other words, in the argillites and siltstones, the folds are tighter, the fold axes closer, and the dips on beds steeper, whereas the thick succession of quartzites have more open and wider folds, have more widely spaced fold axes, and in many instances have folds that are gentle rolls. Locally the rolls are so gentle that it is almost impossible to recognize them in outcrops because the dip is too low. This suggests disharmonious folding.

The folds trend northeasterly and their axial planes are vertical to steeply east. There is no evidence of overturning. As suggested by lineation the plunge is low, and locally it was measured to be around 20 degrees northerly. In the Contwoyto Lake area, some warping of the rocks seems to have taken place with the development of folds trending northwesterly, suggesting cross-folding during a second period of folding that affected the Goulburn rocks, at least in the Contwoyto Lake area.

A few faults were mapped in the area underlain by the Goulburn Group. There are probably many more than those shown in the two areas studied. Many were probably missed because of the small scale of mapping, the low dip of the formations in some parts of the area, and because offset along the faults commonly is small. Most of the faults mapped are normal, with small vertical offset, and most trend east-west; a few strike north-south. A small number are probably low angle thrust faults of unknown displacement.

Many faults were recognized in the Bathurst Inlet area. A few outline a pronounced depression that was traced on aerial photographs from the source of the Ellice and Western Rivers to the Arctic Coast. The writer suggests that this feature be named the Bathurst Trench, after Bathurst Inlet with which it is closely associated and is probably a graben as younger rocks have been down faulted in its centre in relation to the rocks on its edges. It is considered to be a tectonic feature of crustal dimension as it is at least 200 miles long, as the apparent horizontal offset (left handed) of the formation along it is of the order of twenty miles (50 miles according to Fraser who refers to this depression as the Bathurst Fault, 1964), as many gabbro dykes and sills are closely associated with it at its southern end, and as at this end the rocks adjoining it on both sides are locally faintly schistose and carry late sericite and muscovite. Its extension to the south in the basement rocks is marked by a wide mylonite zone and suggests that it is an old feature.

CONDITIONS OF DEPOSITION

The Goulburn Group is made up almost entirely of clastic rocks, predominantly argillites, siltstones, quartzites, and sandstones. Limestone and dolomite at most represent 10 per cent of the succession and they are mostly concentrated in the upper half. The clastic rocks typically alternate several times in the successsion from predominantly argillite and siltstone to quartzite or sandstone, starting with a great thickness of argillite and ending with an unknown thickness of sandstone and conglomerate. The Burnside River Formation represents the thickest (more than 9,000 feet locally) sandstone succession of the Goulburn Group. Conglomerates occur as a layer at the base of the succession and as beds or lenses of various thickness at different levels in the succession, and are fairly abundant in the uppermost Brown Sound Formation. These broad lithological changes, from argillaceous to sandy, repeated several times in the succession, and, in some sections of the succession, the close interlayering on a minor scale of these same rock types, suggest slight but rapid changes in the depth of the basin of deposition, quiet environment, and possibly slight changes in the relief of the source area.

The basal conglomerate is a mature rock, suggesting long transportation, and in addition its sheet-like nature also suggests transgressive beach conditions over a surface of low relief, probably in a basin area that became larger as transgression progressed. The composition and roundness of the fragments of all the other conglomerates, suggest long abrasion and these rocks probably also were deposited under beach conditions in shallow water. Because none of the fragments are greywacke and argillite related to the Yellowknife-type sediments and because most of them are not similar to gneiss and granite that outcrop north and south of the area of Goulburn rocks, it is at the moment impossible to determine the source rocks or source areas for the fragments of these conglomerates.

In argillites and siltstones grain gradation was not recognized, but mud-cracks were seen on loose slabs, and ripple-marks up to giant size were noted on some sandy beds, suggesting deposition in shallow water. The feldspar content of some of the rocks, and the mixture of clay and sandy grains reflect fairly rapid deposition and a metamorphic or igneous source terrane. The age of 2,380 m.y. on clastic muscovite from the argillite near the base of the group is indicative of such a source because the basement nearby was dated between 2,390 and 2,530 m.y.

Sandstones occur as rare beds within thinly bedded argillaceous rocks and as great thicknesses interlayered with the predominantly argillaceous sections of the succession. In these sandstones crossbeds were noted at several places and they indicate a northwesterly direction of transport (see Fig. 4). The good sorting of these sandstones, the roundness of their grains and their small clay content suggest long transportation. A sedimentary source rock is indicated. The crossbeds suggest shallow water and current transport.

Dolomite occurs as a thick succession in the upper half of the Goulburn Group, as two minor sections in the Western River Formation and as individual beds scattered throughout the whole succession. The dolomite in general is abundantly stromatolitic, suggesting shallow, warm-water deposition in an environment that could have been either marine or continental. The few tourmaline grains recognized here and there may suggest a marine environment. Some of the breccias associated with the main dolomite occurrences suggest mud-crack effects which also indicate shallow water.

The above remarks suggest that the source for the argillites and siltstones could have been any of the nearby pre-Goulburn rocks. The source area for the sandstones cannot be ascertained, but apparently was a sedimentary terrane. It is likely, however, that the source area for all rock types was to the south, east or southeast of the present area of Goulburn rocks, as suggested by the crossbeds in the quartzites and sandstones. Deposition of all the above rocks took place in shallow to relatively shallow water, where mud-cracks, ripple-marks and crossbeds could form. The environment could have been marine in part because the dolomite have stromatolites.

AGE

No granite is known to cut the Goulburn rocks. Everywhere that granite and Goulburn rocks were seen in contact, the Goulburn rocks rest unconformably on the granites. K/Ar ages on biotites from porphyritic granite (D on Fig. 1; 2,390 m.y.) and from staurolite schist (C on Fig. 1; 2,490 m.y.) in the Beechey Lake area, and on muscovite from pegmatite (2,530 m.y.) in the vicinity of Contwoyto Lake area put a maximum age limit for the formation of the rocks of the Goulburn Group. The K/Ar age of 2,380 m.y. (A on Fig. 1) on clastic muscovite from argillites at the base of the Goulburn rocks suggests that these rocks were derived from the granite and schist, or related rocks of the basement, dated above. The Goulburn rocks thus are definitely younger than 2,500 m.y.

A partly transgressive gabbro sill occurs in both areas mapped by the writer. In Beechey Lake area it is at the base of the Western River Formation in the east, but 16 miles west it intrudes the overlying Burnside River Formation. The same relationship, oriented differently, was recognized in the Contwoyto Lake area. According to Fraser's map, in Beechey Lake area this sill extends much higher up in the succession, transgressing the Burnside River, Peacock Hills, and Kuuvik Formations. It is shown also cutting the Brown Sound Formation and other rocks higher in the succession east of the Bathurst Trench, but it does not appear to cut Fraser's map-unit 15 which is correlated here on lithology with the upper part of the Brown Sound Formation. In the Beechey Lake area, a specimen from this sill near the base of the Goulburn succession was dated at 1,215 m.y. (E on Fig. 1). A similar sill in the Rocking Horse Lake area was dated (Bostock, 1966) at 1,550 m.y.

Numerous gabbro dykes that cut the Goulburn rocks trend mainly north-northwesterly and are up to 600 feet thick. A few cut all four lower formations of the Goulburn succession as well as the dated gabbro sill mentioned above. They probably also cut the Brown Sound Formation, although Fraser's map does not show gabbro dykes cutting it and his map-unit 15. A whole rock age on one of these dykes gave an age of 1,050 m.y. (F on Fig. 1). From this and other dates given above, it is concluded that the Goulburn rocks were deposited between 1,050 and 2,530 m.y. and probably between a much narrower range, possibly between 1,550 and 2,530 m.y. To follow the usages established by Stockwell (1964), the Goulburn rocks were probably deposited in Aphebian time. It is possible, however, that some of the rocks of the latest formation formed in Paleohelikian time.

METAMORPHISM

Most of the rocks of the Goulburn Group are unmetamorphosed or at least appear to be so on the outcrops. In thin section, however, a few features were observed which could be interpreted as indicating the effects of a very low grade metamorphism. The most striking of these features, and at the same time the most common, is the occurrence of felted aggregates of sericite and chlorite surrounding or filling spaces between the clastic grains of the various rock types. These aggregates are believed to represent recrystallized clay material. This feature is accompanied locally by some silica regrowth on quartz grains and locally siliceous regrowth on feldspar grains also.

On the other hand, although most Goulburn rocks appear to be unmetamorphosed, in a few places they are definitely schistose, have recrystallized to hornfels and skarn rocks, or are strongly indurated. Such areas, however, are generally of local extent only and are associated with areas of local folding or are found in the contact zones bordering the gabbro sill and dykes mentioned above. Thus, a distinct cleavage was mapped in most argillites and siltstones in the Unit Lake area and also in the red concretionary argillite south of this area in Contwoyto Lake. Much chlorite and sericite have formed in these highly cleaved rocks. Near the large gabbro sill on the north shore of Contwoyto Lake, many of the limy concretions in the concretionary red argillite and a few of the limy beds in the Lower Argillite member have recrystallized, and minerals such as feldspar, epidote, amphibole and hematite are abundant. In other places, where the contacts are with quartzite or siliceous argillite instead of carbonate rocks, the rocks are indurated and completely recrystallized, forming a rock that is dense, somewhat cherty and has a baked appearance.

The occasional tourmaline crystals noted in most thin sections of the Goulburn rocks are probably authigenic and related to the low metamorphic effects mentioned above.

CORRELATION

Available information on the Goulburn rocks is not complete enough to permit definite correlation with other rock groups. However, suggestions are made on the probable relationship of the Goulburn Group to the Dubawnt and Epworth Groups.

Within the Bathurst Trench in Beechey Lake area a conglomerate with numerous fragments of the Burnside River quartzite was mapped at the base of a pink to grey sandstone succession. The grey sandstone is characterized by a white kaolinitic cement. This conglomerate-sandstone succession, at least 200 feet thick, is here named the Tinney Cove Formation and was correlated with Fraser's map-unit 16 (1964, Map 45-1963) which rests unconformably on Fraser's map-unit 15 which is correlated with the Brown Sound Formation or the uppermost formation of the Goulburn Group.

A similar conglomerate-sandstone succession was mapped about 30 miles to the southeast of the above grey sandstone succession on the probable extension of the Bathurst Trench. This succession has at the base about 250 feet of sandy, shaly and limy rocks and covers an area of about 20 square miles. The sandstone is here named the Ellice sandstone and is very similar lithologically to the sandstone (Tinney Cove) of the Bathurst Trench. Because of this similarity, proximity and location on strike, it is probable that they should be correlated. The Ellice sandstone, then, also is later than the Goulburn Group.

Correlation on similar bases could be probably extended to the Thelon sandstone of the Dubawnt Group (Donaldson, 1965) about 100 miles to the southeast. The Thelon sandstone lithologically much resembles the Ellice sandstone and the sandstone (Tinney Cove) in the Bathurst Trench. But correlation of the Dubawnt Group as a whole with the Goulburn Group is not possible at present on lithology alone because their lithologic successions are too different. The Kazan rocks of the Dubawnt Group were not recognized in the Goulburn Group, but this may indicate only different environments of deposition. Radiometric ages on volcanic rocks from the Dubawnt succession (Donaldson, personal communication) and on gabbro dykes cutting Dubawnt rocks, suggest a range within the Goulburn age range.

To the west, correlation of the Goulburn Group with the Epworth Group has been suggested by Fraser. Outcrops of both groups are as close as 20 miles, and there are similarities of lithology in the lower and in the upper parts of the succession of both groups. However, the rocks of the Epworth Group appear to be locally much more deformed than those of the Goulburn Group, and on the west they are cut and metamorphosed by granite which is not the case with the Goulburn Group. This granite was dated at about 1,700 m.y. a date much younger than that for the granites underlying the Goulburn rocks. However, the possibility that similar young granite cuts and locally affects Goulburn rocks cannot be ruled out.

Finally the Epworth, the Dubawnt and the Goulburn Groups all rest on basement rocks. Locally the Epworth and the Goulburn Groups have a regolithic zone at their base. A similar zone occurs in the Dubawnt Group at the base of the Thelon Formation. Possibly there were two ages of regolith formation.

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