GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

BULLETIN 184

STRATIGRAPHY OF THE DEVONIAN SOUTHESK CAIRN CARBONATE COMPLEX AND ASSOCIATED STRATA, EASTERN JASPER NATIONAL PARK, ALBERTA

W. S. MacKenzie

Ottawa
Canada
1969

Price $2.00

STRATIGRAPHY OF THE DEVONIAN SOUTHESK CAIRN CARBONATE COMPLEX AND ASSOCIATED STRATA, EASTERN JASPER NATIONAL PARK, ALBERTA

1,450—1969—5885-2

Technical Editor
E. J. W. IRISH

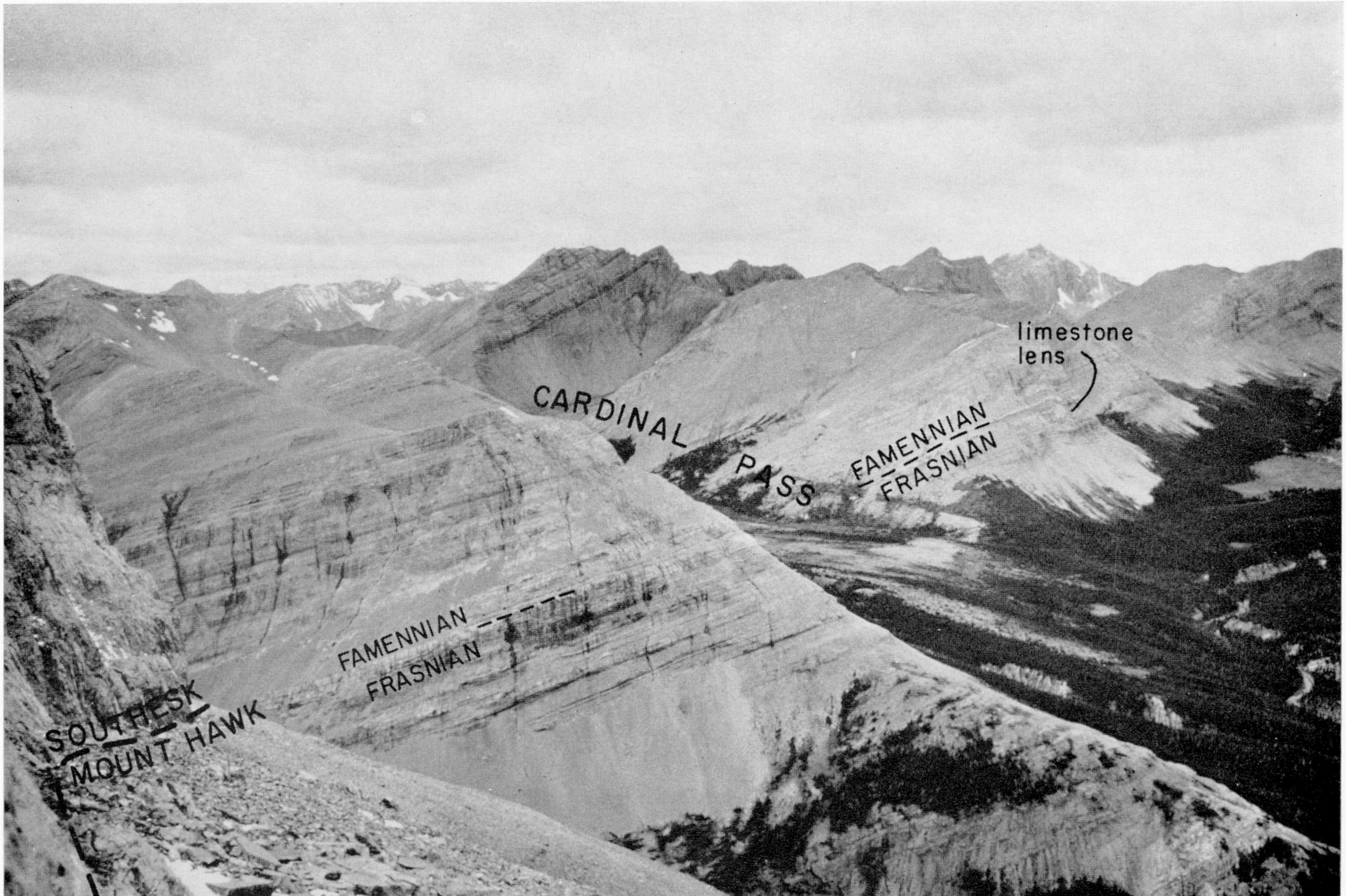
Critical Reader
R. A. PRICE

Editor
EDNA DASHNEY

Printed on No. 1 ENAMEL

Set in Times Roman with
20th Century captions by
CANADIAN GOVERNMENT PRINTING BUREAU

Artwork by CARTOGRAPHIC UNIT, GSC



200166c

PLATE I. View to the northwest across Cardinal Pass from near the Southesk/Mount Hawk Formation contact on Mount MacKenzie. In this area, near the northwest margin of the carbonate complex, carbonate strata transitional to the adjacent argillaceous province become progressively more argillaceous, less resistant to weathering, and finally disintegrate into isolated limestone lenses.

GEOLOGICAL SURVEY
OF CANADA

BULLETIN 184

STRATIGRAPHY OF THE DEVONIAN SOUTHESK CAIRN CARBONATE COMPLEX AND ASSOCIATED STRATA, EASTERN JASPER NATIONAL PARK, ALBERTA

By
W. S. MacKenzie

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
CANADA

Available by mail from the Queen's Printer, Ottawa,
from the Geological Survey of Canada,
601 Booth St., Ottawa

and at the following Canadian Government bookshops:

HALIFAX
1735 Barrington Street

MONTREAL
Æterna-Vie Building, 1182 St. Catherine Street West

OTTAWA
Daly Building, corner Mackenzie and Rideau

TORONTO
221 Yonge Street

WINNIPEG
Mall Center Building, 499 Portage Avenue

VANCOUVER
657 Granville Street

A deposit copy of this publication is also available
for reference in public libraries across Canada
or through your bookseller

Price $2.00 Catalogue No. M42-184

Price subject to change without notice

Queen's Printer for Canada
Ottawa, 1969

PREFACE

Rapid facies changes in Devonian carbonate rocks and complex relationships to "off-reef" beds have created problems in interpreting their geological history. This report presents the results of a detailed investigation of a well-exposed Upper Devonian carbonate complex in southeast Jasper National Park. Stratigraphic sections were examined by the author along five major thrust sheets. Lithologic units and contacts were traced where possible, and stratigraphic relationships to adjacent "off-reef" beds were closely examined. The petrography of the limestone carbonate rocks provided an insight into the depositional history of the almost entirely dolomitized complex.

Since the discovery of oil at Leduc in 1947, Devonian carbonate rocks have been recognized as potential reservoirs for hydrocarbons. This study of mountain outcrops of laterally equivalent carbonates gives a clearer understanding of the subsurface "reefs" and provides criteria for locating them.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, September 5, 1968

BULLETIN 184 — Die Stratigraphie des devonischen Southesk-Cairn Karbonatkomplexes und assoziierter Formationen im östlichen Jasper-Nationalpark in Alberta

W. S. MacKenzie

Dieser Bericht enthält Einzelheiten über die Ergebnisse einer ausführlichen Untersuchung des gut exponierten oberdevonischen Karbonatkomplexes im südöstlichen Jasper-Nationalpark.

БЮЛЛЕТЕНЬ 184 — Стратиграфия девонского карбонатного комплекса Соутэск Кэрн и сопряженной свиты пластов восточной части Национального парка Джаспер провинции Альберта.

Уаррен С. МакКензи

В этой работе представлены результаты детального изучения хорошо обнаженного карбонатного комплекса верхнего девона юго-восточной части Национального парка Джаспер.

CONTENTS

Illustrations

STRATIGRAPHY OF THE DEVONIAN SOUTHESK CAIRN CARBONATE COMPLEX AND ASSOCIATED STRATA, EASTERN JASPER NATIONAL PARK, ALBERTA

Abstract

Upper Devonian carbonate bodies, which are stratigraphically equivalent to oil- and gas-producing reefs in the Alberta subsurface, outcrop in the Rocky Mountain Foothills. They are easily accessible and provide a valuable supplement to subsurface studies.

A platform deposit of dark biostromal carbonate and calcarenite was laid down over large areas during the time when late Devonian seas transgressed eroded Upper Cambrian rocks. On this platform, in regions favourable to organic growth, stromatoporoidal carbonates began to accumulate, and with increasing depth of water, topographically higher areas became the sites of continued carbonate deposition. Two stages of carbonate complex development can be recognized. During the first stage, water depth increased rapidly so that regions occupied by the dark, organic carbonates decreased progressively upward in areal extent, and in many areas were onlapped by the surrounding black euxinic shales. Small bioherms grew for a time in marginally suitable environments along the periphery of the main carbonate body, but were soon drowned in the deepening and presumably oxygen-depleted water. A change of environment marked by the appearance of light coloured calcareous sands reflects the beginning of a period of relative stability characteristic of the second stage of carbonate bank development. During this time shallow-water conditions prevailed. There was widespread deposition of calcareous sands, the bank grew laterally, and the regions of carbonate sedimentation increased progressively upward in areal extent. A thick sequence of the shallow-water sediments developed indicating that the period of crustal stability lasted for an appreciable time. Slightly deeper water returned temporarily, allowing deposition of dark *Amphipora*- and coral-rich carbonates of the Grotto Member in marginal areas of the carbonate complex. Silty beds common in the upper part of the carbonate complex and in the adjacent argillaceous strata are forerunners of a period of marine regression. The carbonate complex is overlain by a disconformity with widespread evidence of erosion and non-deposition.

Marine plant and animal life played an important role in the accumulation of carbonate sediments by the volumetric contribution of their calcareous skeletons and by the stabilizing effects of their roots and the baffle action of their bodies on the freshly deposited, unconsolidated sediment and the water through which it settled. Dense lagoonal carbonate beds accumulated in the interior regions of the carbonate complex, and these, by virtue of their association with porous marginal strata, are of interest for petroleum exploration. Small carbonate mounds developed on the Flume Formation carbonate platform. These, together with an increase in carbonate content in the overlying formations and the presence of isolated limestone lenses in the upper part of the Fairholme Group sequence, are other sedimentary phenomena, which if encountered in drilling, can be used to infer proximity to reefs.

Résumé

Des masses de carbonate du Dévonien supérieur, correspondant stratigraphiquement aux formations récifales pétrolières et gazifères qu'on retrouve en profondeur en Alberta, affleurent dans les contreforts des montagnes Rocheuses. Ces formations sont faciles d'accès, et constituent un complément utile à l'étude de celles qui reposent en profondeur.

Un dépôt en plate-forme constitué de biostromes foncés de calcarénite et de carbonate recouvre de vastes étendues; ce dépôt a été mis en place au moment où les mers du Dévonien récent transgressaient et érodaient les roches du Cambrien supérieur. Sur cette plate-forme, dans les régions favorables à la vie, des carbonates de stromatoporidés ont commencé à s'accumuler et, le niveau des eaux augmentant, des régions topographiquement plus élevées ont reçu une sédimentation continue de carbonate. On peut distinguer deux étapes de la mise en place du dépôt de carbonate. Au cours d'une première étape, le niveau des eaux a augmenté rapidement, de sorte qu'à mesure que les mers s'élevaient, les dépôts de carbonates foncés, très étendus à leur base, diminuaient progressivement vers les couches supérieures; dans plusieurs régions, ces carbonates ont été recouverts par les schistes noirs euxiniques des environs. De petits bioherms se sont édifiés pendant un certain temps dans des milieux présentant les conditions minimales de survie, à la périphérie du dépôt principal de carbonate, mais ils ont été rapidement noyés dans des eaux de plus en plus profondes et dépourvues d'oxygène. Un changement dans les conditions du milieu ambiant, marqué par l'apparition de sables calcaires de couleur pâle, indique le commencement d'une période de stabilité relative caractéristique de la seconde étape de la mise en place des bancs de carbonate. Tout au cours de cette période, des conditions de sédimentation en mer peu profonde ont prévalu. Des sables calcaires se sont déposés un peu partout, les bancs se sont élargis et les couches supérieures de carbonate sédimentaire se sont accrues progressivement en étendue. Une succession épaisse de sédiments déposés en eau peu profonde indique que la période de stabilité a été relativement longue. La profondeur des mers a augmenté pendant un certain temps, ce qui a permis la mise en place des carbonates foncés *Amphipora* et d'autres carbonates riches en coraux, appartenant au terme Grotto, dans les zones périphériques du dépôt de carbonate. La présence de couches de silt, qu'on retrouve aussi bien dans la partie supérieure du dépôt de carbonate que dans les strates argileuses adjacentes, annonce une période de régression marine. Le complexe de roches carbonatées est surmonté d'une discordance d'érosion où les traces d'érosion et l'arrêt de la sédimentation sont facilement reconnaissables.

Les plantes marines et la vie animale ont joué un rôle important dans l'accumulation des sédiments de carbonate par la masse accumulée des squelettes calcaires des animaux par l'effet de stabilisation des racines des plantes et l'action rétentrice exercée par leur enchevêtrement sur les particules sédimentaires non consolidées. Des couches denses de carbonate de lagune se sont accumulées dans les zones intérieures du complexe de roches carbonatées, et ces couches présentent un intérêt pour l'exploration du pétrole du fait qu'elles sont associées à des strates poreuses périphériques. De petits monticules de carbonate se sont formés sur la plate-forme de carbonate de la formation de Flume. La présence de ces monticules ainsi que l'augmentation de la teneur en carbonate des formations sus-jacentes et la présence de lentilles isolées de calcaire dans les couches supérieures des roches du groupe de Fairholme sont d'autres signes géologiques pouvant indiquer, lors de forages, la proximité de formations récifales.

INTRODUCTION

The Upper Devonian Fairholme Group of formations is remarkably well exposed along the eastern Foothills of the Rocky Mountains and within the report area (Fig. 1) where the regional structure is simple and where the character of the exposures and distribution of the rocks has been little affected by major mountain-building movements. This study was undertaken to determine constituent lithologic and biogenic units within the dominantly carbonate formations of the Fairholme Group to outline the three dimensional form and origin of their component parts and their relationship to the stratigraphically equivalent shale and argillaceous limestone sequence.

Location and Accessibility

Figure 2 (*in pocket*) shows details of the study area, and within it the positions of measured stratigraphic sections. The carbonate complex is named after Southesk Cairn, an isolated topographic feature at the summit of Southesk Pass near the centre of the report area.

The most practical means of access, other than by helicopter, is by car along highway 16 from Edmonton to the town of Edson (Fig. 1), then southward along a maintained gravel road (highway 47) through Cadomin and Mountain Park to a point within the northeast corner of the report area. Another route, not explored by the writer, is an improved gravel road northwest from Nordegg to within 5 miles of Brazeau River. From here, horses can be used to follow trails along Brazeau River southward into the eastern part of the report area. Alternatively from a point on highway 93 near the Athabasca Glacier, pack horses can provide transportation northward along maintained park trails into the southern and eastern parts of the region.

Previous Geological Work

An early insight into the nature of Devonian stratigraphy in the mountains was provided by McConnell (1886) who used the term "intermediate limestone" for brown and grey, crystalline carbonates exposed along the Front Ranges in the Bow River valley, and by Dowling (1912) who described a shale and limestone sequence of the same age on Roche Miette. These two men provided early descriptions of Upper Devonian rocks in the two locations mentioned, but although the approximate stratigraphic equivalence of these areas was appreciated at the time, details of their mutual relationships were not resolved until some 40 years later.

Discovery of oil at Leduc in 1947 drew attention to the importance of carbonate rocks as potential reservoirs for hydrocarbons, and emphasized the importance of

MS. received November 26, 1965; revised September 5, 1968.

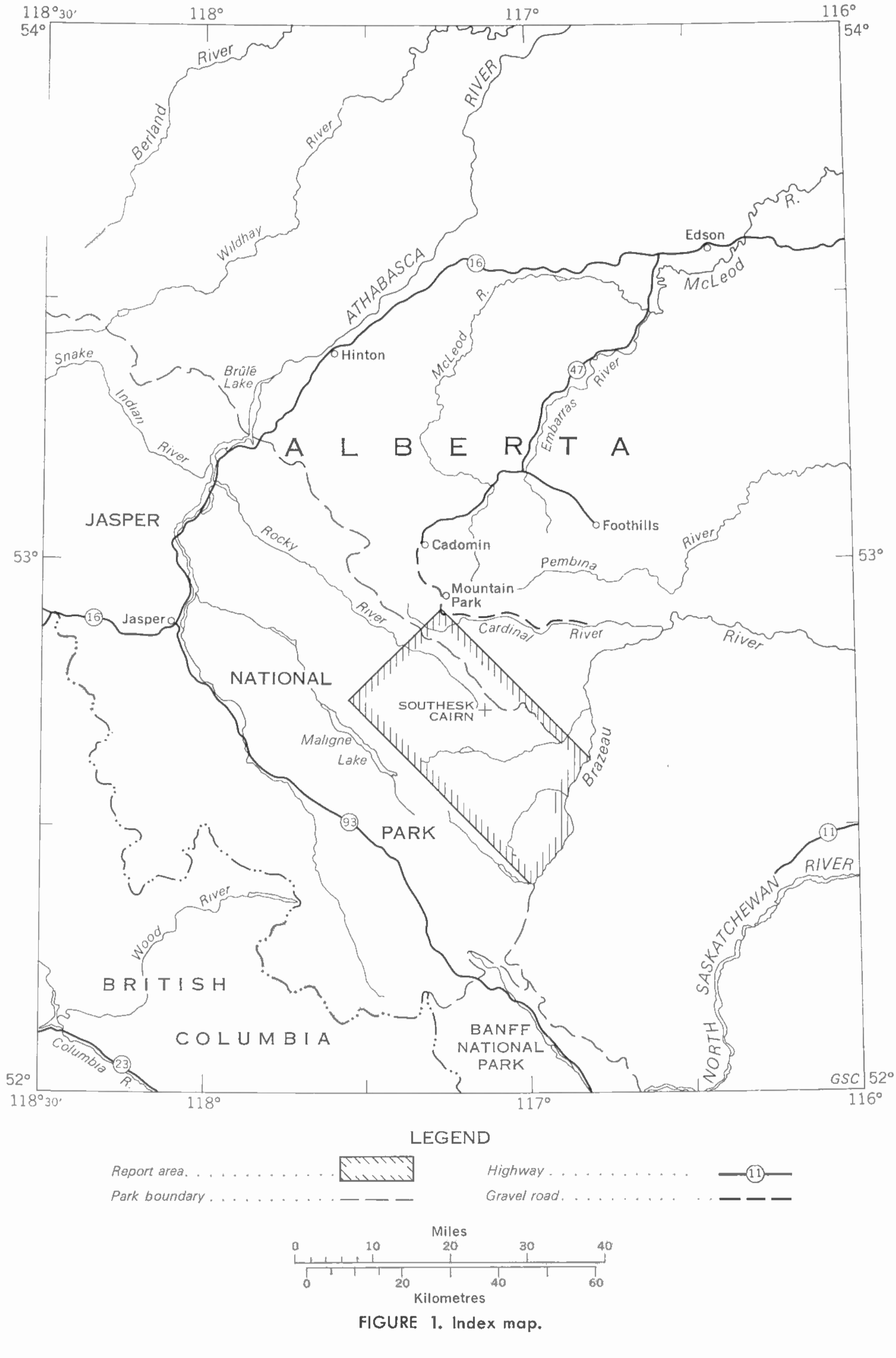


FIGURE 1. Index map.

stratigraphic relationships established in the mountains as a basis for study and reinterpretation of the subsurface carbonate bodies. A comprehensive picture of Devonian stratigraphy in the Mountain and Plains areas has subsequently been presented through significant papers published by Belyea (1957), McLaren (1956, 1959), Hargreaves (1959), and Taylor (1957) dealing with correlations between rock sequences in the two locations. Much of the foregoing work involves regions that are rather far removed from the report area, but it is directly concerned with the interpretation of relationships between the carbonate facies and the stratigraphically equivalent argillaceous or basinal sequence. McLaren and Mountjoy (1962) and Mountjoy (1965) made significant contributions that helped resolve the problem of suggested stratigraphic equivalence of strata of Frasnian and Famennian ages in transitional areas of carbonate deposition.

Field Work and Acknowledgments

This report is based on a thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy at the University of Toronto. The problem was suggested by R. J. W. Douglas and E. W. Mountjoy of the Geological Survey of Canada and carried out for the Geological Survey.

Field work was supervised by E. W. Mountjoy and by F. W. Beales of the University of Toronto, who also directed the laboratory research. M. A. Fritz of the University of Toronto identified the fossil stromatoporoids and bryozoans, and D. J. McLaren and A. W. Norris of the Geological Survey of Canada identified the coral and brachiopod fauna. E. W. Mountjoy introduced the writer to Devonian geology in the eastern Rockies, and along with H. R. Belyea, R. J. W. Douglas, P. Harker, R. R. H. Lemon, and D. J. McLaren, provided helpful discussion and criticism of various phases of the research.

Appreciation is extended to J. G. Buckingham and D. B. Smith for able geological assistance during the 1961 season, and to R. Bugry, J. D. Reid, and D. B. Nelson for their contribution to the 1962 field work. Sincere thanks are due as well to the outfitter J. Kostynuk and his assistants and to the park wardens for their help and cheerful cooperation.

STRATIGRAPHY

The Upper Devonian Fairholme Group of formations, as observed within the report area and as described from adjacent regions (McLaren, 1956), consists of two contrasting macrofacies. One group of formations, composed largely of allochthonous, terrigenous, and clastic sediments, makes up the argillaceous or basinal facies; the other, composed of relatively pure, dominantly autochthonous carbonate sediments, makes up the carbonate complex. Either the Sassenach or the overlying Palliser Formation rests disconformably on the Fairholme Group.

Formational Nomenclature

The twofold formational terminology used in this report to distinguish the lithologically contrasting carbonate from the argillaceous facies dates from Sir James Hector's (1861) first published geological accounts of Devonian strata in the Rocky Mountains, and has evolved through the contributions of several authors. Summaries and discussions dealing with the development of a stratigraphic nomenclature for this particular group of Devonian rocks have been published by Lang (1946), de Wit and McLaren (1950), Fox (1951), McLaren (1953, 1956), Taylor (1957), and Belyea and McLaren (1957). A recent contribution by McLaren and Mountjoy (1962) clarified stratigraphic relationships among the equivalent carbonate and argillaceous formations, particularly in regions of transition from a dominantly carbonate to an argillaceous or basinal facies. These authors introduced new formation and member names that are now included in the current system of terminology (Fig. 3).

The Carbonate Complex

Within and near the study area, Paleozoic strata of the Front Ranges are broken by a series of subparallel thrust faults whose main glide surfaces are largely confined to horizons within the Upper Cambrian. Thick successions of Devonian and Mississippian limestone acted as competent units so that outcrops of the carbonate facies occur along successive segments of relatively undeformed thrust sheets. In areas where the sediments are composed dominantly of shale, on the other hand, tight folding is more common, as, for example, along the west side of Cardinal Pass where thin-bedded limestones of the Mount Hawk Formation have been compressed into chevron folds (Pl. VI–1). Stratigraphic sections, as closely spaced as possible, were measured where Upper Devonian Fairholme Group strata are exposed along five different thrust sheets. Their stratigraphic and petrographic analyses constitute the body of this report.

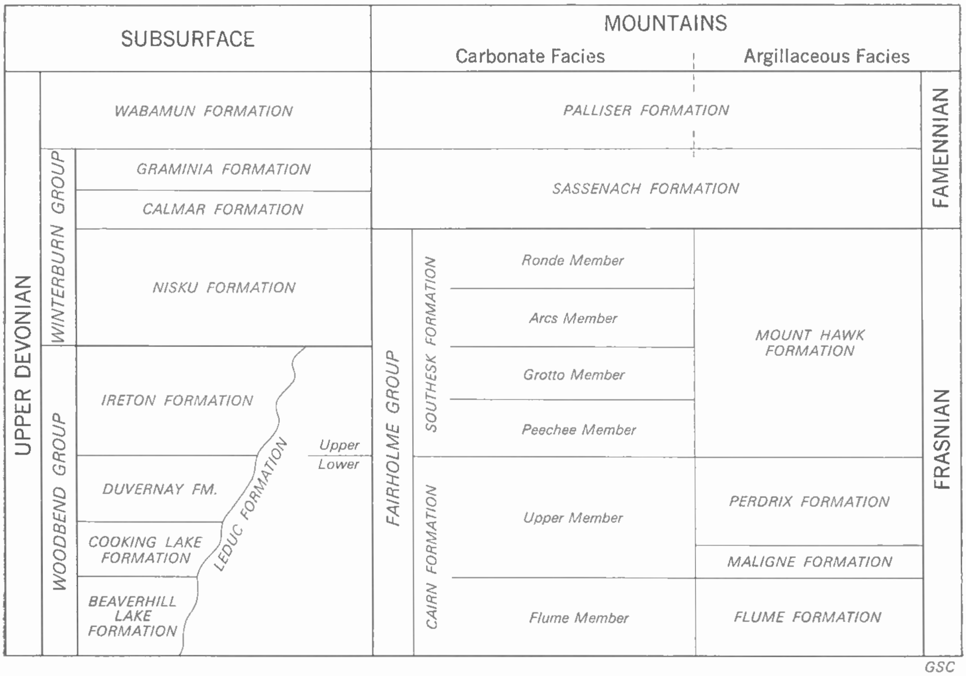


FIGURE 3. Correlation table.

Upper Devonian carbonate units that underlie the Alberta Plains, such as the Bashaw Complex and the Rimby-Meadowbrook reef chain (Fig. 4), have not been affected by thrust faulting and occur as elongate, north- to northeasterly trending masses of considerable areal extent. In contrast, mountain outcrops of similar carbonate bodies have been compressed by crustal shortening and fail to reveal such trends. The Southesk Cairn carbonate complex, for example, occurs in the mountains in offset segments of successive thrust sheets, its original areal distribution having been modified substantially by the thrust faulting. If the effects of deformation by thrust faulting are disregarded, the west margin of the carbonate complex appears to trend in a north to northwesterly direction (Fig. 2). Interpretation based on a palinspastic reconstruction (Fig. 5, *in pocket*)[1], however, shows that the margin of the complex before faulting probably lay essentially parallel to the Upper Devonian Rimby-Meadowbrook and other reef chains of the Plains (Figs. 4, 5).

The general term "carbonate complex" is used here to denote a layered sequence of organic sediments, dominantly biostromal, surrounded by shales and argillaceous limestones. Rocks of the carbonate sequence in the mountains are similar lithologically to those that form reefs in the Alberta subsurface, but despite this similarity the term carbonate complex has been adopted for dominantly carbonate facies of the Fairholme Group within the report area. The name has little descriptive or genetic implication and so allows freedom for interpretation of environments and classification of microfacies within the carbonate body.

[1]Figure 5 is a palinspastic reconstruction by R. A. Price based on purely structural considerations.

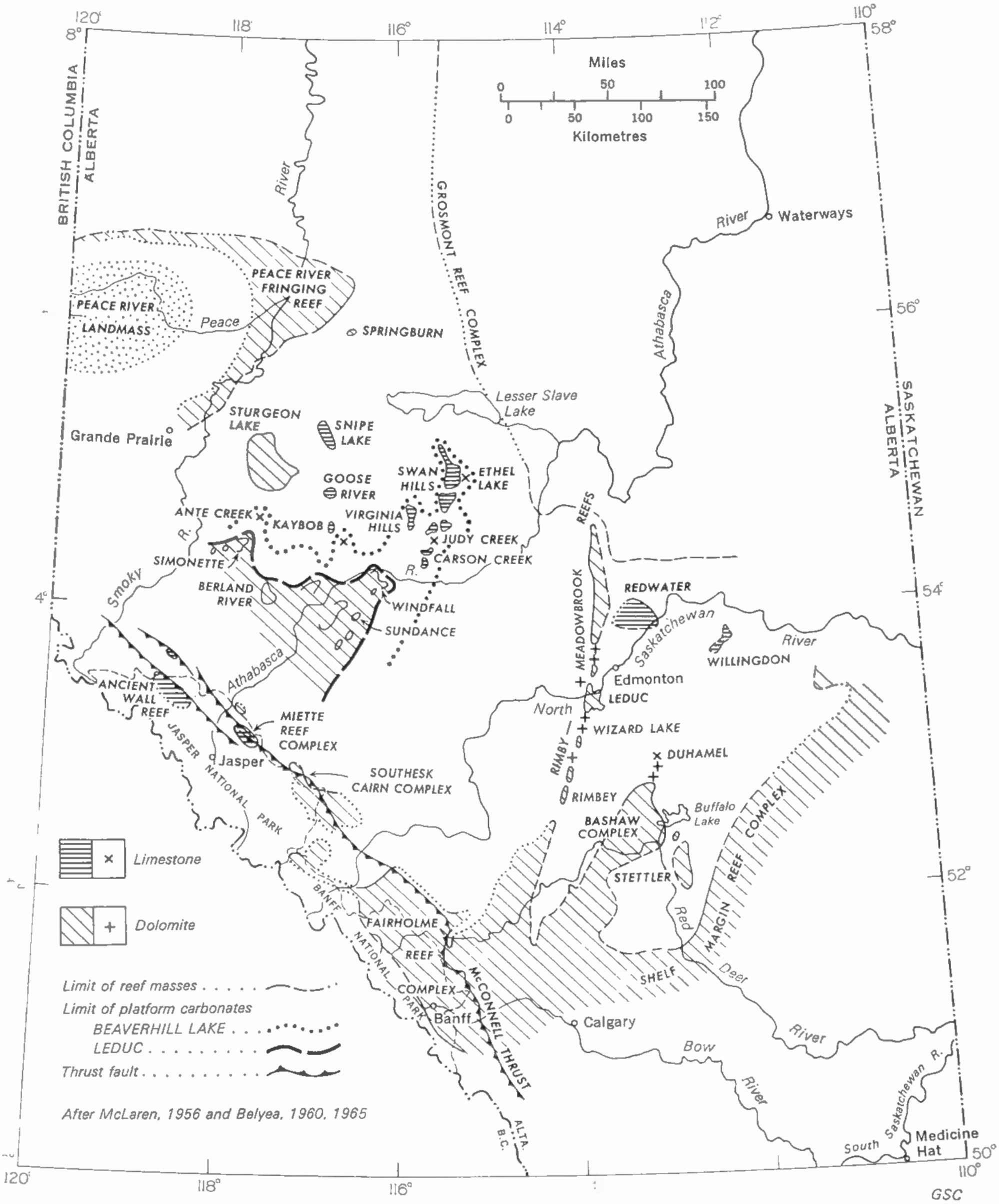


FIGURE 4. Upper Devonian reefs, central Alberta.

Figure 2 shows the interpreted areal distribution of the carbonate complex within the report area. Strata to the west of the carbonate complex comprise the "argillaceous facies" of the Fairholme Group. The Foothills area to the northeast, where Cretaceous beds occur at the surface (McKay, 1929), is probably underlain at depth by an appreciable area of the potentially oil- or gas-bearing Fairholme Group "carbonate facies". Regional thrust faults named after local geographic features are shown, as are the locations of measured stratigraphic sections. Offsets of the margin of the carbonate complex from one thrust sheet to the next (Fig. 2) are a reflection of the amount of differential movement between the thrust sheets.

The earliest sediments of the Fairholme Group formed a widespread platform deposit throughout the region and can be separated into two distinct lithologic units, a lower chert-free carbonate and an upper cherty carbonate unit. Together they constitute the Flume Formation in areas where the overlying formations are dominantly argillaceous, and the Flume Member of the Cairn Formation (Mountjoy, 1965) in regions where the unit is overlain by carbonate strata. The sediments were laid down in Upper Devonian seas transgressing eroded silty carbonates of Upper Cambrian age. Local depressions on the old erosion surface probably contain some basal Devonian sediments, but they have not been differentiated for this report. Variations in thickness of the lower carbonate unit of the Flume Formation and Member may be related to the distribution and amount of relief on the pre-Devonian erosion surface; for example, areas where the unit is thin or absent can be inferred to have stood higher than areas where it is thick. Where the lower carbonate unit is absent locally, the overlying cherty carbonate can be as much as 50 feet thinner than its average 95-foot thickness within the report area. The combined absence, locally, of about 100 feet of the lower carbonate unit plus 50 feet of the overlying cherty unit indicates a maximum relief of about 150 feet on the erosion surface.

Following widespread deposition of the lower and cherty carbonate units (Flume Formation and Member), carbonate sediments continued to accumulate in areas that were favourable to organic growth, while argillaceous deposits were laid down in other parts of the basin. These carbonate sediments, rich in organic material, constitute the Upper Member of the Cairn Formation. They correspond in areal distribution to the Cairn Formation, because in accordance with established nomenclature, the combined lower and cherty carbonates are called the Flume Formation where no Upper Member occurs above them, and called the Flume Member of the Cairn Formation in areas of carbonate build-up. The Cairn Formation varies in thickness throughout the report area, but the changes are largely confined to the periphery of the carbonate complex. In those regions the thickness of the Cairn Formation increases progressively toward areas of continued carbonate accumulation, and at the same time beds higher in the sequence occupy a progressively smaller area. Stratigraphic profiles along the different thrust sheets all show the same progressive thickening of the Cairn Formation toward the carbonate complex. The rate of thickening, however, changes in different areas presumably because of subtle differences locally in relative rates of subsidence, varying patterns of nutrient-bearing currents and their effect on organic life, or to combinations of these and other factors. The Cairn Formation profile is generally steeper along thrust faults to the south. In contrast to the Cairn Formation, carbonate sediments of the overlying Southesk Formation become more widespread higher in the sequence and extend progressively farther beyond the limits of the carbonate complex. Carbonates of the Southesk Formation were probably deposited during a period of relative crustal stability, and loose sediment was washed out for appreciable distances beyond the carbonate bank. Changes in depositional environment, perhaps brought about by minor differential subsidence, varying current patterns, and other factors, are reflected in the areal distribution of the Southesk sediments as they are with the Cairn Formation. In the southern part of the report area the uppermost beds of the Southesk Formation extend for several miles beyond the carbonate complex (Pl. II), but in the north they are more restricted, and near Mount Meda (Fig. 2) they extend only a short distance beyond the region of complete carbonate build-up. A notable aspect of the gross morphology of the carbonate front in profile is its different configuration in different areas (Fig. 6, *in pocket*). Palinspastic reconstruction of the thrust sheets shows that the northwest margin of the carbonate complex trends roughly northeast as do the Upper Devonian reef chains of the Plains (Figs. 4, 5).

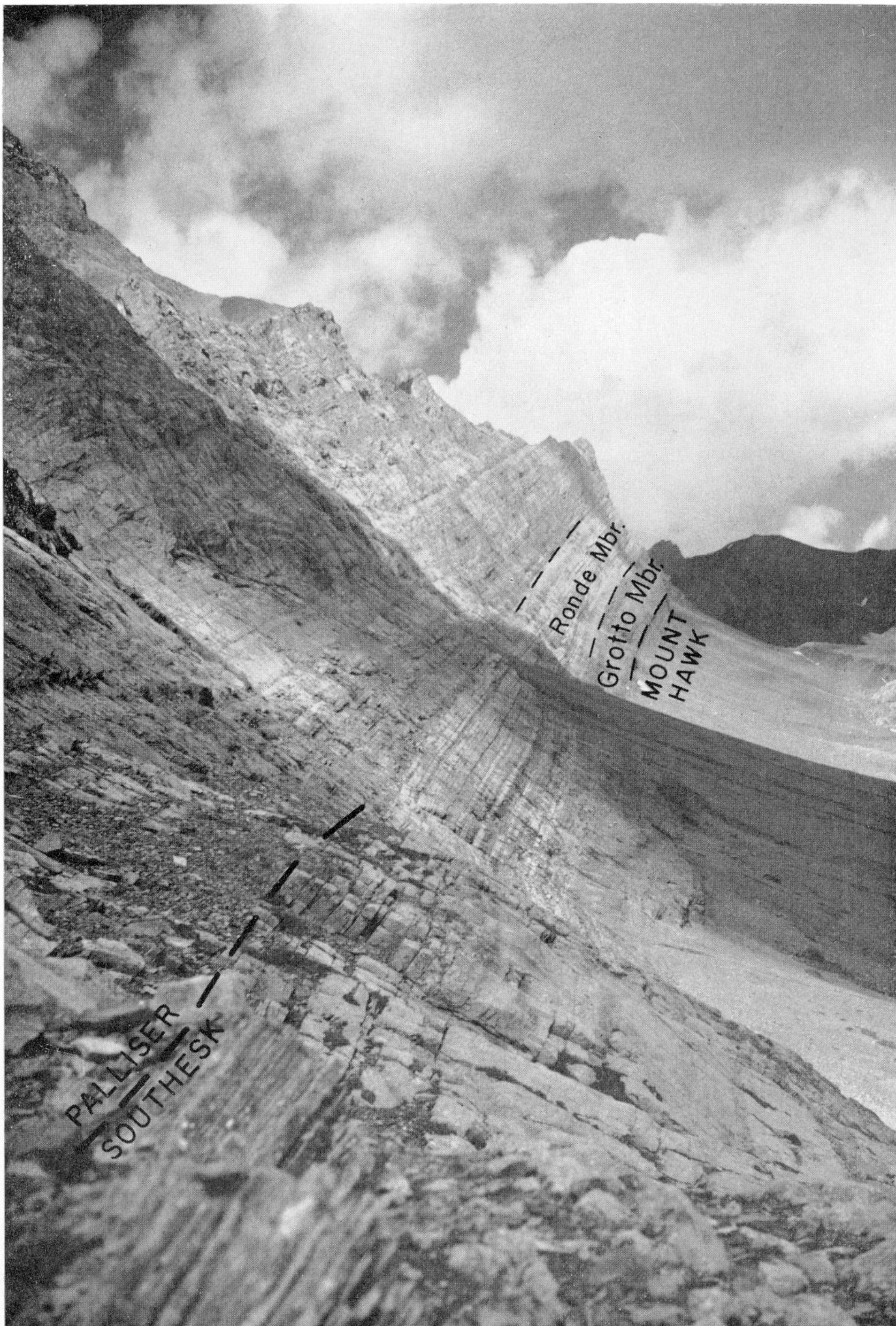
Cairn Formation

The type section of the Cairn Formation is located on the northern spur of Mount Dalhousie (McLaren, 1956). The formation is widespread throughout the Foothills and Front Ranges of the eastern Rocky Mountains where it forms the lowermost unit of the carbonate complex. Its thickness ranges from a few feet along the periphery of the carbonate complex to an average of 600 feet within the carbonate facies. The Cairn Formation consists predominantly of brown, medium crystalline dolomite that McLaren separated (1956) into a basal, cherty dolomite and an overlying organic dolomite unit. These units are now referred to as the Flume Member and the Upper Member, respectively, of the Cairn Formation (Mountjoy, 1965).

Flume Member

The Flume Member, which reaches a maximum thickness of 235 feet within the report area, can be further subdivided into basal chert-free and overlying cherty carbonate units. The differentiation of a basal chert-free carbonate within the Flume Member provides important evidence relating to the nature of the pre-Devonian erosion surface. The overlying cherty carbonate, a widespread and distinctive unit within the Cairn Formation, is characterized by an abundance of black chert that commonly occurs as nodules and pinching and swelling lenses distributed parallel to the bedding. Less frequently the chert is in irregularly shaped masses; when samples were treated with hydrochloric acid in the laboratory they proved to be leached, regularly shaped nodules that had been subsequently filled with carbonate. Carbonate replacement of the chert nodules would probably produce a similar texture.

Spherical stromatoporoids and branching *Amphipora* are the most conspicuous faunal elements within the Flume Member. The stromatoporoids probably grew with their laminae convex upward. Based on this assumption, most of their remains are not preserved in growth position. The *Amphipora* probably also grew as upright forms, but in the rocks their branches commonly lie parallel to the bedding.



120468

PLATE II. In the vicinity of Sawtooth Mountain, a carbonate tongue from the upper part of the Southesk Formation extends beyond the northwest margin of the carbonate complex and overlies strata of the adjacent argillaceous facies.

Upper Member

The Upper Member of the Cairn Formation ranges in thickness from 410 feet to 650 feet where a complete carbonate sequence is present. Lenses and nodules of black chert similar to those in the underlying Flume Member occur occasionally, as, for example, at Saracen Head and Sawtooth Mountain (Fig. 2), but they have little lateral persistence. For this reason, and because of their stratigraphic position, associated strata are not likely to be confused with lithologically similar Flume Member beds.

Extensive dolomitization has obliterated most of the original rock textures, but relics of some of the macro-features that existed in the original rock have been preserved. In addition, there are occasional small isolated areas of undolomitized limestone that provide an indication of the nature of the original sediment. Beds of light coloured, relatively pure and essentially non-fossiliferous dolomite, from a few inches to several feet thick, alternate with similar thicknesses of dark brown, argillaceous dolomite (Pl. VI–2). The upper surfaces of the light coloured beds appear in many instances to have been eroded either under water or subaerially. The traces of such surfaces in outcrop are undulating to irregular, and spherical stromatoporoids of various sizes frequently rest in various attitudes on them (Pl. VI–2).

The contact of the Upper Member with the overlying Southesk Formation is sharp in some areas and gradational in others. Near Saracen Head, thin, dark brown, *Amphipora*-bearing beds lithologically similar to sediments of the Upper Member occur within the lower 150 feet of the Southesk Formation. Thin sections show that the limestones from rare undolomitized areas are composed of fine and medium calcarenite and dark grey argillaceous limestone. Finely comminuted and unidentifiable skeletal remains are common in the argillaceous beds.

With the exception of *Amphipora* and the large globular stromatoporoids, identifiable fossils are not numerous in the Cairn Formation. The following brachiopods were collected at several localities:

Atrypa cf. *A. multicostellata* Kottlowski, from within and immediately above the Flume Member

Eleutherokomma reidfordi Crickmay, from 100 feet above the Flume Member

Allanaria sp., from within the Flume Member

Atrypa sp., from various horizons

Productella sp., from immediately above the Flume Member

Southesk Formation

The type section of the Southesk Formation is located at Mount Dalhousie near the junction of Brazeau and Southesk Rivers (McLaren, 1956). It overlies the Cairn Formation and has a similar areal distribution. Within the report area its thickness is about 700 feet with local increase to a maximum of 820 feet near Brazeau River east of Chocolate Mountain (Fig. 2). The formation consists predominantly of light grey coarsely crystalline dolomite, light brown limestone, and dark brown argillaceous dolomite containing corals.

At the type locality the members of the Southesk Formation correspond lithologically to units established by Belyea and McLaren (1957), and consist of a basal Peechee Member of coarse-grained, light grey dolomite with a few stromatoporoid and coral remains; a middle Grotto Member of brown-grey, medium-grained dolomite with abundant corals; *Amphipora* and other stromatoporoids; and an upper Arcs Member of bedded, granular limestone. According to current usage (McLaren and Mountjoy, 1962), an overlying unit of limestone, silty limestone, and silty dolomite—the Ronde Member—is now included in the Southesk Formation so that at the Mount Dalhousie type locality the revised Southesk Formation consists from the base upwards of the Peechee, Grotto, Arcs, and Ronde Members. Total thickness of the formation in this region is 650 feet.

Peechee Member

The Peechee Member consists largely of light grey, coarsely crystalline dolomite, commonly with good intercrystalline porosity and minor amounts of light brown limestone. In some areas near the base of the member, thin, intercalated beds (as thick as 10 feet) of dark brown dolomite containing *Amphipora* indicate a contact by interfingering with the underlying Cairn Formation. This type of contact can be seen near the headwaters of Toma Creek and at Saracen Head (Fig. 2).

Although the Peechee Member is composed almost entirely of dolomite throughout most of the report area, the sequence at Mount McBeath (Fig. 2) is less dolomitized and consists of about 30 per cent limestone. The limestone occurs as thin, intercalated beds of light brown, medium-grained calcarenite with a cement of clear, coarsely crystalline calcite. Dolomitization has affected some of the limestones and has replaced first the intergranular calcite cement and then the limestone grains. Not many fossils occur in the Peechee Member; a few scattered remains of *Amphipora*, ostracods, calcispheres, and unidentifiable comminuted remains were observed in thin beds of microcrystalline limestone.

The average thickness of the Peechee Member within the report area is 321 feet. A conspicuous deviation from this thickness exists near Sawtooth Mountain (Fig. 2) where only 235 feet of Peechee Member dolomite overlie, with a sharp contact, about 720 feet of the Cairn Formation. At Saracen Head the sequence is slightly thicker than average, probably because of interfingering with the Cairn Formation in the lower 150 feet.

Grotto Member

The Grotto Member consists typically of dark brown, finely crystalline dolomite containing abundant coral and stromatoporoid remains. Where the member is not completely dolomitized, as at Mount McBeath, Mount Isaac, and Arête Mountain (Fig. 2), intercalated beds of dark grey, argillaceous, microcrystalline limestone contain coral colonies, numerous *Amphipora*, small brachiopods (*Atrypa* spp.), calcispheres, and unidentifiable fossil fragments. Elsewhere, because of extensive dolomitization, corals and *Amphipora* are about the only fossil remains that can be recognized. The average thickness of the Grotto Member within the report area is 235 feet. Unlike the underlying Peechee Member, which is found everywhere within the carbonate complex, the Grotto Member appears to attain its maximum development near and beyond the peripheral areas of carbonate sedimentation and is sometimes absent over the interior regions of the carbonate bank. It is present, for example, near the edge of the carbonate facies at Mount Toma in the Mount MacKenzie thrust sheet, but absent from outcrops to the southeast along the same thrust fault to the limit of the study area at Saracen Head. Grotto Member dolomites occur at the northwestern margin of the carbonate complex in the Cardinal Mountain thrust sheet between Cardinal Mountain and Mount Toma, but are absent from an appreciable area to the southeast, reappearing only as a 45-foot-thick bed at Mount Dalhousie about 14 miles away. Mountjoy (1965, p. 20) also noted the absence of Grotto Member dolomites from some areas. The Grotto Member is present in average thickness throughout the Mount Meda, Sawtooth Mountain, and Chocolate Mountain thrust sheets, and in this region extends as a tongue for several miles beyond the carbonate front (Pl. II). Similar, dark, organic dolomites in the subsurface also occur as tongues that extend beyond the upper part of reef complexes in the Drumheller area (Kirker, 1959).

Arcs Member

The Arcs Member has an average thickness of 191 feet within the report area. It attains its maximum thickness in the central part of the carbonate complex and is absent near the margins of the carbonate body (Fig. 6). In contrast, the Arcs Member in the Miette area is present at the edge of the reef and extends beyond it into the adjacent Mount Hawk Formation of the argillaceous facies (Mountjoy, 1965, p. 20).

Light brown, microcrystalline limestone containing few fossils, and fine calcarenite are the dominant rock types of the Arcs Member. The rock texture and fossil content is similar to that found in modern carbonate sediments deposited on carbonate banks in protected lagoonal areas such as in the Bahamas. Such features as presumed worm burrows, finely comminuted skeletal remains, thin laminations, fecal pellets, and scattered algal remains are common evidence for sedimentation in quiet protected areas. Scattered thin beds containing *Amphipora* and a few brachiopods occur, but they are quantitatively unimportant.

Ronde Member

McLaren and Mountjoy (1962) proposed the name Ronde Member for strata that had formerly been referred to the lower member of the Alexo Formation. The type section is at Roche Miette. At this locality the Ronde Member is 113 feet thick and consists of lower, silty carbonates and overlying, bedded, fine-grained carbonates. Within the report area, the unit has an average thickness of 180 feet, and as at the type locality the basal beds consist of recessive, silty carbonates, as thick as 50 feet in some regions, overlain by light brown, relatively pure limestone containing a few corals and stromatoporoids. The corals and stromatoporoids are most abundant in the uppermost beds and near the margins of the carbonate complex. The twofold separation of the Ronde Member into lower, recessive, silty beds and upper, cliff-forming limestones is conspicuous in outcrop and can be traced in the different thrust sheets for several miles along the mountain front.

A study of thin sections shows that fine-, medium-, and coarse-grained calcarenites are common. Also present are microcrystalline limestones, frequently with irregularly shaped "eyes" of sparry calcite and containing calcispheres, traces of algae, and scattered comminuted skeletal remains of corals, bryozoans, brachiopods, and ostracods. Authigenic quartz and feldspar occur in insoluble residues of the limestones. Corroded and pitted quartz grains are a common constituent of the silty beds.

Near the margin of the carbonate complex, in the Mount MacKenzie, Cardinal Mountain, and Mount Meda thrust sheets, the lower contact of the Ronde Member is marked by a change upward from dark brown, argillaceous dolomite of the Grotto Member to light coloured, silty carbonates. In the same thrust sheets, but southeastward away from the marginal areas of carbonate sedimentation, the Ronde Member rests on the Arcs Member, and its lower contact is marked by a change upward from light brown, relatively pure, Arcs Member limestone to the typical, silty carbonates of the Ronde Member. These basal silty carbonates are not so conspicuous in the southernmost Sawtooth Mountain and Chocolate Mountain thrust sheets, but the change from underlying dark brown Grotto Member dolomite to the light coloured strata above is easy to recognize. The Ronde Member is overlain in most areas by recessive, yellow- and orange-weathering silty dolomite, and dolomitic siltstone and sandstone of the Sassenach Formation. The Sassenach Formation is absent from the margins of the carbonate complex in the Mount Meda, Sawtooth Mountain, and Chocolate Mountain thrust sheets, possibly because of post-Frasnian erosion or non-deposition. In these regions the Ronde Member is overlain by dark grey limestone of the Palliser Formation.

Arcs Member Microfacies

With the exception of the Arcs Member of the Southesk Formation, all lithologic units of the carbonate complex have been dolomitized, some almost completely, with consequent obliteration of almost all primary sedimentary textures. Because they have been little affected by dolomitization, the carbonates of the Arcs Member were separated into microfacies, and an attempt has been made to map the areal distribution of these subunits.

Comparison with modern sediments suggests that the various microfacies of the Arcs Member were deposited in protected lagoons, marshy areas, tidal flats, and tidal channels. Sediments deposited in modern lagoons show a great variation in lithology (Van Straaten, 1959, p. 202). Rapid changes in lithology of the Arcs Member limestones, both laterally and vertically, were observed both in the outcrops and also in the laboratory where more than one microfacies could frequently be seen in a single thin section.

The various closely related microfacies compare with Klovan's (1964) back-reef facies of the Redwater oil field that was made up of similar closely related rock types. Relatively wide spacing of measured sections within the report area prevented determination of a preferred areal distribution pattern for the individual microfacies, but their occurrence, confined to the central part of the carbonate body, supports the concept of an extensive lagoonal or back-reef type of deposit. Within this habitat, plant and animal communities probably influenced water movement locally to produce different textures in closely related microfacies. The various rock types are commonly found in close association, and although individually subject to rapid local variation, as a group they constitute a laterally persistent unit that can be traced for long distances.

Micrite. The term micrite is used here to denote a microfacies in which the average crystal size is about 8 microns. Leighton and Pendexter (1962, p. 35) used micrite for particles that were once mud-like and gave them an upper size limit of 30 microns. The micrite microfacies within the report area has probably been recrystallized with consequent coarsening of the primary texture. Micrite, as defined by Folk (1959), had an upper size limit of only 4 microns. Typical specimens of the micrite microfacies contain scattered, irregularly shaped, sharply defined "eyes" of coarsely crystalline calcite (Pl. VI–3), and scattered, more coarsely crystalline areas with diffuse borders. The calcite "eyes" probably represent precipitation of calcite in open voids, whereas the diffuse patches of relatively coarse crystals are likely areas that have been more strongly affected by recrystallization. Fine fractures are common in these finely crystalline rocks. Many seem to have remained open for a time before being cemented, because they are partly filled by fine sediment (Pl. VI–4). Graded bedding is conspicuous in some of the fine sediment and indicates a number of separate influxes of the fine carbonate mud. The mud may have been washed into the open cracks on tidal flats or subaqueously during intermittent storms.

Burrowing organisms appear to have been active in stirring up the fine sediment before it became consolidated. Their presence is indicated by the irregularly shaped and sometimes ovoid "eyes" of coarsely crystalline calcite that are typical of this microfacies. Folk (1959) mentioned burrowing organisms as possible agents in the formation of this distinctive "birds-eye" texture. The enigmatic calcite-filled voids now occupied by coarsely crystalline calcite are all that remain as supposed traces of the burrowing animals. Soft, unconsolidated sediment may have flowed into these voids and thus obliterated from the sedimentary record many similar traces of organic life.

Biomicrite. The biomicrite microfacies is relatively rare in the Arcs Member because of a general scarcity of fossil remains. Rocks so classified contain an estimated 25 per cent or more of skeletal remains. When a dominant fossil element can be identified generically the name is used as a modifier, for example, *Amphipora* biomicrite (Pl. VI–5). *Stachyodes*, bryozoan, and coral biomicrite are other varieties of this microfacies.

All primary pores have been effectively occluded in the micrite microfacies: the presumed worm burrows by an infilling of calcium carbonate cement, and the pores in smaller openings (such as the axial and peripheral canals of *Amphipora*) by flat-topped deposits of internal sediment (Pl. VI–5). Even tiny calcispheres, about 200 microns in diameter, frequently contain some of the fine calcite ooze. Many calcispheres of the spiny variety are covered by a thin micrite coating, and because of their rough exterior seem to have been effective sediment collectors.

Fine quartz silt is a common constituent of this microfacies. The relatively coarse fossil fragments characteristic of these rocks suggests local, strong transporting currents. Numerous fine fractures, probably caused by minor adjustments within the compacting sediment, cut across the skeletal fragments.

Pelleted micrite. The pelleted micrite microfacies is estimated to contain more than 25 per cent of pellets. In thin section the pellets show a common, brownish tinge owing to the presence of organic material. Pellets frequently occur as clusters of uniformly sized round to ovoid grains; individual grains, in some areas, merge into the enclosing microcrystalline material as would be expected of soft fecal material in a loosely consolidated sediment.

Bored and pelleted micrite. This microfacies consists basically of microcrystalline calcite, essentially non-skeletal, with numerous borings filled with coarsely crystalline calcite (Pl. VI–6). The irregularly shaped, frequently vermiform areas of coarsely crystalline calcite, which in places constitute more than 30 per cent of the thin section, have been attributed to the work of burrowing organisms and the presence of algae whose remains have since decayed and left the spaces now filled with calcite cement. The generally disturbed appearance of this microfacies suggests abundant organic life probably concentrated near the water–sediment interface. The large percentage of void-filling calcite cement suggests early lithification of the lime muds, at least to a degree where the primary porosity was not destroyed by collapse of the material under its own weight. An algal framework may have caused some of the sediment binding by acting as a support for the loose material. Kornicker and Boyd (1962) described shallow-water sediments from the Alacran reef that were so tightly bound by roots of *Thalassia* that samples could be collected only with difficulty. Similar ancient sites of deposition may have been intermittently exposed to subaerial drying that would also promote rapid lithification. The benthonic algae have destroyed almost all the primary sedimentary textures in the bored and pelleted microfacies except for local areas that still show vague traces of bedding. Scattered fossil fragments appear to have no preferred orientation in the rock. Whole ostracods with geopetal fabrics in different orientations are the most common skeletal remains.

Laminated calcarenite. Relatively little attention has been drawn to this rather distinctive microfacies which consists essentially of alternating layers, from 1 to 3 mm thick, of dense microcrystalline calcite and fine-grained calcarenite (Pl. VI–7). Ideally, each lamination grades upward from fine calcarenite near a sharp lower contact to microcrystalline calcite in the upper part of the graded unit. Gradual overlap of low-energy environments over high-energy environments on tidal flats is one of nine processes listed by Klein (1965) that may produce graded beds. Probable worm burrows are relatively abundant in these rocks. Many occur within the calcarenite areas, showing a preferred orientation parallel to the bedding; others cut across and disrupt the fine laminae. The individual laminations are frequently discontinuous; the thin calcarenite bands grade laterally into dense microcrystalline calcite which in turn grades downward to fine calcarenite to produce an overlapping or *en echelon* effect. Polished surfaces of hand specimens that are cut normal to the bedding and to one another show that the laminae form undulating discontinuous sheets. Similar deposits are being formed today in shallow water where the sediment fabric is strongly influenced by the presence of a mat of filamentous algae, such as in the Florida Keys area (Pl. VI–8). The laminated nature of this microfacies of the Arcs Member along with scattered occurrences of algae suggests an analogy to the present day algal-stabilized sediments. Such laminated textures in limestones are thought to be a good indication that the sediments accumulated in shallow water, probably above low tide level.

Calcarenite. The calcarenite microfacies consists essentially of rounded grains of microcrystalline calcite embedded in a coarsely crystalline calcite cement (Pl. VII–1). Locally, closely packed grains show microstylolitic contacts, but this phenomenon is rare. Skeletal fragments, detrital quartz silt grains, and coated limestone grains also occur infrequently. The common, rounded nature of most of the constituent limestone grains, including those with tabular and irregular shapes, suggests that the calcarenite microfacies was formed largely by erosion and reworking of a relatively soft, incompletely lithified sediment. Fine fractures filled with graded sediment and calcite cement are found in places (Pl. VII–2) and suggest desiccation of the soft sediment on temporarily exposed mud flats before final consolidation. Skeletal remains are not usually numerous, but occasional fragments of branching *Amphipora* and bryozoans encased in a matrix of lime mud suggest that there were nearby quiet-water environments of calcium carbonate deposition, and currents sufficiently strong to redistribute the mud-coated fragments. Some of the calcarenites have a matrix composed largely of fine lime mud. According to Folk (1962), this type of unwinnowed granular rock may have formed when currents, temporarily stronger than usual, swept calcite grains into a normally calm environment of calcite ooze deposition.

Calcirudite. The most common type of calcirudite observed consists of rounded, tabular and elongate, composite limestone fragments made up essentially of aggregates of discrete grains of finely crystalline calcite (Pl. VII–3). The individual composite grains have a texture similar to that of the calcarenitic matrix in which they occur. They are not rounded and appear to be only loosely consolidated. This type of coarse-grained sediment might be produced by currents not strong enough to dislodge similar large fragments from a non-granular micritic sediment. Other calcirudites comprise rounded fragments of silty micrite enclosed in a matrix of fine calcarenite. In contrast to the composite fragments shown on Plate VII–3, this distinctive, but less common type of rudite fragment, the texture of which is unlike that of the enclosing matrix, appears to have been transported for some distance into its present environment. Still other calcirudites, with a characteristic lumpy shape, occur locally and have probably been derived from an older, recrystallized parent rock. Differential erosion during transport and reworking, between the resistant microcrystalline calcite grains and the apparently softer, interstitial, recrystallized calcite cement, is thought to be the reason for their irregular shape.

The calcirudite microfacies consists dominantly of rocks that probably formed by the breaking up of relatively soft, loosely consolidated sediments. With rare exceptions the individual clasts do not seem to have been moved far before they came to rest and were recemented. Intermittent storms may have been effective agents in breaking up the original soft sediment by stirring up the water from time to time, and by sweeping tabular desiccation flakes and granular fragments into locally sheltered areas where they eventually became consolidated. The calcirudites are not a common rock type, and this along with their restricted occurrence suggests a local origin for their constituent grains.

Marginal Facies of the Carbonate Complex

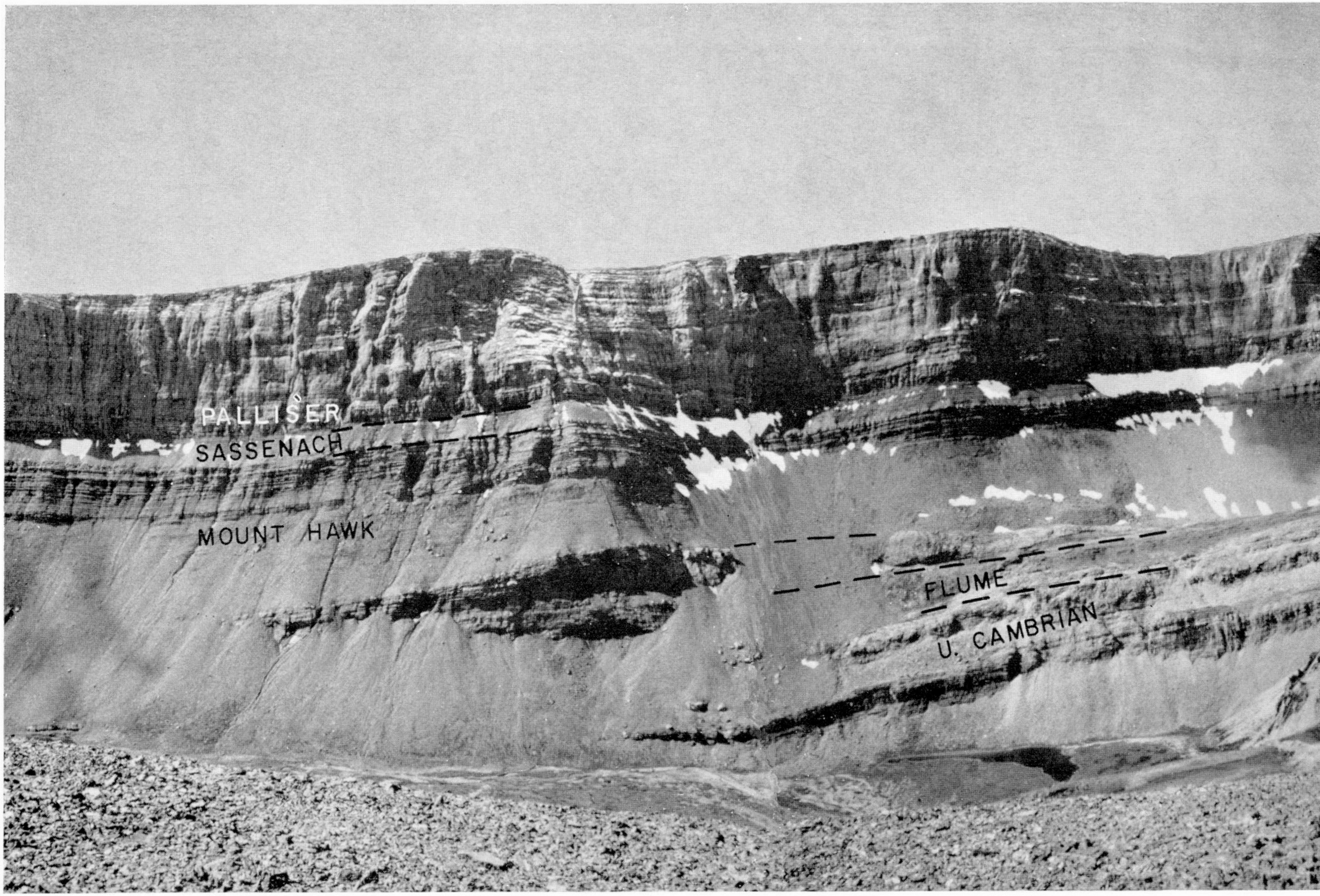
The marginal facies of the carbonate complex comprises sediments that were deposited in the zone of transition between the "carbonate" and adjacent "argillaceous" facies. In this transition zone the percentage of carbonate is higher in sediments close to the carbonate complex than it is farther to the northwest. Dolomite mounds developed within the transition zone in an environment only marginally suitable to lime-secreting organisms; the initial carbonate banks were built from the remains of these organisms. Higher in the section, isolated limestone lenses associated with the latter stages of carbonate accumulation also form part of the carbonate–argillaceous facies transition.

Phenomena associated with the carbonate–argillaceous facies transition are best illustrated by outcrops near Mount MacKenzie and Cardinal Mountain. The same transition, though less well exposed, can be seen along succeeding thrust sheets to the south. In all areas marginal to the carbonate complex, subtle differences in the factors influencing sedimentation are reflected in slightly different relationships between the carbonate and adjacent argillaceous facies.

Where sediments of the Cairn Formation are involved the carbonate–argillaceous facies transition takes place, with little evidence of interfingering, along a simple contact that rises stratigraphically toward the carbonate body. In contrast, the change from Southesk Formation carbonates to adjacent argillaceous formations is accompanied by intertonguing, and the gradational contact rises across stratigraphic layering away from the carbonate complex.

In the vicinity of Mount MacKenzie the zone of transition extends for about 12 miles to the northwest beyond the carbonate complex. In this region small dolomite mounds developed on the Flume Formation in an environment probably less suitable to organic life and carbonate disposition than that existing where the nearby large carbonate banks of the Cairn Formation formed. One such dolomite mound can be seen along the Mount MacKenzie thrust sheet near the headwaters of Cardinal River about 8 miles beyond the margin of the carbonate complex (Fig. 2; Pl. III). Here the Flume Formation is overlain by a sequence of indistinctly bedded, light grey carbonates that have formed a lenticular mound-like accumulation with low relief, and whose estimated minimum dimensions are 300 feet vertically and ½ mile horizontally. Plate III shows the mound and illustrates its gross morphology.

Another similar mound is exposed in the Cardinal Mountain thrust sheet on the east side of Deception Creek about 6 miles northwest of the carbonate complex margin (Fig. 2; Pl. IV). The apparent dimensions of this mound, which has a steeper profile and is appreciably smaller than the one previously described, are 200 feet thick by about 800 feet long. Small carbonate tongues near the base of the mound extend for only a short distance into the adjacent shale facies. The contact of beds



200378-379

PLATE III. A dolomite mound developed on the Flume Formation near the headwaters of Cardinal River about 8 miles beyond the northwest margin of the carbonate complex. Approximate dimensions of the mound are 300 feet vertically by $\frac{1}{2}$ mile horizontally.

120479

PLATE IV. A dolomite mound developed on the east side of Deception Creek where the Cairn Formation is relatively thin. Adjacent argillaceous beds in the right foreground onlap the mound whose approximate dimensions are 200 feet thick by 800 feet long.

in the upper part of the mound with the surrounding shales is conspicuously sharp (Pl. IV). The surrounding shales clearly lap on the light grey weathering dolomites and so must have been deposited later. In addition, there is practically no carbonate detritus in the surrounding shales, which indicates that there was little erosion of the mound while the surrounding argillaceous sediments were accumulating, presumably in quiet water. Small brecciated zones about 5 feet in maximum dimension occur near the top of the mound. They consist of a mixture of dark grey shale and angular dolomite fragments from 4 to 6 inches long. Irregularly shaped, shale-filled openings and cavities are found in the underlying carbonate material. The breccia together with the underlying leached carbonate of the mound suggests possible temporary subaerial exposure with consequent leaching, brecciation, and infiltration prior to shale deposition.

Extensive dolomitization has obliterated almost all primary features from the mound sediments leaving a coarsely crystalline, and in places, a sucrosic and porous dolomite texture (Pl. VII–4). Scattered ghosts of fossil *Amphipora* and stromatoporoids and spherical cavities occur locally, and suggest that the skeletons of these and other organisms made up most of these mound-like accumulations.

No comparable mound-like features were observed in the succeeding thrust sheets to the south near Mount Meda, Sawtooth Mountain, and Chocolate Mountain. Throughout this southern region the Cairn Formation carbonates, like those of the mounds, are not noticeably more argillaceous near their contact with adjacent strata of the argillaceous province. The Cairn Formation of the carbonate complex, like the nearby mounds and the Belgian Devonian reefs described by Lecompte (1956), decreases in circumference progressively upward. Its constituent sediments are considered to have been deposited in a similar but more widespread environment to that in which the mounds grew. Also, like the mounds, the sediments have a simple contact with adjacent argillaceous strata. The contact rises toward the carbonate complex.

In contrast to the Cairn Formation, successively younger beds of the Southesk Formation become progressively more widespread, and their transition to the laterally equivalent, argillaceous facies of the Mount Hawk Formation is accompanied by intertonguing. A part of the transition involving mainly the lowermost Peechee Member of the Southesk Formation can be seen about 2½ miles southeast of Mount Meda. The relatively pure and resistant Peechee Member dolomites form conspicuous outcrops along the hillside in this area. Northwestward, toward the dominantly argillaceous sites of deposition, scattered argillaceous zones occur within the dolomite. These become thicker and more numerous away from the carbonate body, thus separating the Peechee Member into tongues that become progressively more argillaceous, less resistant, and thinner, until finally they lose their identity in the adjacent argillaceous limestones of the Mount Hawk Formation. A change from dolomite to limestone accompanies this gradual transition. The dense, argillaceous, and compact Mount Hawk Formation limestones were probably less susceptible to dolomitization than the more porous carbonates. In some areas this change from dolomite to limestone was used as a criterion for distinguishing the calcareous, reef margin facies of the Mount Hawk Formation from the contiguous carbonate facies of the Southesk Formation. The carbonate tongues that interfinger with the argillaceous beds to the northwest were probably formed from detritus and lime muds rich in organic remains that were swept outward from the main part of the carbonate body to mix with the nearby argillaceous, basin margin deposits. More distant areas that were less strongly contaminated by the lime muds, but which still became calcareous, are included in a reef margin facies of the Mount Hawk Formation. Carbonate sedimentation took place in a shallow, well-aerated environment. A scarcity of recognizable fossils in the Peechee Member beds, along with their common light colour, suggests turbulent water and a shallow, oxidizing environment in which the skeletal remains were broken up and worn away by the currents.

The Grotto Member, composed typically of dark brown, argillaceous dolomite rich in coral and stromatoporoid remains, overlies the Peechee Member, commonly with a sharp contact. Although not observed directly in outcrop, transition of the Grotto to an argillaceous facies away from the areas of carbonate sedimentation is probably similar to that of the underlying Peechee dolomite. Along the periphery of the carbonate complex, the Grotto Member increases in areal extent upward and encroaches progressively on the dominantly argillaceous formations to the northwest. In the vicinity of Mount MacKenzie, closely spaced traverses and measured sections show that the Peechee Member grades northwestward into a reef margin facies of the Mount Hawk Formation, and that still farther to the northwest the reef margin facies is overlain by successively higher beds that represent the Grotto sequence. In the southern part of the report area, near Sawtooth and Chocolate Mountains, the Grotto Member dolomites extend for several miles beyond the main area of carbonate sedimentation (Fig. 2; Pl. II). Although these dolomites are ubiquitous in the marginal areas of carbonate sedimentation, they are thin or absent over some parts of the carbonate complex, particularly toward the interior of the carbonate body southeast of Mount MacKenzie and Cardinal Mountain (Fig. 2).

The transition from the overlying, light coloured, relatively pure, Ronde Member carbonates to an equivalent argillaceous facies can be examined near Mount MacKenzie and Cardinal Mountain, and to the northwest. In the region of transition the resistant Ronde Member limestones of the upper part of the Southesk Formation become progressively more argillaceous away from the carbonate complex. As a result they are less resistant to weathering and no longer form conspicuous cliffs along the hillside. This is particularly well illustrated at Mount MacKenzie where strata laterally equivalent to cliff-forming carbonates no longer form prominent ledges on adjacent mountain spurs but weather to form a smooth profile (Pl. V). Still farther to the northwest away from the carbonate complex the cliff-forming tongues deteriorate into isolated limestone lenses, one of which can be seen on the west side of Cardinal Pass about 2 miles from the west margin of the complex (Pl. I). This lens (Pl. VII–5), inaccessible on a nearly vertical cliff face, is estimated to be about 75 feet thick. Two, thin, closely spaced, light-weathering bands of limestone immediately above the lens mark the top of the Fairholme Group in this area. Carbonate tongues, probably composed of material derived from the lens, dip down from and become progressively thinner away from its sides. Twenty to thirty feet of topographic relief is estimated locally while the tongues were forming. Argillaceous beds

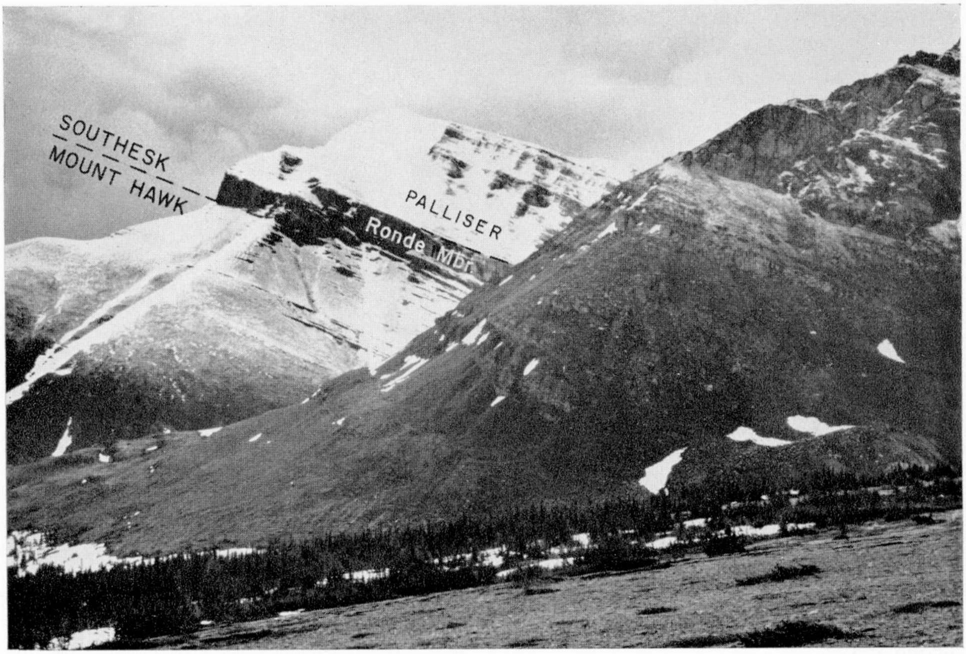


PLATE V. Carbonate strata in the upper part of the Southesk Formation form resistant, nearly vertical cliffs on Mount MacKenzie. Laterally equivalent beds on the ridge in the foreground are more argillaceous and less resistant to weathering.

overlying the lens are conspicuously thinner than on its flanks. Another limestone lens of comparable size occurs on the east side of the Pass opposite Cardinal Mountain in the next thrust sheet to the south (Fig. 2). It too is well exposed, though inaccessible, on a nearly vertical cliff face (Pl. VII–6). The thinning limestone tongues associated with this lens also can be traced for appreciable distances into the surrounding argillaceous sediments. Some of the thin limestone tongues pinch and swell to form a bead-like series of small isolated lenses that decrease progressively in size away from the parent body. Limestone debris as thick as 8 feet in maximum dimension occurs within the surrounding argillaceous beds. This debris has clearly been broken from the lens and transported along the adjacent sediment surface. Many of the blocks are angular and have sharp corners that cut across the fine sediment laminae. Apart from this minor, local, marginal fragmentation near the lenses, there is no evidence of any over all disruption and deformation of the surrounding stratification that would be expected had entire lenses been transported from the carbonate complex. Similar though smaller and less sharply defined lenses outcrop in accessible areas along the west side of Cardinal Pass in the same thrust sheet. These accessible lenses, though often partly masked by talus cover, provide data on the composition of the lens carbonates. They consist of fine- to medium-grained calcarenite, commonly with abundant remains of small brachiopods, ostracods, and foraminifera (*Nanicella* sp., *Multiseptida* sp. cf. *M. corallina* Bykova, 1952). The inaccessible lenses probably have a similar composition. Traces of algae, mostly *Girvanella* tubules, can be seen in most thin sections of the lens carbonates. Some of the smaller lenses consist entirely of coral colonies (*Phillipsastrea* sp.). The small colonies, probably in growth position, apparently began to form on a substratum of soft argillaceous lime mud. They probably represent embryonic reef growth that began but was unable to maintain itself in the marginally favourable environment of the transition zone. Thin sheet-like coral colonies also occur parallel to the bedding and support the concept of an autochthonous origin for many of the small lenses. The larger lenses are believed to represent similar in situ accumulations, with bedding within the lenses parallel to the regional stratification and composed largely of fine calcarenite derived from broken, calcareous skeletons that were swept into heaps and bars by currents. Because they are relatively abundant in all the lenses studied, ancient algae, like some modern forms, probably played an important role in binding and stabilizing the loose sediment grains.

The three-dimensional shape of the limestone lenses is not known. Outcrops in other thrust sheets to the south, together with those within the report area, indicate that the margin of the carbonate complex in this region trends approximately northeast, roughly parallel to the Upper Devonian, Rimby-Meadowbrook reef chain of the Alberta Plains. These limestone lenses may represent sections cut normal to the long direction of bars that formed parallel to the carbonate front. Such bar-like accumulations may have originated and reached their present dimensions by the action of concentration of skeletal fragments and by the trapping influence of sediment-binding algae.

No limestone tongues or lenses were observed in the transition zone farther to the south near Mount Meda where the facies change is rather abrupt. Oncolite beds (Pl. VII–7) occur in argillaceous limestone in the upper part of the Mount Hawk Formation, however, and reflect the presence of the carbonate complex a few hundred feet away. By way of contrast, still farther south in the vicinity of Sawtooth and Chocolate Mountain, tongues of the upper part of the Southesk Formation extend for several miles beyond the west margin of the carbonate complex (Pl. II). Unfortunately because of hazardous terrain they could not be traced to their limit.

Argillaceous Facies

Argillaceous limestones and shales, laterally equivalent to the carbonate complex, comprise the "argillaceous facies" of the Fairholme Group within the report area. The sequence from bottom to top consists of the Flume, Maligne, Perdrix, and Mount Hawk Formations. The Flume Formation, although very similar lithologically to the stratigraphically equivalent Flume Member of the carbonate complex, is nevertheless listed with the formations of the argillaceous facies.

Flume Formation

The type section for the Flume Formation is on Roche Miette (Raymond, 1930). It was divided into upper and lower members by de Wit and McLaren (1950), but has subsequently been restricted by Taylor (1957). It now comprises only the lower cherty dolomite member of the original Flume Formation, and this has been further subdivided by Mountjoy (1965) into lower chert-free and upper cherty units, both within the report area. The formation is a widespread platform deposit that occurs throughout the eastern Foothills and Front Ranges of the Rocky Mountains in most of the main thrust sheets. Its thickness at Medicine Lake and Job Creek East is 150 and 169 feet, respectively (McLaren, 1956). Within the study area the thickness ranges from 55 to 130 feet with the thickest sections occurring near the periphery of the carbonate complex.

Dark brown, medium crystalline dolomite with some unaltered areas of dark grey, argillaceous limestone constitutes the dominant rock type of the Flume Formation. The lower chert-free and overlying cherty dolomite units correlate with identical units in the Flume Member of the carbonate complex. Large globular stromatoporoids and branching *Amphipora* are the main organic rock-formers within the cherty unit. The underlying chert-free dolomite unit contains less organic material, although a few *Amphipora* and brachiopod and gastropod remains may occur locally.

Thin sections of rock from the relatively rare areas of limestone frequently reveal the presence of appreciable quantities of silt and argillaceous material in the matrix of many of the calcarenitic rocks. This is thought to have contributed to the characteristic brown colour of the dolomitized sediment. Most of the dolomite is composed of medium-sized, anhedral, interlocking crystals that show little effective porosity except where leaching has created vugs and where fossil remains have been dissolved away to leave open cavities in the rock. A little intercrystalline porosity is found where the texture is sucrosic.

The Flume is the oldest Upper Devonian formation in the eastern foothills of Alberta; it rests on a gently undulating surface of eroded Upper Cambrian strata. Basal Devonian beds probably occur locally but no attempt was made to differentiate them for this study. Variations in thickness of the lower dolomite unit of the Flume Formation and its absence locally can perhaps be attributed to relief on the erosion surface during the initial Devonian transgression. Contact with the underlying Cambrian beds is normally abrupt, although in some areas the silty nature of the basal part of the Flume Formation suggests some reworking of the underlying sediments. In the field, the formation can be recognized easily by a sharp colour change from light yellow-grey weathering Upper Cambrian strata to dark brown weathering Flume Formation dolomites and by the common occurrence of fossil remains in the overlying Devonian beds.

With the exception of the rock-forming *Amphipora* and other stromatoporoids, identifiable fossils are not numerous within the Flume Formation. *Eleutherokomma* sp. and *Atrypa multicostellata* Kottlowski were collected.

Maligne Formation

The name Maligne was first proposed by Taylor (1957) for a thin, fossiliferous limestone unit that he excluded from the underlying Flume Formation, and which is transitional between the Flume carbonates and overlying Perdrix Shales. The type section is at Cold Sulphur Spring about 13 miles north of the town of Jasper along highway 16.

The areal distribution of the Maligne Formation is the same as that of the underlying Flume. The formation is 52 feet thick at the type locality (Fox, 1951; Taylor, 1957, p. 190); it is about 50 feet thick near the Miette reef complex (Mountjoy, 1965, p. 26). Within the report area the sequence ranges from 37 feet to a maximum of 80 feet near the west margin of the Cairn Formation northwest of Mount Meda. At Cold Sulphur Spring the formation consists of dark grey to black, argillaceous, thin-bedded and rubbly limestone, fossiliferous in the upper few feet. Toward the margin of the carbonate complex the Maligne limestones tend to become less argillaceous and are dolomitized in places. There the presence of numerous fossil brachiopods that are conspicuous on weathered surfaces and the absence of black chert lenses in the Maligne Formation serve to distinguish it from the underlying Flume Formation. Thin sections of typical specimens of Maligne limestone show that they are fine to microcrystalline, considerably argillaceous, and contain abundant brachiopod and other comminuted skeletal remains.

The lower contact of the Maligne Formation with the underlying Flume is commonly sharp and involves a conspicuous change from the dark brown, cherty and siliceous Flume Formation dolomites to overlying dark grey, fossiliferous limestones. Unlike the underlying dolomite units the formation cannot be separated within the adjacent carbonate complex. It becomes progressively more calcareous, changes to dolomite, and can no longer be identified.

Fossils are abundant, particularly in the younger beds. *Calvinaria variabilis athabascensis* (Kindle) and *Eleutherokomma reidfordi* (Crickmay) were collected.

Perdrix Formation

The type section of the Perdrix Formation is on Roche Miette about 24 miles north of the town of Jasper along highway 16. The formation was named by Raymond (1930), and originally consisted of about 600 feet of dark grey, calcareous shale and argillaceous limestone. The name was later restricted by McLaren (1956) to the lower 380 feet of Raymond's formation that comprises lower, black, non-calcareous shales and upper, black, calcareous shales. The thinner succession agrees closely with a 385-foot sequence of the Perdrix Formation measured by Mountjoy (1965) in the same area.

Within the report area both the lithology and thickness of the Perdrix Formation are comparable to that of the type section. The formation consists of a series of recessive, black- to brown-weathering shales that are commonly calcareous, particularly in the upper strata where there are thin beds of dark grey argillaceous limestone. The maximum measured thickness was 387 feet. The Perdrix Formation becomes progressively thinner towards the carbonate complex and is finally replaced by stratigraphically equivalent Cairn Formation dolomites. It is in sharp contact with the underlying Cairn Formation near the margin of the carbonate complex and with the overlying Maligne away from areas of carbonate build-up. There is little evidence of intertonguing or of a gradual transition even where the Perdrix shales give way laterally to dolomites of the Cairn Formation. Although the Perdrix Formation is generally sparsely fossiliferous, specimens of *Thomasaria rockymontana* (Warren), *Calvinaria albertensis* (Warren)?, and *Styliolina* were collected from 100 feet below the top of the sequence in the area southeast of Southesk Lake (Fig. 2). *Leiorhynchus carya* (Crickmay), *Warrenella nevadensis* (Walcott), *Calvinaria variabilis insculpta* (McLaren), and *Calvinaria variabilis athabascensis* (Kindle) are found 98 feet below the top of the formation near Mount Meda (Fig. 2). *Tentaculites* was collected from the talus in the lower part of the formation at several localities near the margin of the carbonate complex.

Mount Hawk Formation

The Mount Hawk Formation with type section on Roche Miette was named by de Wit and McLaren (1950). It originally included 475 feet of beds, but was later redefined by McLaren to include some of the underlying Perdrix Formation making a total thickness of 549 feet. At its type locality the Mount Hawk Formation is actually transitional between a (full) carbonate sequence and adjacent argillaceous beds and contains an upper grey limestone unit that is stratigraphically equivalent to the Grotto and Arcs Members of the Southesk Formation. A typical argillaceous sequence occurs at The Palisade just west of highway 16 about 8 miles north of Jasper where it consists of 259 feet of black argillaceous limestone with interbedded calcareous shale.

Within the report area the formation consists of lower, dark grey, argillaceous limestones and upper, less argillaceous limestones in beds from 6 to 8 inches thick commonly separated by thin shale partings. Some of these upper beds outcrop on the valley floor along the west side of Rocky Pass where they have been compressed into chevron folds (Pl. VI–1). Near the carbonate complex, the lower zone of argillaceous mudstones and limestones becomes more calcareous and frequently contains intercalated thin limestone beds. In these peripheral areas, isolated, lenticular bodies of relatively pure limestone as much as 300 feet long by 100 feet thick occur in the upper part of the formation. Although inaccessible, they can be seen on north-facing cliffs overlooking Cardinal River just west of Cardinal Pass (Pl. I), and behind Mount MacKenzie on the east side of Cardinal Pass opposite Cardinal Mountain (Pl. VII–6). On the valley floor west of Mount MacKenzie, and on the west side of Rocky Pass opposite Cardinal Mountain, similar small lenticular bodies consist of light and medium grey, microcrystalline limestone with a few comminuted skeletal remains. The lime mud may have been stabilized by algae, traces of which are found in thin sections of the rock. Silty zones occur in the upper part of the Mount Hawk Formation, and in the neighbourhood of Mount MacKenzie and Cardinal Mountain they can be traced into the adjacent carbonate complex where they serve to confirm the stratigraphic equivalence of these lithologically distinct but laterally contiguous formations.

The Mount Hawk Formation is abundantly fossiliferous throughout, particularly in transitional areas near the margins of the carbonate complex. Among the corals that are more characteristic of its upper 150 feet are "*Phillipsastrea exigua* (Lambe)", *Thamnophyllum colemanense* (Warren), *Thamnophyllum* cf. *T. tructense* (McLaren), and *Coenites* sp. In addition to the corals, the following brachiopods occur in the interval from 150 feet to 300 feet above the base of the formation.

Warrenella nevadensis (Walcott)
Thomasaria rockymontana (Warren)
Hypothyridina sp.
Gypidula sp.
Devonoproductus sp.
Schizophoria sp.
Theodossia keeni (Crickmay)
Calvinaria albertensis (Warren)?
Leiorhynchus carya (Crickmay)

Overlying Formations

The boundary determined in the Upper Devonian succession between strata of Frasnian age and overlying beds of Famennian age represents an important interruption in sedimentation that has been reported from widely separated areas of North America. It occurs in the Alberta subsurface (Belyea, 1955), in northwestern Montana (Hurley, 1963), in northeastern British Columbia and northern Alberta (Belyea and McLaren, 1962), and in the Foothills and Rocky Mountains near Jasper, Alberta (McLaren and Mountjoy, 1962; Mountjoy, 1962, 1965).

Strata of Famennian age rest disconformably on both the Frasnian "carbonate" and "argillaceous" successions of the Fairholme Group throughout the report area. They comprise two formations: a lower Sassenach Formation of silty mudstone and silty and sandy dolomite, and an overlying Palliser Formation of grey limestone. The Sassenach Formation attains its maximum thickness away from the carbonate complex and is thin or absent locally over areas occupied by the carbonate facies. Where the Sassenach Formation is absent the Palliser Formation is in contact with the carbonate complex.

Sassenach Formation

The type section of the Sassenach Formation is on a ridge southeast of Thornton Creek about 2½ miles southeast of Mount Haultain in the region northwest of Jasper (McLaren and Mountjoy, 1962). The formation is widespread throughout the argillaceous province and overlies most of the carbonate complex as well. It corresponds closely to the Alexo Formation of McLaren (1956) at Rocky Forks and Deception Creek. The reader is referred to McLaren and Mountjoy (1962) for a discussion of Alexo–Sassenach Formation relationships.

The Sassenach Formation, 601 feet thick at the type locality, consists of a lower silty mudstone member and an upper sandy member (McLaren and Mountjoy, 1962). Both units are continuous throughout the argillaceous province, but thin eastward by onlap against the carbonate complex so that only non-fossiliferous strata of the upper silty unit overlie the carbonate facies; even these may be absent locally. Near Mount Meda, for example (Fig. 2), the Sassenach Formation members (Pl. VII–8) rapidly become thin by onlap, and about a mile to the southeast are absent locally along the periphery of the carbonate complex. In this area dark grey Palliser Formation limestone is in contact with underlying light brown Southesk Formation carbonates. Close to such areas the uppermost beds of the carbonate complex are leached and brecciated. These zones can be seen at several places along the mountain side (Pl. VIII–1); they consist of large angular fragments of dolomitic siltstone, as much as 4 feet in maximum dimension, embedded in the underlying, vaguely stratified, leached dolomites of the Southesk Formation. Similar brecciated zones occur immediately below the Sassenach Formation at the margin of the carbonate complex near Mount MacKenzie. In the southern part of the report area, in the vicinity of Sawtooth and Chocolate Mountains, tongues of carbonate rock from the upper part of the Southesk Formation extend for several miles beyond the carbonate complex (Pl. II) and are overlain near their limit to the northwest by a thin sequence of Sassenach Formation siltstone along a brecciated contact. A ragged, karst topography characterizes the brecciated area, with sink holes and other openings and channels on its surface in which silty sediments collected. These became consolidated into siltstones and were subsequently broken up and recemented into breccias after continued leaching and collapse of the underlying carbonates.

In areas occupied by the carbonate facies, the Famennian–Frasnian contact is marked by a change upward from light brown, commonly coral- or stromatoporoid-bearing carbonates of the complex, to dolomitic siltstone or grey limestone of the Sassenach or Palliser Formations, respectively, which contain no corals or stromatoporoids. Brecciated zones are associated with this contact. Above the argillaceous facies the contact is marked by a lithologic and faunal change from underlying dark grey, argillaceous, coral-bearing, Mount Hawk Formation limestone, to the lower, silty, mudstone member of the Sassenach Formation that contains the distinctive fauna listed below.

Cyrtiopsis mimetes Crickmay
Sinotectirostrum sp.
Cyrtospirifer sp.
"*Nudirostra*" *seversoni* McLaren
"*Camarotoechia*" sp.
"*Leiorhynchus*" *walcotti* Merriam

Palliser Formation

Beach (1943) described the Palliser Formation in the Bow River valley type area and described major lithologic units within it. No formal subdivision was made, however, until de Wit and McLaren (1950) named the lower Morro and overlying Costigan Members.

The formation occurs throughout the eastern Foothills and Front Ranges of the Rocky Mountains from south of the Bow River valley to the Athabasca River and northward. It is uniformly between 800 and 950 feet thick. Within the report area the thickness of the formation, composed of the lower 725-foot-thick Morro and the upper 200-foot-thick Costigan Members, is 925 feet with maximum range in total thickness of less than 30 feet. The light grey weathering limestones are so conspicuously cliff-forming that the formation can usually be recognized on topographic maps by the close spacing of contour lines.

The most common rock type of the Palliser Formation is dark grey, argillaceous limestone with characteristic brown-weathering, vermiform areas of dolomite mottling. Along parts of the periphery of the carbonate complex the lowermost beds of the Palliser Formation have been altered to brown, coarsely crystalline, porous, reef-like dolomite in which crinoid stems and other fossil fragments can still be identified. These porous, dolomitized areas are most conspicuous over the margin of the carbonate body southeast of Mount Meda where the Sassenach Formation siltstones are absent locally, and also in the next thrust sheet to the south where they are quite thin.

The contact of the Palliser with the underlying Southesk and Sassenach Formations is commonly abrupt and easy to recognize in the field. Thin lenses and beds of dolomitic siltstone occur locally in the lower part of the Palliser Formation in parts of the argillaceous province, however. In these regions the base of the formation was arbitrarily placed at the first occurrence of limestone typical of the Palliser cycle of deposition. Where the Sassenach Formation is absent over some parts of the carbonate complex, the Palliser–Southesk Formation contact is marked by a change upward from light brown, stromatoporoid-bearing limestones of the complex to overlying dark grey, argillaceous and dolomite-mottled beds of the Palliser Formation. This relationship is typical in the vicinity of Sawtooth Mountain (Pl. II).

PLATE VI

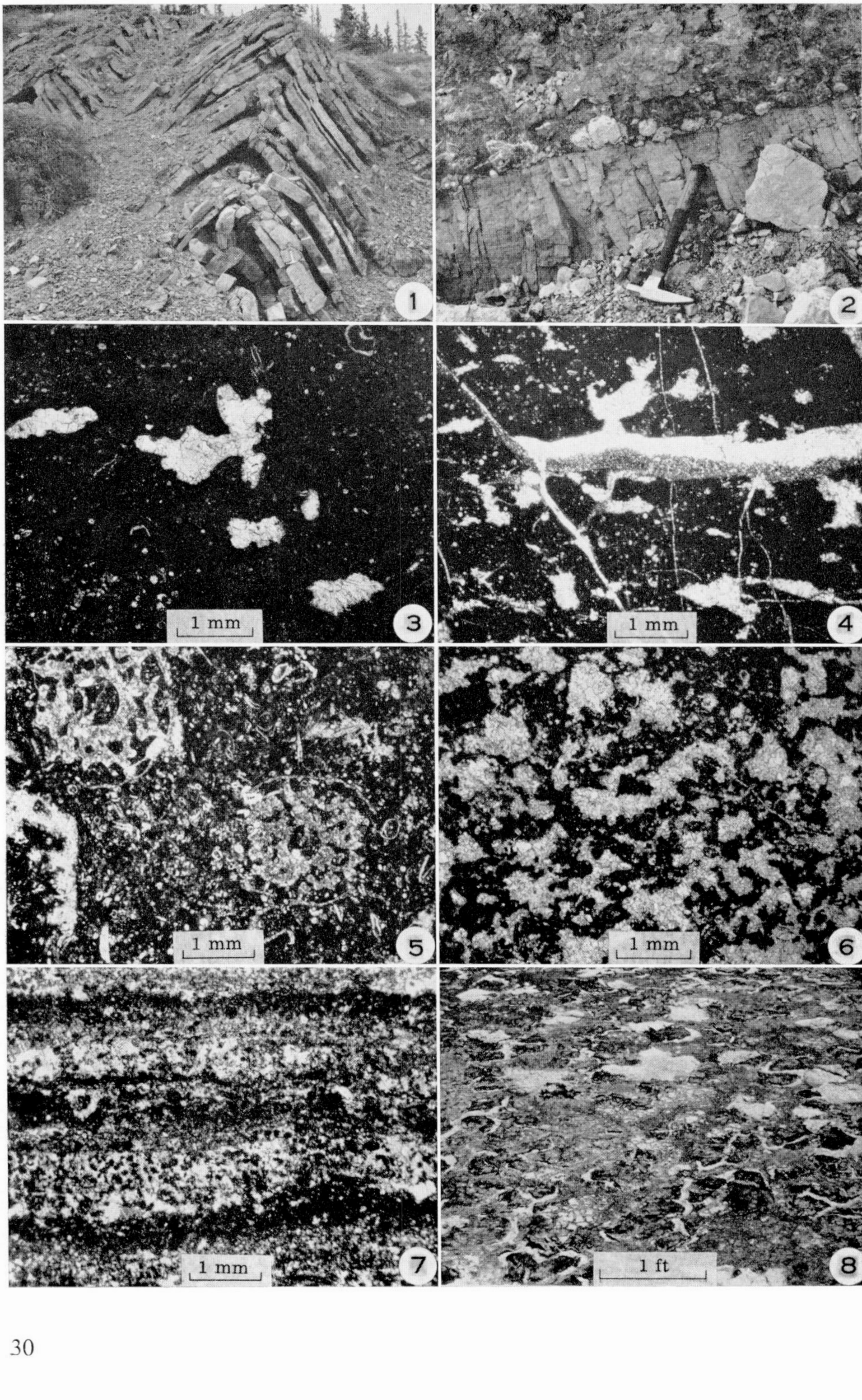


PLATE VI

1. Thin-bedded Mount Hawk Formation strata compressed into chevron folds outcrop on the valley floor along the west side of Cardinal Pass.

2. Interbedded light brown, non-fossiliferous and dark brown stromatoporoid-bearing dolomite from near the top of the Cairn Formation. Light coloured spherical stromatoporoids in the photo are resting on an irregular upper surface of the light coloured bed; north spur of Mount Toma.

3. Photomicrograph of typical micrite microfacies showing characteristic irregularly shaped "eyes" of coarsely crystalline calcite in surrounding dark microcrystalline calcite; from 80 feet below the top of the Arcs Member, near Saracen Head.

4. Photomicrograph showing fractures common in the micrite microfacies. The fractures appear to have remained open for a time prior to cementation by coarsely crystalline calcite; from 60 feet below the top of the Arcs Member, near headwaters of Thistle Creek.

5. Photomicrograph of typical *Amphipora* biomicrite. Relatively undeformed circular cross-sections of central canals in the *Amphipora* suggest little post-depositional compaction in this carbonate microfacies; from 30 feet below the top of the Arcs Member, near headwaters of Thistle Creek.

6. Photomicrograph of typical bored and pelleted micrite microfacies. The irregularly shaped light areas of coarsely crystalline calcite, which constitute as much as 30 per cent of the rock, suggest relatively rapid lithification; from near the top of the Southesk Formation, west flank of Mount Toma.

7. Photomicrograph of typical laminated calcarenite; the alternating layers of dark microcrystalline calcite and fine-grained calcarenite are from 1 to 3 mm thick; from the Southesk Formation, near Sawtooth Mountain.

8. Recent algal mat from Crab Key in the Florida Keys area; parts of the mat are overturned in some areas (light area, bottom right of photo).

PLATE VII

1. Photomicrograph of typical calcarenite microfacies; average grain size is about 120 microns; from the base of the Arcs Member, southeast side of Mount Lagrace.

2. Photomicrograph of graded internal sediment occupying fractures in medium calcarenite; the fractures presumably remained open while several layers of fine sediment were deposited in them and then were cemented by coarsely crystalline calcite; from near the top of the Arcs Member, near the headwaters of Thistle Creek.

3. Photomicrograph of typical calcirudite microfacies; the rudite grains are made up essentially of aggregates of discrete grains of microcrystalline calcite; from 30 feet below the top of the Arcs Member, near the headwaters of Thistle Creek.

4. Photomicrograph of typical sucrosic dolomite with intercrystalline porosity; dark argillaceous material occurs between the crystals in this specimen and effectively reduces the porosity; from the top of the Cairn Formation, about $1\frac{1}{2}$ miles southeast of Mount Meda.

5. Inaccessible isolated limestone lens near the top of the Mount Hawk Formation on the west side of Cardinal Pass. The lens is estimated to be about 75 feet thick. Two light-weathering limestone beds above the lens mark the top of the Frasnian stage.

6. Inaccessible isolated limestone lens near the top of the Mount Hawk Formation on the east side of Cardinal Pass. Thinning limestone tongues can be seen dipping down and away from the sides of the lens. Angular fragments presumably broken from the lens occur in the adjacent shale.

7. Oncolite beds in the upper part of the Mount Hawk Formation in the transitional zone between the carbonate complex and the adjacent argillaceous facies. Thin sections from the oncolites show abundant fine tubules, probably *Girvanella*.

8. The Sassenach Formation Upper Sandy and Lower Silty Mudstone Members near the carbonate–argillaceous facies transition zone southeast of Mount Meda.

PLATE VII

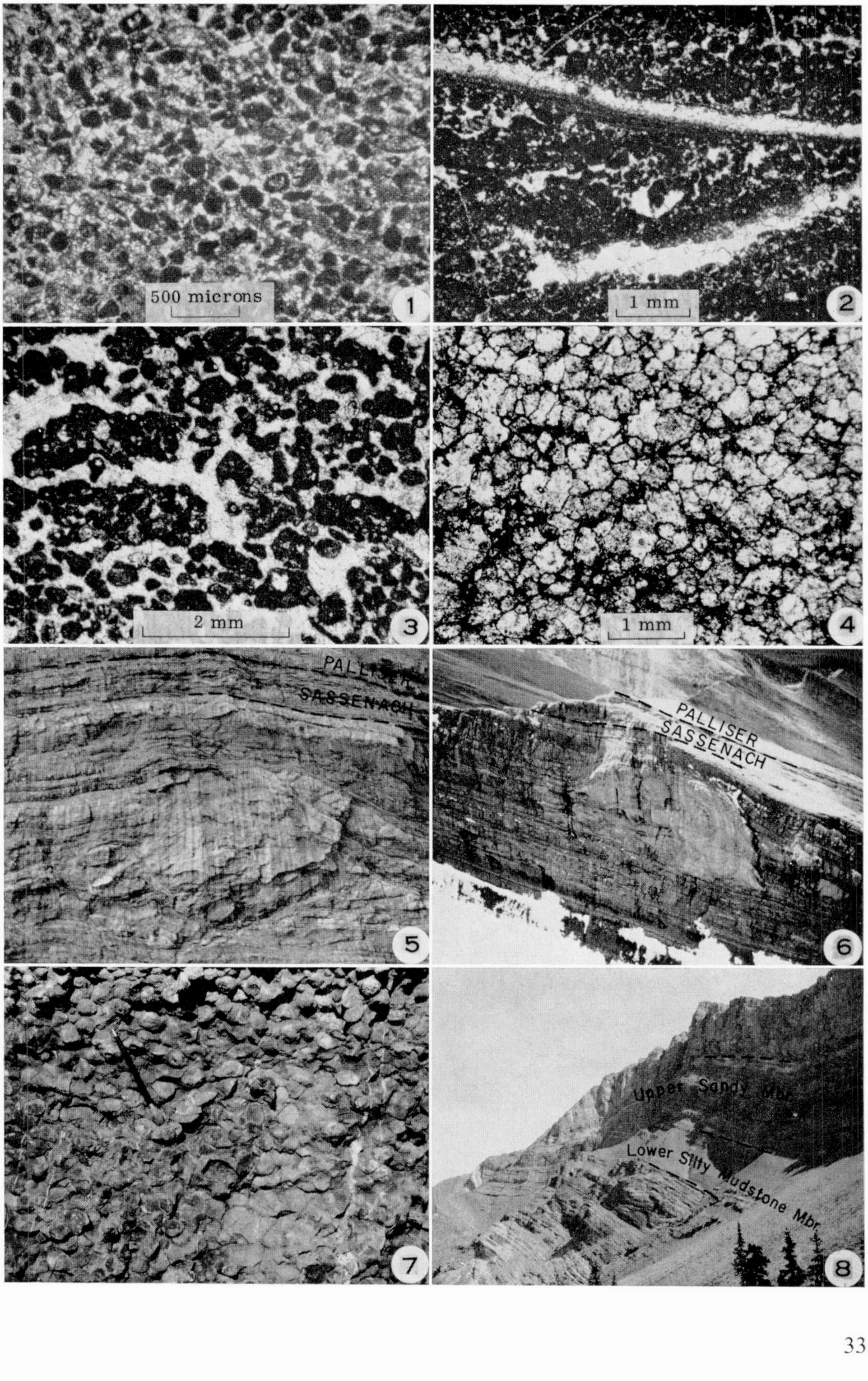
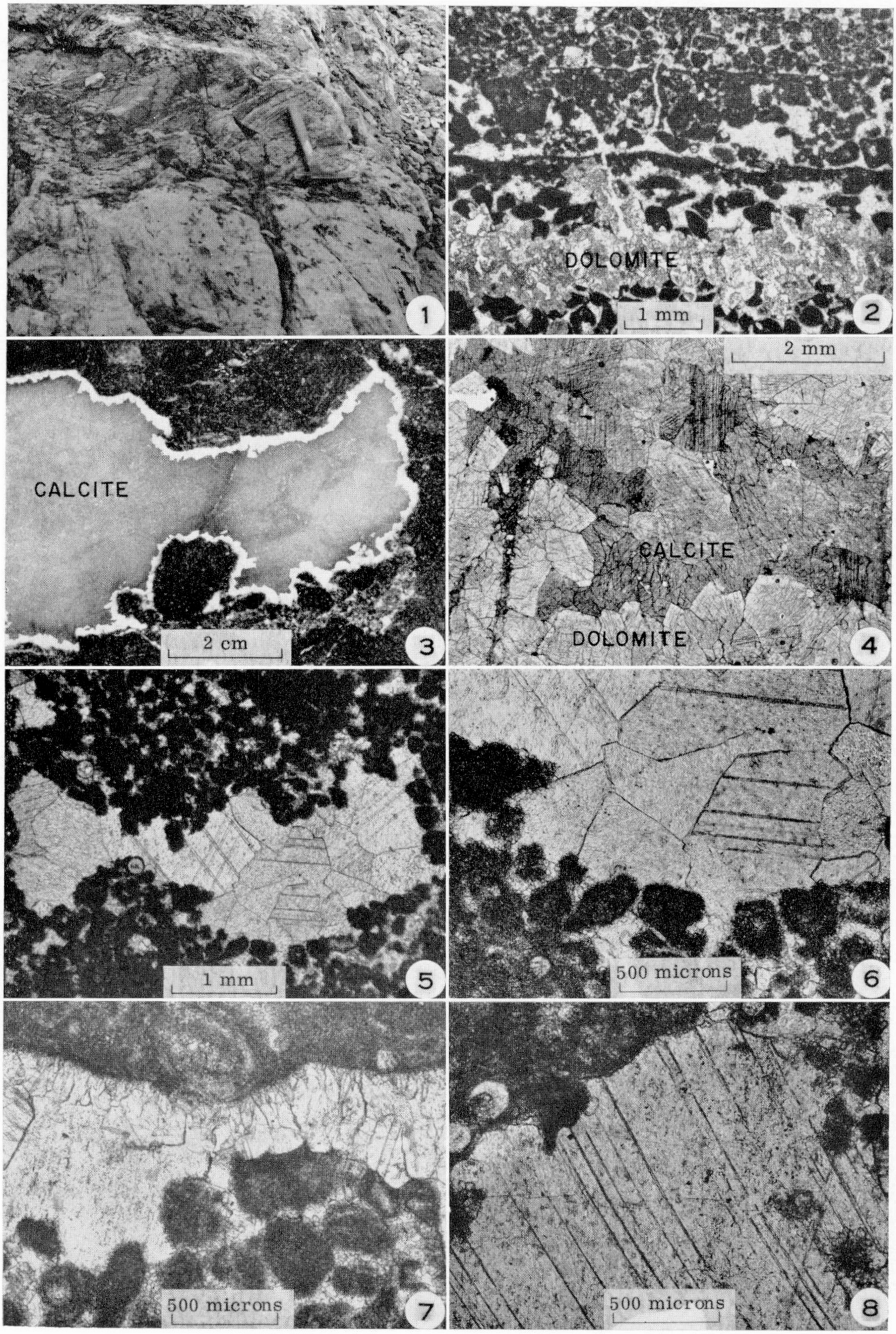

500 microns
1
1 mm
2
2 mm
3
1 mm
4
PALLISER
SASSENACH
5
PALLISER
SASSENACH
6
7
Upper Sandy Mbr.
Lower Silty Mudstone Mbr.
8

PLATE VIII



DOLOMITE
1 mm
CALCITE
2 cm
2 mm
CALCITE
DOLOMITE
1 mm
500 microns
500 microns
500 microns
1
2
3
4
5
6
7
8

PLATE VIII

1. An irregular brecciated surface at the Famennian/Frasnian boundary about 4 miles southeast of Mount Meda. Dark-weathering fragments of Sassenach Formation dolomitic siltstone occur in the underlying light-weathering Southesk Formation immediately below the contact.

2. Photomicrograph showing dolomitization controlled by magnesium-bearing solutions migrating along porous zones associated with fractures and bedding planes; from 275 feet below the top of the Southesk Formation, southeast side of Mount Lagrace.

3. Stained polished rock surface showing porosity in vugs occluded by internal precipitation of coarsely crystalline calcite. Fragments of dolomite have dropped from the roof of the cavity and now constitute an internal sediment on its floor beneath a lining of light-coloured dolomite; from the base of the Cairn Formation, Balcarres Mountain.

4. Photomicrograph showing dark stained calcite filling vuggy porosity in light-coloured dolomite; from 200 feet above the base of the Southesk Formation, about 3 miles southeast of Mount Meda.

5. Photomicrograph showing precipitated calcite filling vugs in medium calcarenite; straight boundaries are conspicuous between the large crystals; from 30 feet below the top of the Arcs Member, Mount Dalhousie.

6. An enlargement of part of Plate VIII-5; the crystals have straight boundaries, but there is no conspicuous increase in crystal size away from the cavity wall and no lining of small elongate crystals; from 30 feet below the top of the Arcs Member, Mount Dalhousie.

7. Photomicrograph showing light coloured calcite precipitated beneath limestone fragments; elongate crystals beneath the fragment increase progressively in size downward; their lower contact is sharp in some areas and diffuse in others, centre right and lower left of photo respectively; from 30 feet below the top of the Arcs Member, Mount Dalhousie.

8. Photomicrograph showing a large crystal of presumed precipitated calcite. In some areas it has a sharp contact with the adjacent dark limestone, in others the contact is diffuse and the crystal contains relics of limestone grains, upper left and right side of photo respectively; from 30 feet below the top of the Arcs Member, Mount Dalhousie.

POST-DEPOSITIONAL CHANGES

The Southesk Cairn carbonate complex consists almost entirely of dolomite. Thus, the most conspicuous post-depositional change has been dolomitization of the original limestone and accompanying obliteration of many sedimentary textures that might have been useful in unravelling the depositional history of the deposit. Leaching and filling of vugs and fractures, silicification of skeletal remains, and the development of stylolitic bedding contacts constitute other easy to recognize but perhaps less striking post-depositional phenomena. Still less conspicuous changes, such as the modification of primary textures by recrystallization, have taken place, and these must be studied with the petrographic microscope.

Dolomitization

The process of dolomitization is widespread and generally conceded to be related to porosity in rocks and to migration of magnesium-bearing solutions. Magnesium enrichment and dolomitization appear to be common phenomena in intertidal areas and restricted lagoons, and sediments deposited in such environments would probably be the most susceptible to dolomitization. The dense limestones of the carbonate complex that are interpreted as having been deposited in a protected lagoonal environment, however, have escaped dolomitization almost entirely. Fairbridge (1957) described some Australian shallow-water limestones that had a history of intertidal exposure and also remained undolomitized. Dolomitization was presumably inhibited by rapid lithification and occlusion of primary porosity in these fine-grained sediments.

In outcrop, frequently porous elongate lenses of dolomite show a preferred orientation parallel to the bedding, thus supporting the concept of dolomitizing solutions migrating along bedding planes and through associated porous zones. This association of dolomitization with porous strata is further demonstrated in the vicinity of Mount Meda and Sawtooth Mountain (Fig. 2) where the Palliser Formation, dolomitized over a vertical interval of several hundred feet, rests disconformably on the carbonate complex. Brecciation and slumping of leached beds below the disconformity in these areas is thought to have been a factor in promoting dolomitization in the overlying Palliser Formation by providing a means of access for the magnesium-bearing fluids. Sonnenfeld (1964) drew attention to what he termed dolomitization by aquifers; that is, dolomitization of rocks already underlain by dolomitized strata by upward-migrating magnesium-bearing solutions. Porosity that is primary or due to early diagenesis appears to have been one of the main factors controlling the replacement of bedded limestone by dolomite. Thin sections show that dolomitization is frequently related to bedding plane microporosity and porosity along fractures in the calcarenitic and finely crystalline rocks (Pl. VIII–2). On a larger scale the non-compacted and relatively porous carbonates of the complex have been extensively dolomitized, whereas the adjacent beds of the argillaceous facies, presumably less porous and permeable, have not been affected.

Dolomitization is a secondary process by definition. In partly altered strata, limestone pellet and grain boundaries can usually be seen within the dolomite crystals, but with progressive dolomitization their outlines tend to disappear. Some of the skeletal remains can still be identified in the completely dolomitized sequence, sometimes at the generic level, for example, *Stachyodes* sp. The crystal size of the dolomitized fossil fragments and the surrounding matrix is commonly different, and the absence of argillaceous material in the fossil remains makes them distinctly lighter in colour. Other dolomitized skeletal remains, such as gastropods, contain geopetal fabrics within them in the form of flat-topped internal deposits of argillaceous sediment now replaced by finely crystalline argillaceous dolomite and overlain by coarser, non-argillaceous, dolomite crystals. Both the fossil fragments and matrix show preferred dolomite crystal sizes that appear to be related to the size of the original limestone crystals. This is significant because it provides at least a qualitative appreciation of primary limestone textures.

The results of various stages in the process of dolomitization can be seen in many of the Fairholme Group carbonates. Medium- and coarse-grained calcarenites from the base of the Arcs Member near Mount Isaac (Fig. 2) have been partly altered to dolomite by progressive replacement. The intergranular, coarsely crystalline cement is replaced first, and then the constituent microcrystalline limestone grains, to produce coarsely crystalline dolomite. The coarse, spar-cemented calcarenites can be traced into coarsely crystalline dolomite within a strike distance of about 25 yards; thus, the results of all stages in the dolomitization process, ranging from the original calcarenite to the completely dolomitized rock, can be observed. Medium- and coarse-grained calcarenites in some parts of the Peechee, Arcs, and Ronde Members enclose patches and lenses of dolomite or grade laterally into coarsely crystalline porous dolomite. It is thought that these dolomites were at one time composed of calcarenite like the surrounding rock, and that the calcarenite was replaced by dolomite probably because the primary porosity had not been destroyed.

No conspicuously porous calcarenitic limestones were observed within the report area. Accordingly it can not be established that dolomite porosity was inherited from the limestones. The coarse, sucrosic texture and excellent porosity common in the carbonate complex, particularly in the Peechee Member, is most likely related to dolomitization. Landes (1946) advanced the theory of porosity development through dolomitization caused by an excess of solution over deposition during replacement of the limestone. This process, discussed qualitatively and quantitatively by Murray (1960) and Weyl (1960), is thought to have been a factor in promoting the development of porosity in the Fairholme Group carbonates.

The dolomitized strata, however, appear to have been substantially more porous at one time than they are now. Vugs and fractures, probably once open but now filled by calcite or dolomite, occur abundantly in the carbonate facies (Pl. VIII–3). On a smaller scale, thin sections and polished rock surfaces treated with alizarin red stain reveal small minute unsuspected vugs, fractures, and intercrystalline areas filled with calcite cement (Pl. VIII–4). Thin sections show also that dolomite rhombohedra continued to grow by simple accretion of rims of clear dolomite in optical continuity with earlier, darker, argillaceous crystals. This type of crystal enlargement has reduced effective porosity appreciably, and in many instances has continued until the rock has become a dense mosaic of anhedral and subhedral interlocking crystals with little or no pore space remaining. Less frequently, pore spaces are occupied by anhydrite or by calcite or dolomite that has replaced anhydrite. According to Murray (1960), anhydrite commonly occurs as a cement in void spaces from which it extends into the adjacent rock by replacement. The anhydrite tends to retain its rectangular crystal outline during replacement, so that when it is finally removed by leaching, rectangular vugs are left behind as sites of calcite or dolomite precipitation.

Compaction

The Fairholme Group of formations is conspicuously thinner throughout the argillaceous province than it is in areas occupied by the carbonate complex. Differential compaction between the argillaceous and carbonate facies, which took place during progressive burial of the carbonate complex following deposition of the Sassenach Formation in Famennian time, can probably account for most of the difference in thickness. The argillaceous muds that accumulated away from the carbonate complex were probably capable of much greater reduction in volume than the limestone framework of the carbonate complex. Near Mount MacKenzie, adjacent argillaceous and carbonate sections differ by about 14 per cent (233 feet) in thickness. The measured sequence near Mount MacKenzie, however, occurs close to the carbonate complex and comprises a more calcareous "reef margin" facies of the Mount Hawk Formation which presumably was less affected by post-depositional compaction than typical facies of the argillaceous province. In a typical argillaceous facies at Deception Creek, for example, the Fairholme Group is about 38 per cent (520 feet) thinner than its carbonate equivalent about 9 miles to the southeast.

At some places within the carbonate complex, low amplitude stylolitic bedding contacts attest to some minor reduction in thickness that probably took place late in the history of the rock. Thin sections of the rock show that stylolitic contacts between grains are rare, and because the individual grains show no signs of plastic deformation, they were probably formed after complete induration of the rock. Microfossils also show little evidence of deformation. Thin, fragile, fossil shells and fecal pellets that were originally soft are not crushed or flattened. Other small features, such as the peripheral and axial canals of *Amphipora* (Pl. VI–5) and fragile, thin-walled calcispheres, show no modification of their circular cross-sections. Thus, there is abundant evidence to support the hypothesis of early diagenetic cementation in the carbonate beds with consequent formation of a rock that was subject to little subsequent reduction in volume through compaction. Evidence of early cementation of soft, calcareous material in recent sediments has been observed by Illing (1954). Commenting on the same phenomenon, Sujkowski (1958) mentioned that pure calcareous deposits showing little diagenetic change of this nature were rare even from the younger geologic periods.

The argillaceous strata adjacent to the carbonate complex are potential source beds for hydrocarbons. During compaction the volume of sediments is reduced and connate fluids are expelled. Extensive dolomitization of the carbonate complex, a phenomenon commonly considered to be related to migrating fluids and porous strata (Illing and Wells, 1964), suggests the retention of effective porosity within the carbonate beds at a time when pore space was being reduced and obliterated in the adjacent argillaceous sequence. The lack of compaction in the carbonate strata favoured the retention of primary porosity and thus assumes economic significance in two ways. It provides a reservoir for migrating hydrocarbons and also provides a means of access for dolomitizing fluids, which, in turn, are believed to promote development of an increased secondary porosity (Layer, 1949).

Recrystallization

To discuss the process of recrystallization in carbonate rocks it is necessary to distinguish between recrystallized and primary calcite. The two varieties resemble one another superficially, for example, each has relatively large crystals in addition to other less conspicuous physical attributes. Both recrystallized and introduced primary calcite have been significant factors in the early lithification of carbonate sediments. An understanding of their distribution in rocks is important, for they are related to the processes of dolomitization, development of secondary porosity, and accumulation of hydrocarbons.

Primary limestone textures in the Southesk Cairn carbonates appear to have been extensively modified by recrystallization. In some places, particularly in the muddy microfacies, vaguely defined and irregularly shaped areas of relatively coarse crystals can be classified as recrystallized calcite with reasonable assurance, whereas filled cavities clearly contain precipitated calcite (Pl. VIII–5). In many of the relatively coarse grained calcarenitic rocks, however, it is difficult to distinguish between recrystallized and primary calcite. What frequently seems to be a drusy cement may be partly due to recrystallization. Areas of coarsely crystalline calcite with some of the physical attributes of precipitated calcite, such as conspicuous planar intercrystalline boundaries (Bathurst, 1958), are relatively common. The large crystals with their typical planar interfaces appear to constitute a cavity filling, but certain other criteria diagnostic of precipitated calcite are lacking (Pl. VIII–5, 6), such as a peripheral lining of small elongate crystals oriented perpendicular to the supposed cavity wall, and a progressive increase in crystal size away from the wall (Bathurst, 1958, Fig. I–1). Without these or other distinguishing features, such as geopetal fabrics, it is difficult to classify areas of coarse crystals as either recrystallized or primary calcite.

Small elongate crystals similar to those described by Bathurst (1958) do occur in many rocks of the carbonate complex as a lining of various sorts of cavities. They are most conspicuous where the rock texture has a directional element, for instance, beneath large composite grains and limestone fragments. The fine, elongate crystals oriented essentially perpendicular to the roofs of such cavities grew downward into the once open voids and at the same time increased progressively in size (Pl. VIII–7). They consist of drusy or precipitated calcite. There is, however, no lining of small crystals along the floors of many of these supposed cavities as would be expected. In some areas of the thin section the crystals appear to have encroached on the rock matrix along a sharp suture-like contact (Pl. VIII–7, centre right; Pl. VIII–8, top left). The contact appears to be stylolitic, the primary cavities having been enlarged probably through removal of material by solution. The ultimate filling of this type of void space in carbonate rocks may have been due to pressure and solution transfer associated with stylolitization, with the larger crystal phases growing at the expense of the metastable fine material (Beales, pers. com., 1964). The suture-like contacts between the large crystals and the microcrystalline limestone grains certainly resemble incipient stylolitization. The coarse calcite crystals can also have diffuse rather than sharp contacts with the surrounding microcrystalline material (Pl. VIII–7, lower left). Many of the large crystals contain relics of partially digested microcrystalline limestone grains (Pl. VIII–8, lower right).

Although limestone textures are commonly made coarser by recrystallization, a decrease in crystal size can also accompany the process (Folk, 1964; Orme and Brown, 1963; Wardlaw, 1962). The phenomenon of grain diminution through recrystallization is most easily recognized when the coarsely crystalline texture of fossil remains becomes progressively finer and finally merges with the enclosing microcrystalline matrix. Skeletal remains, whose textures have been extensively modified by this type of recrystallization, commonly appear as vague shapes suggestive only of fossil fragments. If the entire fragment has been affected, no trace of it will be visible in the microcrystalline matrix. Some calcispheres illustrate this type of alteration. They occur in all stages of preservation from specimens complete with calcite envelope (Pl. IX–1) to those that are barely discernible from the enclosing microcrystalline matrix (Pl. IX–2). The coarsely crystalline texture of the calcisphere envelope and the internal filling became progressively finer until almost the entire structure was reduced to microcrystalline calcite. If the initial and resulting crystals represent the same phase, a decrease in crystal size (the degradational recrystallization of Folk, 1964) requires an input of energy into the system. Wardlaw (1962) observed that some decrease in crystal size could be related to shearing and the consequent straining of rock crystals, and Voll (1960) noted that degradational recrystallization occurred at low temperatures and pressures in slightly strained limestones. Other suggested means of energy input include minor chemical differences within the sediments induced by decaying organic material and the addition of acids from the excretory products of organisms. Minor compaction readjustments could also account for locally strained areas whose acquired energies might have been used to transform large crystals into smaller ones. If the process has been extensive, an unknown percentage of fossil debris may have been incorporated into the rock.

The foregoing examples serve to emphasize the difficulties that hinder attempts to evaluate quantitatively the amount of recrystallization that has taken place in limestones of the carbonate complex. A significant aspect of the process of recrystallization in carbonate rocks is that large stable crystals of calcite, once they have been formed, seem to be able to increase as a solid mass and encroach on some of the surrounding material leaving little or no trace of where the encroachment began. Consequently, the original size of the primary openings is difficult to evaluate. It is

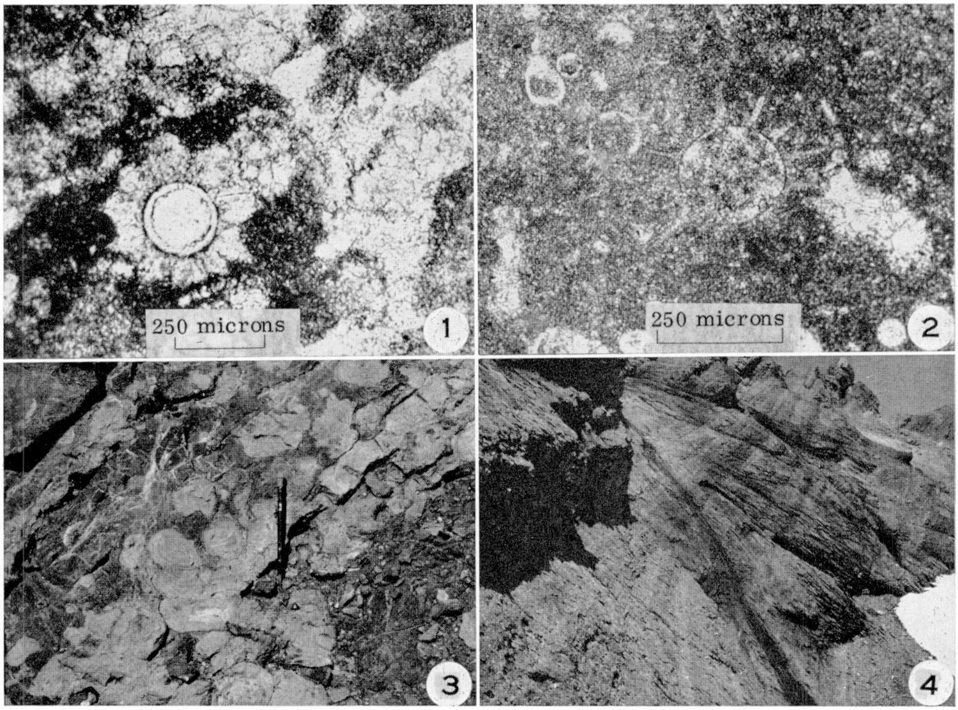


PLATE IX

1. Photomicrograph of calcisphere with surrounding envelope, little affected by recrystallization; from top of Peechee Member, near Mount Lagrace.
2. Photomicrograph of calcisphere made barely visible by the effects of recrystallization through decrease in crystal size; from the base of the Arcs Member, near Saracen Head.
3. Abundant light-weathering globular and encrusting stromatoporoids near the margin of the carbonate complex; Cairn Formation, vicinity of Mount Meda.
4. Argillaceous, relatively non-fossiliferous dolomite strata typical of sedimentation away from the margins of the carbonate complex; Cairn Formation, southeast of Sawtooth Mountain.

certain that large crystals did grow in open cavities, for they occur in what clearly were former open spaces underneath fossil shells and in bridge-over areas under limestone grains. Their morphology during the early stages of cavity filling complies with existing criteria for the identification of this type of calcite, but during the latter phase of crystal enlargement the only certain diagnostic criteria are gross fabric relationships such as the presence of undigested relict structures and transected limestone grains. Orme and Brown (1963) suggested that even the fine, elongate crystals taken to be diagnostic of the first stage of calcite precipitation in voids could be a replacement product, thereby introducing further doubt as to the dimensions of primary cavities. Because of the uncertainties involved in distinguishing primary from recrystallized calcite, it is difficult to reconstruct original pore volumes and pore shapes in recrystallized limestone rocks. Estimates of primary porosity based on the presence of large, supposedly void-filling, calcite crystals obviously tend to be too high if primary crystals can merge imperceptibly into replacement ones. Until definitive diagnostic criteria become available such estimates must remain qualitative.

DEPOSITIONAL HISTORY

Carbonate complexes and carbonate reefs of Frasnian age in western Canada passed through remarkably similar stages during their evolution. Mountjoy (1965) drew attention to the similarity of surface and subsurface reef complexes in widely separated areas and suggested that the effects of eustatic changes in sea level were probably the dominant factor controlling their development. Dooge (1966, Appendix 6) presented his concept of a unified carbonate model for western Canada.

The main stages in the development of the Southesk Cairn complex as revealed by its gross morphology and stratigraphic relationship to surrounding argillaceous deposits and by stratigraphy within the complex and petrographic analysis of its constituent sediments are:

1. An initial transgressive stage during which a platform deposit of stromatoporoidal carbonate was laid down on a gently undulating surface of eroded Upper Cambrian rock (Flume Formation).
2. A period during which organic carbonate biostromes developed on large areas of the platform. Small biostromes grew in marginally favourable areas peripheral to the main sites of carbonate deposition (Cairn Formation, Upper Member, and dolomite mounds).
3. A stable phase associated with the development of banks of relatively pure calcareous sand characteristic of the lowermost Peechee Member of the Southesk Formation.
4. Beginning of a recessive phase; deposition of organic dolomites and restricted limestones of the Grotto and Arcs Members, respectively.
5. More pronounced regression and widespread deposition of siltstones and silty limestones over the carbonate complex and in parts of the argillaceous province as well. The presence of breccias along the periphery of the complex indicates periods of erosion and non-deposition.

The transgressive phase of Upper Devonian sedimentation (Flume and Cairn Formations) reflects a period of progressively deepening water throughout the entire western Canada basin during which widespread platform carbonates and stromatoporoid biostromes developed on the underlying Upper Cambrian erosion surface. The platform carbonates are conspicuously thinner in some areas peripheral to the carbonate complex and relatively thick beneath it, suggesting that combinations of (sediment) floor topography and minor differences in the rate of subsidence locally were factors in providing sites where organic life could continue to flourish in the deeping water, sites that persisted as areas of carbonate accumulation and on which the Cairn Formation biostromes eventually developed. The areas subsequently occupied by the Cairn Formation represent regions of differential subsidence with respect to the adjacent argillaceous province. A similarity in gross lithology of the

Cairn and Flume Formation carbonates throughout the report area suggests that conditions were relatively constant in the depositional environment. Some thin beds of light coloured, relatively pure, non-fossiliferous carbonate are intercalated with the dominantly dark, stromatoporoidal dolomites of the Cairn Formation and indicate intermittent short periods of sea-level stability with deposition taking place in shallow water. Many of the thin, light coloured beds terminate abruptly upward at irregular, bedding plane surfaces (Pl. VI–2). Hadding (1958) attributed comparable bedding plane surfaces in Swedish Ordovician and Silurian rocks to submarine denudation in shallow water. The areal distribution of stromatoporoidal carbonates within the relatively uniform rock sequence of this part of the carbonate complex constitutes evidence that the depositional environment during that time was not entirely uniform. Large globular stromatoporoids (Pl. IX–3), for example, are a common rock-forming constituent near the margins of the complex, whereas, away from these areas towards the centre of the carbonate complex, non-fossiliferous bedded dolomite is a more common rock type (Pl. IX–4). This latter type of rock suggests conditions similar to those found on modern tidal flats where deposition takes place in quiet protected areas. The stromatoporoidal carbonates of the bank margins probably grew in agitated water while carbonates of the interior regions were laid down in relatively quiet water. Aside from minor local brecciation at the margins of dolomite mounds, shales surrounding the complex contain little carbonate debris; thus little erosion of the carbonate bank was taking place while the shales were being deposited. Onlapping shale/carbonate relationships in some outcrop areas (Pl. V) suggest that sediments of the argillaceous facies, the Perdrix Formation, accumulated in quiet water around the banks while stromatoporoids were growing in intermittently agitated water closer to surface, probably near wave base. The dark, pyritic nature of the Perdrix shales indicates a reducing, perhaps anaerobic, environment in the deeper parts of the basin surrounding the complex.

A period of relative stability, characterized by a sequence of light coloured, essentially non-skeletal carbonates, followed the early transgressive phase of sedimentation. Organic growth probably continued in the water that became progressively shallower until light coloured calcareous sands began to form in the new environment. Interbedding of the dark organic and light coloured non-skeletal carbonates at the change from the Cairn Formation to the Southesk Formation suggests intermittent fluctuations in sea level during the transition. Once established, however, the shallow-water environment persisted long enough for more than 300 feet of the Peechee Member to accumulate.

A change to overlying, dark, organic dolomites with abundant corals and *Amphipora* (Grotto Member) indicates the beginning of a period of regression during which sea level was presumably lower and corals and *Amphipora* flourished in the shallow water on the carbonate bank. The change in depositional environment was widespread throughout the Alberta basin as indicated by the distinctive Grotto Member facies found in many mountain and subsurface areas. Its areal distribution within the report area suggests probable control of sediment patterns by ocean currents presumably flowing from the north or northeast along the northwest margin of the carbonate complex. Carbonate detritus, carried from the north by the currents and added to the material being washed out from the main part of the bank into the regions to the south, was most likely a factor in creating the extensive sheets of dark organic dolomite, now seen in outcrop as long tongues extending for several miles beyond the carbonate front (Pl. II). Staplin (1961), Andrichuk (1961), and McCrossan (1961) also interpreted currents from the north to account for stratigraphic relationships and patterns of carbonate development in subsurface Devonian rocks. No comparable tongues of the Grotto Member occur beyond the carbonate front near Mount MacKenzie or Cardinal Mountain to the north, regions from which detritus from the bank was presumably swept away to the south by currents.

Light coloured sediments of the Arcs Member, consisting of mudstones, laminated rocks, and fine calcarenites, represent a later stable phase in the history of the carbonate complex with the thickest sections of the lagoonal, shallow-water sediments collecting over the interior regions of the complex. Macrofossils are rare in the Arcs Member; algae, calcispheres, ostracods, and a few foraminifera are the most abundant fossils.

During the latter stages of Fairholme Group deposition, quartzose clastics and silty carbonates (Ronde Member) were deposited over the carbonate complex and spread over parts of the adjacent argillaceous province as well. Limestone tongues with laterally contiguous isolated lenses occur in the upper part of the Mount Hawk Formation near the carbonate body (Pl. I). Globular and encrusting stromatoporoids, probably representative of water becoming progressively shallower and a more turbulent environment, are found in the uppermost beds, particularly near the margins of the carbonate complex.

Fairholme Group sedimentation was terminated by a period of erosion over the carbonate complex. Topographic relief between the carbonate and argillaceous provinces was progressively reduced by combined filling of the off-reef areas and erosion of the adjacent carbonate strata, until finally Sassenach Formation siltstones covered all but a narrow zone along the northwest margin of the carbonate complex. This too was eventually covered by Palliser Formation limestones of the succeeding cycle of deposition.

REFERENCES

Andrichuk, J. M.

1958: Stratigraphy and facies analysis of Upper Devonian reefs in Leduc, Stettler and Redwater areas, Alberta; *Bull. Am. Assoc. Petrol. Geologists*, vol. 42, pp. 1–93.

1961: Stratigraphic evidence for tectonic and current control of Upper Devonian Reef sedimentation, Duhamel area, Alberta, Canada; *Bull. Am. Assoc. Petrol. Geologists*, vol. 45, pp. 612–632.

Andrichuk, J. M., and Wonfor, J. S.

1954: Late Devonian geologic history in Stettler area, Alberta, Canada; *Bull. Am. Assoc. Petrol. Geologists*, vol. 38, pp. 2500–2536.

Bathurst, R. G. C.

1958: Diagenetic fabrics in some British Dinantian limestones; *Liverpool, Manchester Geol. J.*, vol. 2, pp. 11–36.

1959: Diagenesis in Mississippian calcilutites and pseudobreccias; *J. Sediment. Petrol.*, vol. 29, pp. 365–376.

Beach, H. H.

1943: Moose Mountain and Morely map-areas, Alberta; *Geol. Surv. Can.*, Mem. 236.

Belyea, H. R.

1954: Some reef–shale relationships on Wapiabi Creek, Alberta; *J. Alberta Soc. Petrol. Geologists*, New Bull., vol. 2, No. 9, p. 6.

1955: Cross-sections through the Devonian system of the Alberta plains; *Geol. Surv. Can.*, Paper 55-3.

1957: Correlation of Devonian subsurface formations, southern Alberta; *Geol. Surv. Can.*, Paper 55-38.

1958: Devonian formations between Nordegg area and Rimby-Meadowbrook reef chain, Alberta; *J. Alberta Soc. Petrol. Geologists*, Guide Book, 8th Ann. Field Conf., pp. 75–106.

1960: Distribution of some reefs and banks of the Upper Devonian Woodbend and Fairholme Groups in Alberta and British Columbia; *Geol. Surv. Can.*, Paper 59-15.

Belyea, H. R., and McLaren, D. J.

1954: Revision of Devonian nomenclature in the Rocky Mountains, a discussion; *J. Alberta Soc. Petrol. Geologists*, vol. 5, No. 11, pp. 269–276.

1957: Upper Devonian nomenclature in southern Alberta; *J. Alberta Soc. Petrol. Geologists*, vol. 5, No. 8, pp. 166–182.

1962: Upper Devonian formations, southern part of Northwest Territories, northeastern British Columbia and northwestern Alberta; *Geol. Surv. Can.*, Paper 61–29.

Bergenback, R. E., and Terriere, R. T.

1953: Petrography and petrology of Scurry Reef, Scurry County, Texas; *Bull. Am. Assoc. Petrol. Geologists*, vol. 37, pp. 1014–1029.

Black, M.

1933: Precipitation of calcium carbonate on Great Bahama Bank; *Geol. Mag.*, vol. 70, pp. 455–466.

Braddock, W. A., and Bowles, G. G.

1963: Calcitization of dolomite by calcium sulphate solutions in the Minnelusa Formation, Black Hills, South Dakota and Wyoming; *U.S. Geol. Surv.*, Prof. Paper 475-1.

Brown, P. R.

1963: Some algae from the Swan Hills reef; *Bull. Can. Petrol. Geol.*, vol. 11, pp. 178–182.

Cayeux, L. M.
1916: Introduction à l'étude petrographique des roches sedimentaires; Paris, Imprimerie Nationale.

Clark, E. De C., and Teichert, C.
1946: Algal structures in a western Australian salt lake; *Am. J. Sci.*, vol. 244, pp. 271–276.

Cloud, P. E., Jr.
1953: Facies relationships of organic reefs; *Bull. Am. Assoc. Petrol. Geologists*, vol. 36, pp. 2125–2149.

Cummings, E. R.
1932: Reefs of bioherms?; *Bull. Geol. Soc. Am.*, vol. 43, pp. 331–352.

Cummings, E. R., and Shrock, R. R.
1928: Niagaran coral reefs of Indiana and adjacent states and their stratigraphic relations; *Bull. Geol. Soc. Am.*, vol. 39, pp. 579–620.

Dapples, E. C.
1938: The sedimentational effects of the work of marine scavengers; *Am. J. Sci.*, 5th ser., vol. 36, pp. 54–65.

Darwin, C.
1889: The structure and distribution of coral reefs; 3rd ed., London, Smith, Elder and Company.

Dawson, C. M.
1886: Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 51° 30′; *Geol. Surv. Can.*, Ann. Rept., pt. R, p. 11.

de Wit, R., and McLaren, D. J.
1950: Devonian sections in the Rocky Mountains between Crowsnest Pass and Jasper, Alberta; *Geol. Surv. Can.*, Paper 50–23.

Dooge, J.
1966: The stratigraphy of an Upper Devonian carbonate–shale transition between the North and South Ram Rivers of the Canadian Rocky Mountains; N. V. Drukkerij, J. J. Groen en Zoon, Leiden, Holland.

Douglas, R. J. W.
1950: Callum Creek, Langford Creek, and Gap map-areas, Alberta; *Geol. Surv. Can.*, Mem. 255.

Dowling, D. B.
1912: Geology of the Roche Miette map-area, Jasper Park, Alberta; *Geol. Surv. Can.*, Sum. Rept., pp. 201–219.

Edie, R. W.
1956: Origin and characteristics of evaporite dolomite; *J. Alberta Soc. Petrol. Geologists*, vol. 4, pp. 16–23.
1961: Devonian limestone reef reservoir, Swan Hills oil field, Alberta; *Trans. Can. Inst. Mining Met.*, vol. 64, pp. 278–285.

Emery, K. O.
1953: Some surface features of marine sediments made by animals; *J. Sediment. Petrol.*, vol. 23, pp. 202–204.

Emery, K. O., and Rittenberg, S. C.
1952: Early diagenesis of California basin sediments in relations to origin of oil; *Bull. Am. Assoc. Petrol. Geologists*, vol. 36, pp. 735–806.

Fairbridge, R. W.
1950: Recent and Pliocene coral reefs of Australia; *J. Geol.*, vol. 58, pp. 330–401.
1957: The dolomite question: regional aspects of carbonate deposition (a symposium); *Soc. Econ. Paleontologists Mineralogists*, Spec. Publ. No. 5, p. 178.

Folk, R. L.
1951: Stages of textural maturity in sedimentary rocks; *J. Sediment. Petrol.*, vol. 21, pp. 127–130.
1959: Practical petrographic classification of limestones; *Bull. Am. Assoc. Petrol. Geologists*, vol. 43, pp. 1–38.

Folk, R .L. (*cont.*)
1962: Spectral subdivision of limestone types; *Am. Assoc. Petrol. Geologists*, Mem. 1, pp. 62–107.
1964: Some aspects of recrystallization of ancient limestones (abstr.); *Am. Assoc. Petrol. Geologists*, 49th Ann. Meeting, Toronto, Canada.

Fox, F. G.
1951: Devonian stratigraphy of Rocky Mountains and Foothills between Crowsnest Pass and Athabasca River, Alberta; *Bull. Am. Assoc. Petrol. Geologists*, vol. 35, pp. 822–843.

Friedman, G. M.
1959: Identification of carbonate minerals by staining methods; *J. Sediment. Petrol.*, vol. 29, pp. 87–97.

Ginsburg, R. N.
1953: Beach rock in south Florida; *J. Sediment. Petrol.*, vol. 23, pp. 337–352.
1956: Environmental relationship of grain size and constituent particles in some south Florida carbonate sediments; *Bull. Am. Assoc. Petrol. Geologists*, vol. 40, pp. 2384–2427.
1957: Early diagenesis and lithification of shallow-water carbonate sediments in South Florida; *Soc. Econ. Paleontologists Mineralogists*, Spec. Publ. No. 5, pp. 80–100.

Hadding, A.
1958: The pre-Quaternary sedimentary rocks of Sweden; *Inst's of Mineralogy Paleontol. Quaternary Geol.*, Univ. Lund., Sweden, No. 50, p. 262.

Hargreaves, G. E.
1959: Nisku lithofacies of Rocky Mountains, Alberta; *Alberta Soc. Petrol. Geologists*, Guide Book, 9th Ann. Field Conf., pp. 63–72.

Hatch, F. H., Rastall, H. R., and Black, M.
1938: The petrology of the sedimentary rocks; vol. 2, London, George Allan and Unwin Ltd.

Hector, Sir J.
1861: On the geology of the country between Lake Superior and the Pacific Ocean between the 48th and 54th parallels of latitude; *Quart. J. Geol. Soc.*, vol. XVII, pp. 388–445.

Hurley, W. G.
1963: Distribution and correlation of Upper Devonian formations, Sweetgrass Arch area, northwestern Montana; *Billings Geol. Surv.*, 13th Ann. Field Conf., pp. 23–32.

Illing, L. V.
1954: Bahamian calcareous sands; *Bull. Am. Assoc. Petrol. Geologists*, vol. 38, pp. 1–95.

Illing, L. V., and Wells, A. J.
1964: Penecontemporary dolomite in the Persian Gulf (abstr.); *Bull. Am. Assoc. Petrol. Geologists*, vol. 48, p. 532.

Imperial Oil Limited, Geological Staff
1950: Devonian nomenclature in Edmonton area, Alberta, Canada; *Bull. Am. Assoc. Petrol. Geologists*, vol. 34, pp. 182–203.

Johnson, J. H.
1943: Geological importance of calcareous algae; *Quart. Colo. School Mines*, vol. 38, p. 102.
1961: Limestone building algae and algal limestones; Johnson Publishing Company, Boulder, Colorado.

Johnson, J. H., and Konishi, Kenji
1958: Studies of Devonian algae; *Quart. Colo. School Mines*, vol. 53, pp. 1–114.

Kirker, W. P.
1959: Devonian reef and off-reef relationships in the Drumheller area; *Alberta Soc. Petrol. Geologists*, Guide Book, 9th Ann. Field Conf., pp. 92–102.

Klein, G. de V.
1965: Diverse origins of graded bedding (abstr.); *Bull. Geol. Soc. Am.*, Spec. Paper 82, p. 109.

Klovan, J. E.
1964: Facies analysis of the Redwater Reef Complex, Alberta, Canada; *Bull. Can. Petrol. Geol.*, vol. 12, pp. 1–100.

Konishi, K.
1958: Devonian calcareous algae from Alberta, Canada; Part 2 of studies of Devonian algae; *Quart. Colo. School Mines*, vol. 53, pp. 85–109.
1963: The Bahama Banks; A: "Living" fossil-environments; *J. Geol. Educ.*, vol. 11, pp. 17–25.
Kornicker, L. S., and Boyd, D. W.
1962: Shallow-water geology and environments of Alacran Reef Complex, Campeeche Bank, Mexico; *Bull. Am. Assoc. Petrol. Geologists*, vol. 46, pp. 640–673.
Kornicker, L. S., and Purdy, E. G.
1957: A Bahamian faecal-pellet sediment; *J. Sediment. Petrol.*, vol. 27, pp. 126–128.
Krumbein, W. C.
1942: Physical and chemical changes in sediments after deposition; *J. Sediment. Petrol.*, vol. 12, pp. 11–117.
Ladd, H. S.
1944: Reefs and other bioherms; *Natl. Res. Council, U.S.*, Comm. on Marine Ecology as related to Paleontology, Rept. 4, pp. 26–29.
Landes, Kenneth K.
1946: Porosity through dolomitization; *Bull. Am. Assoc. Petrol. Geologists*, vol. 32, pp. 305–318.
Lang, A. H.
1946: Brûlé and Entrance map-areas, Alberta; *Geol. Surv. Can.*, Mem. 244.
Layer, D. B., and Members of Staff, Imperial Oil Limited, Calgary, Alberta
1949: Leduc Oil Field, Alberta, a Devonian coral reef discovery; *Bull. Am. Assoc. Petrol. Geologists*, vol. 33, No. 4, pp. 572–602.
Leighton, M. W., and Pendexter, C.
1962: Carbonate rock types; *Am. Assoc. Petrol. Geologists*, Mem. I, Classification of carbonate rocks, pp. 33–61.
Lecompte, M.
1938: Quelques types de "récifs" Siluriens et Dévoniens de l'Amérique du Nord. Essai de comparison avec les récifs coraliens actuels; *Musée Roy. Hist. Nat. Belg.*, tome 14, No. 39, p. 51.
1956: Quelques précisions sur le phénomenon récifale dans le Dévonien de l'Ardenne et sur le rhythme sédimentaire dans lequel il s'entegre; *Inst. Roy. Sci. Nat. Belg.*, vol. 32, p. 39.
1959: Certain data on the genesis and ecologic character of Frasnian Reefs of the Ardenns; *Intern. Geol. Rev.*, vol. 1, No. 7, pp. 1–14.
Lowenstam, H. A.
1950: Niagaran reefs of the Great Lakes area; *J. Geol.*, vol. 58, pp. 430–487.
1955: Aragonite needles secreted by algae and some sedimentary implications; *J. Sediment. Petrol.*, vol. 25, pp. 270–272.
MacKenzie, W. S.
1961: The geology of the Mount Stornoway – Redan Mountain Carbonate Complex, Jasper Park, Alberta; M.A.Sc. Thesis, *Univ. Toronto*.
1964: The Southesk Cairn carbonate complex; *Edmonton Geol. Soc.*, Guide Book, 6th Ann. Field Trip, pp. 14–25.
1965: Northwest margin of Southesk Reef, Eastern Rocky Mountains, vicinity of Mount MacKenzie, Alberta; *Geol. Surv. Can.*, Paper 64–19.
1968: Upper Devonian carbonate mounds and lenses, vicinity of Mount MacKenzie and Cardinal Mountain, Alberta; *in* Intern. Symp. on the Devonian System, *Alberta Soc. Petrol. Geologists*, vol. II, pp. 409–418.
McConnell, R. G.
1886: Geological structure of a portion of the Rocky Mountains; *Geol. Surv. Can.*, Ann. Rept., pt. D, p. 20.
McCrossan, R. G.
1961: Resistivity mapping and petrophysical study of Upper Devonian inter-reef calcareous shales of central Alberta, Canada; *Bull. Am. Assoc. Petrol. Geologists*, vol. 45, pp. 441–470.

McKay, B. R.
1929: Mountain Park, Alberta; *Geol. Surv. Can.*, Map 208A.
McLaren, D. J.
1953: Summary of the Devonian stratigraphy of the Alberta Rocky Mountains; *Alberta Soc. Petrol. Geologists*, Guide Book, 3rd Ann. Field Conf., pp. 89–104.
1956: Devonian formations in the Alberta Rocky Mountains between Bow and Athabasca Rivers; *Geol. Surv. Can.*, Bull. 35 (1955).
1959: The role of fossils in defining rock units with examples from the Devonian of Western and Arctic Canada; *Am. J. Sci.*, vol. 257, pp. 734–751; *Geol. Surv. Can.*, Reprint 7.
McLaren, D. J., and Mountjoy, E. W.
1962: Alexo equivalents in the Jasper region, Alberta; *Geol. Surv. Can.*, Paper 62-23.
Mountjoy, E. W.
1961: Rocky Mountain Front Ranges along the Athabasca Valley, Jasper National Park, Alberta; *Edmonton Geol. Soc.*, Guide Book, 3rd Ann. Field Trip, pp. 14–41.
1962: Mount Robson (southeast) map-area, Rocky Mountains of Alberta and British Columbia; *Geol. Surv. Can.*, Paper 61-31.
1965: Stratigraphy of the Devonian Miette Reef Complex and associated strata, eastern Jasper National Park, Alberta; *Geol. Surv. Can.*, Bull. 110.
1968: Factors concerning the development of the Frasnian Miette and Ancient Wall reef complexes (banks and biostromes), Alberta, *in* Symp. on the Devonian System, *Alberta Soc. Petrol. Geologists*, vol. II, pp. 387–408.
Murray, R. C.
1960: Origin of porosity in carbonate rocks; *J. Sediment. Petrol.*, vol. 30, pp. 59–84.
Newell, N. D., and Rigby, J. K.
1957: Geological studies on the Great Bahama Bank; *Soc. of Econ. Paleontologists, Mineralogists*, Spec. Publ. No. 5, pp. 15–72.
Orme, G. R., and Brown, W. M.
1963: Diagenetic fabrics in the Avonian limestones of Derbyshire and North Wales; *Proc. Yorkshire Geol. Soc.*, vol. 34, pt. 1, pp. 51–66.
Pareyn, Claude
1959: Les récifs du Grand Erg occidental; *Bull. Soc. Geol. France*, Série 7, Tome 1, pp. 347–363.
Philcox, M. E.
1963: Banded calcite mudstone in the Lower Carboniferous "Reef" knolls of the Dublin basin, Ireland; *J. Sediment. Petrol.*, vol. 23, pp. 904–913.
Powers, R. W.
1962: Arabian Upper Jurassic carbonate reservoir rocks; *Am. Assoc. Petrol. Geologists*, Mem. 1, pp. 122–192.
Pray, L. C.
1960: Compaction in calcilutites (abstr.); *Bull. Geol. Soc. Am.*, vol. 71, p. 1946.
Purdy, E. G.
1963: Recent carbonate facies of the Great Bahama Bank, petrography and reaction groups; *J. Geol.*, vol. 71, pp. 334–355.
Raymond, P. E.
1930: The Paleozoic formations of Jasper Park, Alberta; *Am. J. Sci.*, 5th ser., vol. 20, pp. 289–307.
Rich, J. L.
1951: Three critical environments of deposition and criteria for recognition of rocks deposited in each of them; *Bull. Geol. Soc. Am.*, vol. 62, pp. 1–20.
Sander, Bruno K.
1936: Contributions to the study of depositional fabrics—rhythmically deposited Triassic limestones and dolomites; translated by E. B. Knopf: *Am. Assoc. Petrol. Geologists*, 207 pp. (1951).

Sonnenfeld, P.
1964: Dolomites and dolomitization; a review; *Bull. Can. Petrol. Geologists*, vol. 12, pp. 101–132.

Sorby, H. C.
1879: On the structure and origin of limestone; *Geol. Soc. London Quart. J.*, vol. 35, pp. 56–95.

Staplin, F. L.
1961: Reef-controlled distribution of Devonian microplankton in Alberta; *Palaeontology*, vol. 4, pp. 392–424.

Stehli, F. G., and Hower, J.
1961: Mineralogy and early diagenesis of carbonate sediments; *J. Sediment. Petrol.*, vol. 31, pp. 358–371.

Sujkowski, Zb. L.
1958: Diagenesis; *Bull. Am. Assoc. Petrol. Geologists*, vol. 42, pp. 2692–2717.

Taylor, P. W.
1957: Revision of Devonian nomenclature in the Rocky Mountains; *J. Alberta Soc. Petrol. Geologists*, vol. 5, pp. 183–195.

Thomas, G. E., and Glaister, R. P.
1960: Facies and porosity relationships in some Mississippian carbonate cycles of western Canada basin; *Bull. Am. Assoc. Petrol. Geologists*, vol. 44, pp. 569–588.

Van Stratten, L. M. J. U.
1959: Minor structures of some recent littoral and neritic sediments; *Geol. Mijnbouw*, n.w. ser. 21e, pp. 197–216.

Van Tuyl, F. M.
1916: The origin of dolomite; *Iowa Geol. Surv.*, vol. 25, pp. 251–422.

Voll, G.
1960: New work on petrofabrics; *Liverpool, Manchester Geol. J.*, vol. 2, pp. 503–567.

Wardlaw, N. C.
1962: Aspects of diagenesis in some Irish Carboniferous limestones; *J. Sediment. Petrol.*, vol. 32, pp. 776–780.

Waring, W. W., and Layer, D. B.
1950: Devonian dolomitized reef, D3 Reservoir, Leduc Field, Alberta, Canada; *Bull. Am. Assoc. Petrol. Geologists*, vol. 34, pp. 295–312.

Weyl, P. K.
1960: Porosity through dolomitization: Conservation-of-mass requirements; *J. Sediment. Petrol.*, vol. 30, pp. 85–90.

Wolf, K. H., and Warne, S. St. J.
1960: Remarks of the application of Friedman's staining methods; *J. Sediment. Petrol.*, vol. 30, pp. 496–497.

APPENDIX

Measured Sections

MEASURED SECTIONS

The measured sections described here were chosen to illustrate changes in lithology in the Fairholme Group sequence of sediments typical of deposition in the basinal areas away from the carbonate complex, through strata of the transition zone, to the relatively pure limestones and dolomites of the carbonate complex. Figure 7 shows the position of the sections chosen and their relation to the carbonate body. All measured sections do not occur along the same thrust sheet.

Changes in lithology were recorded in the field, and the thickness of each rock unit measured. Representative specimens were collected from each unit, and although all specimens were re-examined in the laboratory, the original field descriptions were little modified except for the addition of some data on insoluble residues.

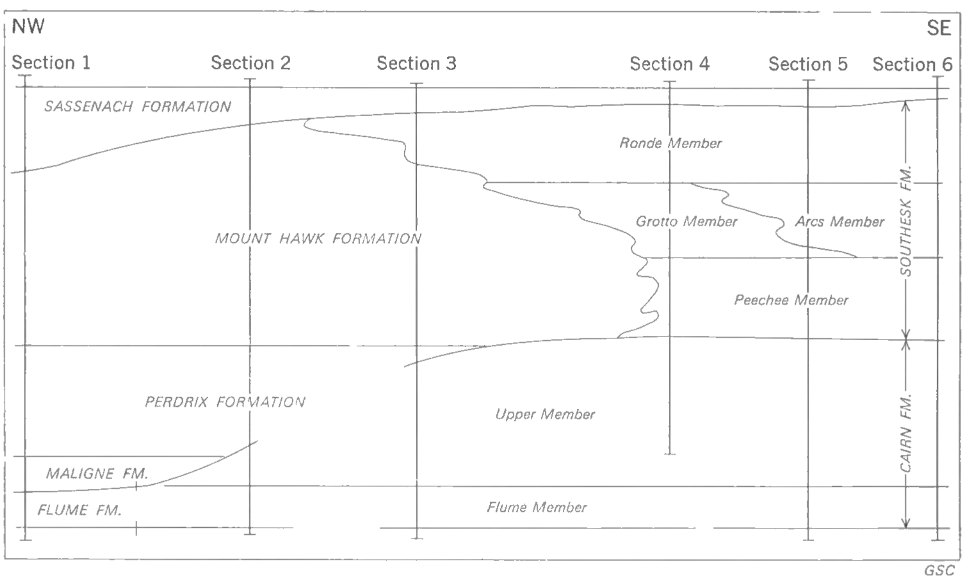


FIGURE 7. Sketch showing the relationship of measured sections described in the Appendix to the argillaceous and carbonate facies within the report area.

TABLE I | *Thicknesses of Formations and Members (in feet)*

Section	Flume Fm.	Maligne Fm.	Perdrix Fm.	Mt. Hawk Fm.	Sassenach Fm.	Cairn Fm.	Upper Mbr.	Flume Mbr.	Southesk Fm.	Ronde Mbr.	Arcs Mbr.	Grotto Mbr.	Peechee Mbr.
1. Southesk Lake	54	37	350	615	393								
2. Mount Meda				695	292	551	168						
3. Mount MacKenzie				754	48	485	413	72	153				
4. Mount Toma					35	300+	300+		620	265		170	185
5. Ruby Creek					18	697	561	136	682	112	188	90	292
6. Saracen Head					23	664	594	70	714	161	107		446

Section 1. Southesk Lake (53°38′ N, 117°15′ W); measured about 1 mile to the southwest of Southesk Lake where Upper Devonian strata and a few feet of the underlying Upper Cambrian outcrop along a steep north-facing slope. Only the dominantly argillaceous group of formations is present in this area which is about 12 miles northwest of the carbonate front at Sawtooth Mountain.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
38	Limestone, argillaceous, dolomitic and slightly silty; microcrystalline, dark grey; dolomite as brown-weathering, resistant mottling, partly nodular beds, remainder massive and cliff-forming; weathers light grey	75	1,524
	SASSENACH FORMATION (393 feet)		
	Upper Sandy Member (263 feet)		
37	Siltstone, argillaceous and dolomitic; fine- and medium-grained, partly sandy, light to medium grey; in moderately resistant 2″–18″ yellow-grey weathering beds	15	1,449
	Note: Unit 37 pinches out about 500′ to the northwest		
36	Limestone, argillaceous, microcrystalline, dark grey; in beds 2′–3′ thick; some dolomite mottling in lower part of unit; resistant beds weather light grey	43	1,434
35	Siltstone, dolomitic and argillaceous, fine- and medium-grained, medium to dark brown, pronounced dolomite mottling in part; in resistant beds; weathers yellow-grey	12	1,391
34	Siltstone, calcareous, fine- and medium-grained, medium to light grey; in moderately resistant beds 1′–2′ thick; fine crossbedding shows on weathered surfaces; weathers yellow-grey	29	1,379
33	Limestone, argillaceous and silty, finely crystalline, medium grey; well bedded in units 1′–2′ thick; pronounced dolomitic and silty mottling; moderately resistant; weathers yellow-grey	39	1,350

Unit	Lithology	Thickness (feet)	Height above base (feet)
	SASSENACH FORMATION		
	Upper Sandy Member (*cont.*)		
32	Limestone, argillaceous and silty, finely crystalline, medium grey; occurs in slightly recessive beds 3″–5″ thick; contains many fossil brachiopods; weathers orange-grey	64	1,311
31	Limestone, argillaceous and silty, finely crystalline, dark grey; in thin nodular beds about 3″ thick; contains fossil brachiopods, weathers yellow-grey	56	1,247
30	Limestone, silty and argillaceous, finely crystalline, dark brown-grey; contains a few brachiopods; in moderately resistant beds 2′–3′ thick; weathers orange-grey	5	1,191
	Lower Silty Mudstone Member (130 feet)		
29	Limestone, argillaceous, microcrystalline, dark grey, in part slightly silty; in nodular beds 2″–3″ thick with thin, intercalated beds of calcareous grey shale; weathers green-grey	26	1,186
28	Limestone, argillaceous and silty, finely crystalline, dark brown-grey; contains many large brachiopods; in massive, resistant beds 2′–3′ thick; weathers yellow-orange	5	1,160
27	Limestone, argillaceous, microcrystalline, dark grey; well bedded in units 3″–8″ thick; contains large brachiopods; weathers yellow-grey	41	1,155
26	Shale, calcareous, fissile and splintery; partly argillaceous limestone; indurated shale concretions common; recessive, dark grey	35	1,114
25	Limestone, very argillaceous, dark grey; numerous fossil remains; weathers light grey	2	1,079
24	Shale, calcareous, fissile and splintery, dark grey; recessive beds weather dark grey	21	1,077
	MOUNT HAWK FORMATION (615 feet)		
23	Limestone, argillaceous and partly silty, finely crystalline, dark grey-black; in resistant beds 8″–10″ thick; weathers orange-grey	34	1,056
22	Limestone, silty and argillaceous, finely crystalline, dark grey; in massive and resistant beds 2′–3′ thick; contains some thin, nodular limestone interbeds, a few scattered brachiopod remains; weathers medium grey	41	1,022
21	Limestone, very argillaceous, finely crystalline, dark grey-black; in recessive, nodular beds; weathers dark grey	37	981
20	Shale, calcareous, brittle and splintery with occasional beds of nodular argillaceous limestone; a recessive unit; weathers dark grey	128	944
19	Limestone, argillaceous, fine and microcrystalline, dark grey-black; in nodular units as thick as 3′; weathers medium grey	51	816
18	Shale, calcareous, fissile and splintery, tends to form spherical concretions, dark grey, recessive; weathers medium grey	106	765
17	Limestone with interbedded shale; limestone argillaceous, fine and microcrystalline, with calcareous dark grey shale; limestone beds 2′–4′ thick alternate with recessive and frequently talus covered shale intervals; weathers medium grey	63	659
16	Limestone, argillaceous, microcrystalline, dark grey to black, in beds as thick as 4″; many intercalated calcareous shale beds; grey-weathering	44	596

Unit	Lithology	Thickness (feet)	Height above base (feet)
15	Limestone, very argillaceous, microcrystalline, dark grey-black; shale, calcareous, dark grey; limestone beds extensively fractured; recessive, weathers medium grey	79	552
14	Shale, calcareous, slightly silty, hard and splintery; in plates as thick as 1½″, partly limestone; recessive beds weather dark grey	32	473
	PERDRIX FORMATION (350 feet)		
13	Shale, calcareous, soft, fissile, dark brown-grey; in recessive beds; weathers brown-grey	11	441
12	Shale, calcareous, thin-bedded, fissile, dark brown-grey, with some indurated platy beds; moderately resistant in part; weathers brown-grey	48	430
11	Limestone and interbedded shale; grey-black limestone in beds 2″–4″ thick; shale beds are as thick as 3″; moderately resistant unit; weathers brown-grey	26	382
10	Shale, calcareous, thin-bedded, fissile, dark brown-grey; recessive beds weather brown-grey	34	356
9	Shale, calcareous; occurs as brown-grey weathering outcrops in a partly talus covered interval	72	322
8	Shale, calcareous, soft, fissile, brown-grey; scattered, poorly preserved fossil remains; recessive beds weather brown-grey	44	250
7	Shale, very calcareous, fissile, dark grey to black; occurs with thin 1″–3″ beds of argillaceous dark grey limestone; partly covered; weathers dark grey	85	206
6	Shale, calcareous, fissile, dark brown-black; contains numerous *Tentaculites* sp. in thin limestone beds; recessive; weathers dark grey	30	121
	MALIGNE FORMATION (37 feet)		
5	Limestone, very argillaceous, finely crystalline, dark grey; in beds as thick as 6″; contains many brachiopod remains, numerous, thin, calcareous shale beds; unit more resistant than above; weathers dark grey	18	91
4	Limestone, argillaceous, fine and microcrystalline, dark grey-black; contains many brachiopod remains; in beds 2″–6″ thick, in part rubbly and fractured, resistant in upper part of unit; weathers dark grey	19	73
	FLUME FORMATION (54 feet)		
3	Dolomite, argillaceous, medium crystalline, dark grey-brown; contains chert nodules and silicified stromatoporoids; forms rather indistinct beds 2′–3′ thick; resistant, cliff-forming; weathers brown-grey	25	54
2	Dolomite, argillaceous and slightly silty, medium crystalline, dark brown, with lenses and nodules of black chert; beds as thick as 6″, a few argillaceous partings; resistant beds weather brown-grey	8	29
1	Dolomite, strongly argillaceous and slightly silty; dark brown-grey, with numerous thin beds of *Amphipora* and a few silicified stromatoporoids, a few nodules of black chert; resistant beds as thick as 4′ weather brown-grey	21	21

Unit	Lithology	Thickness (feet)	Height above base (feet)
	UPPER CAMBRIAN		
	Dolomite, medium and coarsely crystalline, light grey, silty, with thin intercalated beds of brown dolomite; forms massive resistant beds; weathers yellow-grey	30	

Section 2. Mount Meda (52°45′ N, 117°15′ W); measured on the southeast side of a small stream that flows along the southeast of Mount Meda northward into the Medicine Tent River. In this area, a calcareous reef margin facies of the Mount Hawk Formation is overlain disconformably by the Sassenach Formation Lower Silty Mudstone Member, and the Cairn Formation extends to the northwest beyond the margin of the carbonate complex.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
72	Limestone, argillaceous, fine and microcrystalline, dark grey; contains a few small brachiopods; some dolomitic mottling; resistant beds 1′–3′ thick weather light grey	30	1,660
71	Limestone, argillaceous and dolomitic, microcrystalline dark grey, with resistant brown dolomite mottling; in massive cliff-forming beds; weathers light grey	9	1,630
70	Dolomite, slightly silty, fine-grained, pale brown; in thin recessive beds, weathers yellow-grey	8	1,621
69	Limestone, argillaceous, finely crystalline, dark grey with brown dolomite mottling; resistant beds weather light grey	5	1,613
68	Limestone, slightly argillaceous, a fine- to medium-grained calcarenite; forms resistant beds 1′–3′ thick; weathers light grey	8	1,608
67	Siltstone, fine-grained, light brown; weathered surfaces show fine crossbedding; thin recessive beds weather yellow-grey	4	1,600
66	Limestone, slightly argillaceous, microcrystalline in upper part grading to a fine calcarenite at base of unit; resistant beds weather light grey	43	1,596
65	Siltstone, calcareous and silty limestone, fine-grained, light brown; pronounced silty laminations show on weathered surfaces; recessive beds weather yellow-grey	5	1,553
64	Limestone, silty and slightly argillaceous, finely crystalline, brown-grey, in part a fine calcarenite; in resistant light grey weathering beds	10	1,548
	SASSENACH FORMATION (292 feet)		
	Upper Sandy Member (115 feet)		
63	Siltstone, dolomitic, fine- and medium-grained, brown to light brown; in thin recessive beds; weathers orange grey	50	1,550

Unit	Lithology	Thickness (feet)	Height above base (feet)
62	Siltstone, dolomitic, fine-grained, light brown, with silt laminae showing on weathered surfaces; in thin, flaggy beds; recessive; weathers yellow-grey	23	1,500
61	Siltstone, slightly calcareous, fine-grained, medium grey; in recessive beds 4″–6″ thick; weathers yellow-grey	19	1,477
60	Siltstone, dolomitic, medium-grained, light and medium brown; in moderately resistant beds as thick as 3′; weathers orange-grey	23	1,458
	Lower Silty Mudstone Member (177 feet)		
59	Shale, calcareous, soft, fissile, in part silty, grey-green, with strong diagonal shearing; recessive; weathers grey-green	22	1,435
58	Limestone, argillaceous and slightly silty, medium and dark grey; resistant; weathers orange-grey	17	1,413
57	Shale, calcareous, soft, fissile, with strong diagonal shearing; fossiliferous throughout, small brachiopods poorly preserved in more calcareous beds; recessive; weathers grey-green	53	1,396
56	Limestone, argillaceous and silty, finely crystalline, dark grey, with scattered brachiopod remains; in beds 2′–3′ thick; weathers light grey	13	1,343
55	Shale, calcareous, grey with intercalated beds of argillaceous limestone; contains many fossil remains of brachiopods (*Cyrtiopsis mimetes* Crickmay and *Sinotectirostrum* sp., GSC loc. 48370); unit is recessive and weathers dark grey	56	1,330
54	Siltstone, dolomitic, fine- and medium-grained, medium brown; in thin, laminated beds 1″–3″ thick; a few silty shale beds; weathers yellow-grey	22	1,274
53	Siltstone, dolomitic and calcareous, fine-grained, medium grey; moderately resistant beds weather orange-grey	6	1,252
	MOUNT HAWK FORMATION (695 feet)		
52	Limestone, argillaceous and slightly silty, finely crystalline, dark grey-black; in fractured thin beds about 1′ thick, moderately resistant; weathers medium grey	62	1,246
51	Limestone, argillaceous, silty, microcrystalline, dark grey; contains numerous brachiopods (*Atrypa* sp., GSC loc. 48364) in thin beds near top of unit; occasional beds of calcareous, grey-green shale; weathers medium grey	30	1,184
50	Limestone, argillaceous, microcrystalline, dark grey-black; in massive beds as thick as 4′ made up of smaller 2″–3″ nodular units; weathers medium grey	14	1,154
49	Limestone, argillaceous, finely crystalline, dark grey-black, partly silty, with diagonally sheared shale interbeds; in nodular beds; weathers dark grey	16	1,140
48	Siltstone, calcareous and argillaceous, fine-grained, grey and dark grey with thin beds of dark grey silty shale; upper part of unit strongly calcareous and partly limestone; moderately resistant beds weather orange-grey	18	1,124
47	Limestone, argillaceous, with intercalated beds of calcareous shale, dark grey-black; in sheared and fractured nodular beds; moderately resistant beds weather dark grey	26	1,106

Unit	Lithology	Thickness (feet)	Height above base (feet)
	MOUNT HAWK FORMATION (*cont.*)		
46	Limestone, very argillaceous, fine and microcrystalline, dark grey-black, beds extensively sheared and fractured; weathers dark grey.	21	1,080
45	Limestone with interbedded calcareous shale, argillaceous, dark grey-black; in beds as thick as 8″ with 2″–3″ beds of calcareous grey shale; a moderately resistant unit; weathers medium grey	42	1,059
44	Limestone, argillaceous, dark grey, finely crystalline; contains a few fossil fragments; well-bedded, resistant; weathers medium grey	12	1,017
43	Limestone, argillaceous, microcrystalline, with numerous ½″ shale beds; numerous brachiopods (*Calvinaria albertensis* (Warren), GSC loc. 48377); recessive	11	1,005
42	Shale, calcareous, soft, fissile, medium brown-grey; many small brachiopods (*Warrenella* sp., GSC loc. 48376); recessive beds weather dark grey	53	994
41	Limestone, argillaceous, microcrystalline, dark grey-black; small scattered brachiopods; forms a thin, resistant, grey-weathering bed	5	941
40	Limestone, argillaceous, microcrystalline, dark grey; beds of yellow-weathering calcareous and silty shale; moderately resistant, weathers medium grey	27	936
39	Limestone, argillaceous, finely crystalline, dark grey-black in 4″–6″ beds with intercalated thin calcareous shale beds; small brachiopods (*Atrypa* sp., GSC loc. 48379) occur in the shale beds; weathers medium grey	22	909
38	Limestone, silty and argillaceous, with rhythmic alternation of shale beds, microcrystalline, dark grey, 1″–2″ thin nodular beds; numerous brachiopods (*Calvinaria albertensis* (Warren), GSC loc. 48366); weathers dark grey	34	887
37	Limestone, argillaceous, finely crystalline, dark grey, well-bedded, resistant; weathers dark grey	11	853
36	Limestone, very argillaceous, microcrystalline, dark grey, with thin rhythmic alternation of shale beds; some disseminated pyrite, scattered small brachiopods	30	842
35	Limestone, silty and argillaceous, finely crystalline, dark grey; many fossil fragments, weathers medium grey	4	812
34	Limestone, argillaceous and finely crystalline, dark grey; in resistant, nodular beds with interbedded brown-weathering shale; a few brachiopod remains; moderately resistant, dark grey	9	808
33	Limestone, argillaceous, fine and microcrystalline, dark grey-black; in rhythmic 6″ beds with 1″–2″ interbeds of brown-weathering shale; limestone beds extensively fractured and recemented with white calcite; weathers medium and dark grey	126	799
32	Limestone, argillaceous, finely crystalline, dark grey-black, with 1″–3″ beds of brown-weathering calcareous shale; appreciable amount of pyrite in small nodules and disseminated crystals; weathers dark grey	53	673
31	Limestone, argillaceous, finely crystalline, dark grey, with beds of calcareous shale, a few pyrite nodules; numerous fossil brachiopods (*Calvinaria variabilis insculpta* (McLaren), *C. variabilis athabascensis* (Kindle), GSC loc. 48384); weathers dark grey	55	620
30	Dolomite, argillaceous, finely crystalline, dark grey-black; forms resistant 1′–2′ dark grey weathering beds	14	565

Unit	Lithology	Thickness (feet)	Height above base (feet)
	CAIRN FORMATION (551 feet)		
	Upper Member (383 feet)		
29	Dolomite, argillaceous, medium crystalline, dark brown-black with many, large, irregularly shaped vugs as long as 3″ filled with sparry dolomite; resistant; weathers brown-grey	7	551
28	Dolomite, medium crystalline, brown-grey, with numerous calcite-filled vugs 1″ diameter; forms distinct 1′–2′ beds; weathers brown-grey	4	544
27	Dolomite, partly argillaceous, medium and finely crystalline; numerous *Amphipora* and globular stromatoporoids; some stromatoporoids weathered out and filled with sparry calcite; resistant beds weather brown-grey	23	540
26	Dolomite, argillaceous, medium crystalline, brown-grey; in nodular beds with numerous *Amphipora* and globular stromatoporoids; some solitary corals; weathers medium brown	26	517
25	Dolomite, very argillaceous, finely crystalline, dark brown; numerous *Amphipora* and a few globular stromatoporoids; recessive; brown-weathering	3	491
24	Dolomite, medium and finely crystalline, medium brown; many weathered-out, globular stromatoporoids; porous; cavernous beds weather brown-grey	47	488
23	Dolomite, silty, medium crystalline, medium brown, thin, resistant beds weather yellow-brown	8	441
22	Dolomite, argillaceous, medium crystalline, medium brown; in resistant brown-grey weathering beds	37	433
21	Dolomite, medium crystalline, brown-grey, well-bedded in 1′–2′ units; weathers brown-grey	41	396
20	Dolomite, finely and medium crystalline, medium brown; numerous weathered-out, globular stromatoporoids, a few solitary corals; good porosity; in cavernous, brown-weathering beds	135	355
19	Dolomite, argillaceous, finely crystalline, dark brown; in thin, recessive, nodular beds; weathers dark brown	25	220
18	Dolomite, medium crystalline, dark brown to almost black; many globular stromatoporoids, many weathered out to constitute good surface porosity; a few brachiopods near top of unit	26	195
17	Dolomite, medium crystalline, medium brown, a conspicuous, resistant, grey-weathering unit	1	169
	Flume Member (168 feet)		
16	Dolomite, argillaceous and slightly silty, finely crystalline, dark brown; numerous lenses and nodules of black chert, some corals and globular stromatoporoids; weathers dark brown	20	168
15	Dolomite, medium crystalline, medium brown; numerous globular stromatoporoids throughout; moderately resistant; weathers dark brown	40	148
14	Dolomite, argillaceous, finely and medium crystalline, dark brown; numerous globular stromatoporoids and abundant black chert; many stromatoporoids silicified; moderately resistant beds weather brown-grey	41	108

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Flume Member (*cont.*)		
13	Dolomite, argillaceous, dark brown to almost black, fine and microcrystalline, a few thin, silty beds; *Amphipora* and other stromatoporoids in thin beds; some thin beds of intraformational conglomerate	12	67
12	Dolomite, argillaceous, fine and microcrystalline, dark grey, with thin beds of *Amphipora* and scattered small globular stromatoporoids; yellow-weathering chert; resistant beds weather brown-grey	7	55
11	Dolomite, finely crystalline, silty and argillaceous; forms nodular yellow-brown beds	0.5	48
10	Dolomite, very argillaceous, finely and medium crystalline, dark brown-black; contains black chert lenses, *Amphipora* and globular stromatoporoids; weathers brown-grey	7.5	47.5
9	Dolomite, argillaceous, finely crystalline, dark brown; numerous *Amphipora* and globular stromatoporoids; in resistant light brown weathering beds	4	40
8	Dolomite, argillaceous and silty, finely crystalline, brown and dark brown; silty element is confined to thin beds; weathers brown-grey	19	36
7	Dolomite, slightly silty, medium crystalline, grey-brown; weathers light grey	0.5	17
6	Dolomite, argillaceous, finely crystalline; numerous *Amphipora*; recessive; brown-weathering	4	16.5
5	Dolomite, argillaceous, finely and medium crystalline, dark brown to almost black; 3″–4″ fragments of dark grey, argillaceous limestone; resistant; weathers brown-grey	5	12.5
4	Dolomite, argillaceous, finely crystalline, dark grey, partly silty; forms a persistent light grey weathering bed	2	7.5
3	Dolomite, argillaceous, and slightly silty, finely crystalline; silt laminae show on weathered surfaces; weathers brown-grey	2.5	5.5
2	Dolomite, silty and sandy, finely crystalline, medium grey; forms recessive yellow-brown weathering beds	1	3
1	Dolomite, argillaceous and slightly silty, finely crystalline, dark brown; silt laminations show fine crossbedding on weathered surfaces; weathers brown-grey	2	2
	UPPER CAMBRIAN		
	Dolomite, silty, finely crystalline, light brown; in 1′–2′, resistant, yellow-grey weathering beds	35	

Section 3. Mount MacKenzie (52°51′ N, 117°15′ W); measured along the west side of a northerly extending spur of Mount MacKenzie. Access is via an improved gravel road south and east from Mountain Park across "The Divide" to the valley of the Cardinal River and thence south about 3 miles on foot or horseback along a seismic line and trail to near the base of the section. In this area the uppermost limestones of the Southesk Formation extend westward as a tongue and overlie a reef margin facies of the Mount Hawk Formation. Only the uppermost beds of the Sassenach Formation Upper Sandy Member occur here above the disconformity.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
53	Limestone, argillaceous, medium to dark grey, finely crystalline; forms 1′–3′ resistant, light grey weathering beds	35	1,475
	SASSENACH FORMATION (48 feet)		
	Upper Sandy Member (48 feet)		
52	Siltstone, dolomitic and argillaceous, dark brown-grey, medium-grained; average particle diameter about 50 microns; in 1′–2′ recessive, yellow-weathering beds	5	1,440
51	Siltstone, dolomitic, medium brown, coarse-grained; average particle diameter 65 microns; quartz grains poorly sorted, subrounded; 6″–8″ moderately resistant beds weather yellow-grey	17	1,435
50	Limestone, silty and argillaceous, dark grey, finely crystalline; silty element of well-sorted, subrounded quartz grains 70 microns average diameter; 1′–2′ cliff-forming beds weather light grey	7	1,418
49	Siltstone, dolomitic, medium brown, coarse-grained; quartz grains excessively pitted and corroded; weathered surfaces show fine crossbedding; in 6″–1′ recessive, yellow-grey weathering beds	19	1,411
	SOUTHESK FORMATION (153 feet)		
	Ronde Member (153 feet)		
48	Limestone, silty and slightly argillaceous, medium brown, finely crystalline; silty element of subangular and subrounded quartz grains 65 microns average diameter; 6″–8″ resistant beds weather pale yellow-grey	3	1,392
47	Limestone, silty and argillaceous, medium-grey, finely crystalline; silty element of subrounded quartz grains 65 microns average diameter; contains resistant, orange-weathering, silty lenses and stringers; colonial coral remains, *Amphipora*, and globular stromatoporoids are abundant; 2′–4′ cliff-forming beds weather light grey	44	1,389
46	Siltstone, dolomitic, and slightly argillaceous, medium brown, coarse-grained; average particle size 65 microns; 6″–8″ recessive beds weather brown-grey	6	1,345
45	Limestone, slightly argillaceous, medium grey, finely crystalline; contains fragments of *Amphipora* and other stromatoporoids; in resistant, light grey weathering beds	7	1,339
44	Siltstone, argillaceous, medium grey, medium-grained; in thin, platy beds 1″–2″ thick; weathers brown-grey	6	1,332
43	Limestone, slightly silty and slightly argillaceous, medium grey, finely crystalline; silty element consists of corroded quartz grains 60 microns average diameter; contains abundant skeletal remains; 1′–3′ cliff-forming beds weather light grey	19	1,326
42	Siltstone, dolomitic, medium brown, coarse-grained; contains silicified fragments of globular stromatoporoids and other unidentified silicified skeletal remains; in 4″–8″ recessive, orange-weathering beds	37	1,307
41	Covered interval; appears to consist of siltstone as in unit 12 where exposed high on the cliff-face	5	1,270

Unit	Lithology	Thickness (feet)	Height above base (feet)
	SOUTHESK FORMATION		
	Ronde Member *(cont.)*		
40	Siltstone, dolomitic, light to medium brown, coarse-grained; average particle diameter 65 microns; weathered surfaces show fine crossbedding; in 4″–6″ recessive, orange-weathering beds	26	1,265
	MOUNT HAWK FORMATION (754 feet)		
39	Limestone, argillaceous, dark grey, fine and microcrystalline with a little irregular resistant dolomitic mottling. Medium grey weathering beds 1′–3′ thick are moderately resistant. Algal structures, scattered small colonial and solitary corals, a few *Amphipora* and brachiopod fragments occur throughout. *Thamnophyllum* cf. *T. tructense* and *Gypidula* sp.	36	1,239
38	Limestone, silty and argillaceous, finely crystalline, brown-grey; forms distinct, resistant, brown-weathering beds 1′–3′ thick	15	1,203
37	Limestone, argillaceous, silty in part, fine and microcrystalline, dark grey. Beds from 6″ to 1′ thick; weathers dark grey, moderately recessive	6	1,188
36	Limestone, argillaceous and silty, fine and microcrystalline, dark grey; in beds from 6″ to 2′ thick. Beds weather yellow-grey, moderately resistant	15	1,182
35	Limestone, silty and argillaceous, fine and microcrystalline, dark grey; in discrete massive beds 2′–3′ thick that are cliff-forming and weather orange-grey. Resistant, orange-weathering, silty patches produce a pronounced mottled effect	14	1,167
34	Limestone, argillaceous, fine and microcrystalline, dark grey; in medium grey, resistant beds 1′–2′ thick	14	1,153
33	Limestone, silty and argillaceous, finely crystalline, dark grey; in brown-grey resistant beds about 2′ thick	2	1,139
32	Limestone, argillaceous with occasional beds of silty limestone as in the previous unit, fine and microcrystalline, dark grey; in indistinct, highly fractured beds 1′–2′ thick. The poorly bedded strata unite to form massive, resistant, light grey weathering units about 5′ thick	43	1,137
31	Limestone, argillaceous and silty, finely crystalline, dark grey; in indistinctly bedded, recessive, brown-weathering units	10	1,094
30	Limestone, argillaceous, slightly silty in part, fine and microcrystalline; in indistinct highly fractured, moderately resistant, brown-grey weathering beds	37	1,084
29	Limestone, argillaceous, with traces of slightly silty limestone; in distinct light grey weathering, cliff-forming beds 1′–2′ thick	44	1,047
28	Limestone, argillaceous, fine and microcrystalline, dark grey; in brittle, highly fractured, indistinct beds. Beds are cliff-forming and weather light grey	18	1,003
27	Limestone, argillaceous and silty, fine and microcrystalline, dark grey; in indistinct beds which form resistant yellow-weathering units 2′–3′ thick. Numerous brachiopods in small argillaceous lenses	10	985
26	Limestone, shaly, microcrystalline, dark grey; in thin nodular and irregular beds 1″–2″ thick. Strata weather dark grey, moderately recessive	7	975

Unit	Lithology	Thickness (feet)	Height above base (feet)
25	Covered interval	61	968
24	Limestone, argillaceous, partly silty, finely crystalline; in irregular, indistinct, moderately resistant beds 6″–18″ thick	29	907
23	Limestone, argillaceous, fine and microcrystalline, dark grey; in nodular, moderately resistant, yellow-grey weathering beds 2″–6″ thick. Small brachiopods and other comminuted fossil remains are numerous	22	878
22	Limestone, argillaceous, fine and microcrystalline; in nodular, grey-weathering, moderately resistant beds 1″–2″ thick. A few scattered brachiopods	12	856
21	Limestone, argillaceous, fine and microcrystalline, dark grey; in nodular, moderately resistant, grey-weathering beds 1″–3″ thick; contains a few scattered brachiopods and some crinoid fragments	25	844
20	Covered interval	100	819
19	Limestone, argillaceous, fine and microcrystalline, dark grey; in irregular indistinct, yellow-grey weathering beds 1′–3′ thick. Beds are brittle and contain numerous, fine, calcite-filled fractures, a few brachiopod fragments	3	719
18	Covered interval	23	716
17	Limestone, argillaceous, microcrystalline, dark grey; in nodular, grey-weathering, moderately resistant beds about 2′ thick	5	693
16	Covered interval	72	688
15	Covered interval limited at the top by a 6″ exposure of limestone, argillaceous, finely crystalline, dark grey, containing numerous small brachiopods	87	616
14	Limestone, argillaceous, finely crystalline; dark grey, in thin, nodular beds; contains a few fossil fragments	16	529
13	Covered interval	28	513
	CAIRN FORMATION (485 feet)		
	Upper Member (413 feet)		
12	Covered interval	35	484
11	Dolomite, partly argillaceous, fine and medium crystalline, dark brown; in rubbly, cavernous-weathering, indistinct, resistant, brown-grey weathering beds. *Amphipora* and other stromatoporoids are numerous throughout	161	449
10	Dolomite, medium crystalline, light grey; in distinct, light grey weathering, resistant beds from 1′–3′ thick	8	288
9	Dolomite, argillaceous, medium crystalline, dark brown; in indistinct, brown, moderately resistant beds. *Amphipora* and stromatoporoids are numerous throughout; many fine dolomite-filled fractures	31	280
8	Dolomite, slightly argillaceous, medium crystalline, dark brown; in distinct dark brown weathering, moderately resistant beds 2″–1′ thick	24	249
7	Covered interval	19	225
6	Dolomite, slightly argillaceous, medium crystalline, brown; in distinct, light brown weathering beds 1′–2′ thick.	7	206

Unit	Lithology	Thickness (feet)	Height above base (feet)
	CAIRN FORMATION		
	Upper Member (*cont.*)		
5	Dolomite, argillaceous, finely and medium crystalline, dark brown, in indistinct, rubbly and cavernous, brown-weathering units 4′–5′ thick. Numerous globular stromatoporoids 2″–4″ in diameter occur throughout	78	199
4	Partly covered interval; scattered small outcrops throughout; dolomite, argillaceous, finely crystalline, dark brown; scattered *Amphipora* and other stromatoporoids occur; unit is recessive	50	121
	Flume Member (72 feet)		
3	Dolomite, argillaceous, partly silty, finely crystalline; partly medium crystalline, dark brown; in indistinct, rubbly, brown-weathering, moderately resistant beds 2′–4′ thick. Black chert in nodular, pinching and swelling beds as well as scattered *Amphipora* and stromatoporoids	35	71
2	Dolomite, slightly silty, finely crystalline, dark brown; in distinct, yellow-brown weathering, resistant beds 4″–1′ thick. Lenses and nodules of black chert occur over a short interval about 6′ above base of unit. Resistant, silty laminations are conspicuous weathering features	15	36
1	Partly covered interval. Scattered outcrops consist of dolomite, argillaceous and slightly silty, finely crystalline, dark brown to almost black; scattered *Amphipora* occur in thin, more argillaceous beds. Black chert lenses and nodules about 10′ below the top of the unit	21	21
	UPPER CAMBRIAN		
	Dolomite, silty and sandy, finely and medium crystalline, light brown; in distinct, light yellow-grey weathering, cliff-forming beds 1′–2′ thick. Fine crossbedding manifested by resistant silt laminations on the weathered surfaces	77	

Section 4. Mount Toma (52°49′ N, 117°13′ W); measured along the west side of a cirque at the headwaters of a small stream flowing southwest from Mount Toma into the Medicine Tent River. The section is located within the carbonate complex, but near its western margin where only the Peechee, Grotto, and Ronde Members of the Southesk Formation are present.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
22	Limestone, argillaceous and dolomitic, dark grey, finely crystalline, with pronounced brown dolomite mottling; 1′–3′ thick cliff-forming beds weather light grey	60	1,015

Unit	Lithology	Thickness (feet)	Height above base (feet)
	SASSENACH FORMATION (35 feet)		
	Upper Sandy Member (35 feet)		
21	Partly covered interval, with scattered outcrops of siltstone, dolomitic, light brown, coarse grained; in recessive yellow-grey weathering beds	35	955
	SOUTHESK FORMATION (620 feet)		
	Ronde Member (265 feet)		
20	Limestone, dolomitic, light brown, microcrystalline; stromatoporoid and bryozoan fragments in lower part of unit; 2″–4″ recessive beds weather yellow-grey	23	920
19	Limestone, slightly argillaceous, medium brown, microcrystalline with areas of fine- and medium-grained calcarenite; in 1′–3′ resistant, light grey weathering beds	13	897
18	Limestone, medium brown, a fine- to medium-grained calcarenite with numerous calcispheres, a few brachiopod remains; 1′–2′ resistant beds weather light grey	130	884
17	Limestone, medium brown, a fine- to medium-grained calcarenite with a few fragments of branching *Amphipora*; resistant beds weather light grey	20	754
16	Dolomite, light brown, medium crystalline, in part slightly silty; in 6″–1′ beds, weathers light grey	15	734
15	Dolomite, medium brown, medium crystalline, with numerous *Amphipora* and globular stromatoporoids; good intercrystalline porosity in part; weathers medium brown	8	719
14	Dolomite, silty and slightly argillaceous, medium to dark brown, medium crystalline, silty laminations show on weathered surfaces; 6″–1′ recessive beds weather pale grey	17	711
13	Siltstone, dolomitic and slightly argillaceous, medium brown, medium-grained; in thin, recessive 2″–4″ beds; weathers pale grey	39	694
	Grotto Member (170 feet)		
12	Dolomite, argillaceous, dark brown, finely and medium crystalline, with numerous branching *Amphipora* and other unidentifiable fossil remains; weathers brown-grey	5	655
11	Dolomite, argillaceous, dark grey to almost black, finely crystalline; *Amphipora* abundant in upper part of unit; thin, 1″–2″ recessive beds weather medium brown	80	650
10	Dolomite, argillaceous, medium brown-grey, finely crystalline with small brachiopod remains showing on weathered surfaces, a little porosity in small calcite-lined vugs; in 2″–6″ moderately resistant, yellow-brown weathering beds	8	570
9	Dolomite, argillaceous, dark brown, medium crystalline, weathers brown-grey	20	562
8	Dolomite, argillaceous, dark brown, finely and medium crystalline; contains a few branching *Amphipora* in upper part of unit; beds extensively fractured; weathers brown-grey	57	542

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Peechee Member (185 feet)		
7	Dolomite, light grey, coarsely crystalline, with good intercrystalline porosity, some in small vugs; in distinct 1′–3′ resistant, light grey weathering beds	30	485
6	Dolomite, light and medium brown, coarsely crystalline with good intercrystalline porosity; beds uniformly 3′ thick; weathers light grey	30	455
5	Dolomite, light and medium brown, coarsely crystalline with good intercrystalline and vuggy porosity; distinct, 3′ beds weather light grey	25	425
4	Limestone, dolomitic, medium brown, finely crystalline, partly a medium-grained calcarenite; contains a few solitary corals and branching *Amphipora* and numerous fragments of globular stromatoporoids; weathers medium grey	20	400
3	Dolomite, medium brown-grey, coarsely crystalline; in resistant, cliff-forming beds; weathers light grey	33	380
2	Dolomite, light grey, coarsely crystalline with good intercrystalline and vuggy porosity, a few scattered *Amphipora* remains; distinct, 3′ beds weather light grey	47	347
	CAIRN FORMATION		
	Upper Member		
1	Dolomite, argillaceous, dark brown to almost black; contains numerous *Amphipora* and globular stromatoporoids, good porosity in small vugs; weathers brown-grey	300	300

Section 5. Ruby Creek (52°47′ N, 117°09′ W); measured along the southeast side of a small stream that flows from a cirque between Mount McBeath and Mount Lagrace northeast into Ruby Creek. Several feet of Upper Cambrian strata and the overlying Cairn and Southesk Formations are continuously exposed. In this interior region of carbonate deposition, away from the margins of the carbonate complex, the Arcs Member of the Southesk Formation attains nearly maximum thickness, whereas the underlying Grotto Member is much thinner in these areas.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
90	Limestone, argillaceous and slightly silty, dark grey, finely crystalline; insoluble residue predominantly of authigenic feldspar grains 25 microns average diameter; in 3′–4′ cliff-forming, light grey weathering beds	67	1,473

Unit	Lithology	Thickness (feet)	Height above base (feet)
	SASSENACH FORMATION (18 feet)		
	Upper Sandy Member (18 feet)		
89	Sandstone, dolomitic, fine-grained; consists of subrounded quartz grains 80 microns average diameter; in flaggy, recessive, orange-yellow weathering beds	6	1,406
88	Limestone, sandy and argillaceous, medium grey, finely crystalline; sandy element of 80-micron subrounded quartz grains with overgrowths; occurs as 6″–8″ resistant, light grey weathering beds	5	1,400
87	Sandstone, dolomitic and calcareous, fine-grained, medium brown, of moderately well sorted and pitted quartz grains 65 microns average diameter; in 6″–8″ moderately resistant, orange-brown weathering beds	5	1,395
86	Dolomite, silty and sandy, medium brown; sandy element of pitted and corroded quartz grains 65 microns average diameter; pronounced silty laminations show on weathered surfaces; resistant, 6″–1′ beds weather brown-grey	2	1,390
	SOUTHESK FORMATION (682 feet)		
	Ronde Member (112 feet)		
85	Limestone, medium brown, microcrystalline, with numerous, irregularly shaped eyes of clear sparry calcite; insoluble residue predominantly of authigenic feldspar; 1′–3′ resistant beds weather light grey	17	1,388
84	Limestone, argillaceous, silty and sandy, finely crystalline, dark grey; insoluble element occurs as moderately well-sorted quartz grains 75 microns average diameter, some as much as 180 microns; 1′–2′ medium grey weathering beds	12	1,371
83	Limestone, argillaceous and sandy, finely crystalline, dark grey; sand as 65-micron, subrounded and pitted quartz grains; in thin, platy, 1″–3″ moderately recessive, grey-weathering beds	2	1,359
82	Sandstone, fine grained, calcareous, medium brown; sand of corroded and pitted quartz grains 70 microns average diameter; fine crossbedding shows as sandy laminations on weathered surfaces; forms a persistent, orange-brown weathering bed	4	1,357
81	Limestone, with a trace of fine silt, medium brown; a calcirudite of tabular and irregularly shaped, frequently sub-horizontally aligned fragments of microcrystalline calcite as much as 4 mm maximum dimension in a clear sparry calcite cement; pelletoid pockets in interspaces between the larger elements; insoluble residues: 60 per cent slightly corroded, authigenic quartz grains as much as 50 microns in diameter; 40 per cent 40-micron diameter subrounded and corroded quartz grains; forms 6″–1′ resistant, light grey weathering beds	15	1,353
80	Limestone, trace of fine silt, medium brown, finely crystalline; contains irregularly shaped eyes and blebs of clear sparry calcite; silty element consists of extensively corroded authigenic quartz grains; in distinct 2′–3′ pale grey weathering, resistant beds	21	1,338
79	Limestone, light brown, finely crystalline with slight, insoluble residue of corroded authigenic quartz crystals, well bedded in 2′–3′ units, resistant, light grey weathering beds	8	1,317

Unit	Lithology	Thickness (feet)	Height above base (feet)
	SOUTHESK FORMATION		
	Ronde Member (*cont.*)		
78	Limestone, argillaceous and silty, dark grey, finely crystalline; silty element of poorly sorted, subrounded quartz grains 40 microns average diameter; in 6″–8″ grey-weathering beds	25	1,309
77	Partly covered interval, with scattered outcrops of dolomite, silty, dark grey, finely crystalline; silt occurs as poorly sorted, subrounded quartz grains 40 microns average diameter; silty laminations show on weathered surfaces; in recessive orange-yellow weathering beds	8	1,284
	Arcs Member (188 feet)		
76	Limestone, trace only of insoluble residue, largely authigenic feldspar, medium brown, microcrystalline; in resistant grey-weathering beds	146	1,276
75	Limestone, light brown, microcrystalline, numerous irregularly shaped eyes and blebs of sparry calcite, partly leached to constitute good vuggy porosity; porosity reduced by precipitation of secondary dolomite in open vugs; in resistant, light grey weathering beds	25	1,130
74	Limestone, light brown, microcrystalline, partly dense and partly slightly porous with irregularly shaped, sparry calcite eyes leached and almost completely filled with secondary dolomite; in massive 6′–8′ resistant, light grey weathering beds	17	1,105
	Grotto Member (90 feet)		
73	Limestone, slightly argillaceous, dark grey, microcrystalline, a recessive, extensively fractured zone	2	1,088
72	Limestone, slightly argillaceous with trace of fine silt, brown-grey, microcrystalline; numerous *Amphipora*, massive 1′–3′ beds weather light grey	7	1,086
71	Limestone, slightly argillaceous with trace of fine 10- to 15-micron silt, dark brown, microcrystalline; a few *Amphipora*, numerous calcispheres and scattered, irregularly shaped blebs of sparry calcite; forms 4′–5′ light grey weathering beds	16	1,079
70	Dolomite, dark grey to almost black, finely crystalline with numerous *Amphipora*; constitutes a single laterally persistent bed	1	1,063
69	Limestone, trace of corroded, authigenic quartz as insoluble residue, brown-grey, microcrystalline; numerous *Amphipora* with peripheral vesicles frequently occupied by sparry dolomite, also abundant unidentified fossil remains, some possible ostracods; limestone has clotted appearance, well-bedded; weathers light grey	7	1,062
68	Dolomite, light brown, medium crystalline; contains stromatoporoids, a cavernous-weathering unit	3	1,055
67	Dolomite, dark brown-grey, medium crystalline; a few, light grey weathering stromatoporoids and scattered *Amphipora*; forms indistinct, light grey weathering beds	5	1,052
66	Dolomite, brown, medium crystalline with light grey weathering stromatoporoids; forms resistant brown-grey weathering beds	15	1,047

Unit	Lithology	Thickness (feet)	Height above base (feet)
65	Limestone, dark grey; a fine calcarenite with frequently merged and rounded grains 150 microns average diameter, and broken and rounded tabular microcrystalline algal laminae in a sparry calcite cement; some preferred dolomitization of the sparry calcite cement contains numerous *Amphipora* fragments, a few calcispheres and ostracods; 2′–4′ resistant beds weather light grey......	34	1,032
	Peechee Member (292 feet)		
64	Limestone, light brown, predominantly a fine calcarenite; rounded grains 150 microns average diameter with denser laminated areas; frequently has a stirred-up appearance, contains irregularly shaped eyes of sparry calcite; a little preferred dolomitization of the sparry calcite areas; extensively fractured beds weather light grey..........	40	998
63	Dolomite, light brown, coarsely crystalline, sucrosic texture, partly friable with good intergranular porosity; in recessive, yellow-grey weathering beds..........	2	958
62	Limestone, light brown, an intraformational conglomerate or very coarse calcirudite; of poorly size and shape sorted, large, composite fragments and smaller microcrystalline grains in a clear sparry calcite cement; cement partly altered by dolomitization; the large composite fragments consist partly of alternations of dense algal laminae and fine calcarenite; forms a massive, light grey weathering bed..........	2	956
61	Dolomite, light brown, coarsely crystalline, partly friable with good vuggy and intercrystalline porosity; weathers light grey..........	11	954
60	Dolomite, pale brown, coarsely crystalline, friable, excellent vuggy and intercrystalline porosity; a recessive, light grey weathering bed	1	943
59	Limestone, dolomitic with local, completely dolomitized patches, medium brown, medium crystalline; dolomite rhombs show on weathered surfaces; in 5′ light grey weathering beds..........	70	942
58	Dolomite, argillaceous, dark brown and medium brown, finely and medium crystalline, with fair porosity in numerous small $\frac{1}{8}''$ diameter vugs, numerous *Amphipora*; in recessive, nodular, extensively fractured, dark grey weathering beds..........	11	872
57	Dolomite, light to medium grey, medium and coarsely crystalline, with fair to good porosity in small $\frac{1}{4}''$ diameter, partly calcite-filled vugs; a few *Amphipora* massive, resistant beds weather light grey..........	42	861
56	Dolomite, argillaceous, dark grey to almost black, finely crystalline, extensively fractured and recemented by white dolomite; poorly preserved solitary corals, brachiopods and *Amphipora* recognized in scattered thin beds; recessive beds weather dark grey..........	7	819
55	Dolomite, slightly argillaceous, brown-grey, medium crystalline; pronounced argillaceous laminations on weathered surfaces suggest fine crossbedding; in massive brown-grey weathering beds....	13	812
54	Dolomite, medium grey, medium and coarsely crystalline with good intercrystalline and vuggy porosity; massive, resistant 2′–5′ beds weather light grey..........	8	799
53	Limestone, slightly argillaceous, extensively dolomitized, dark grey to almost black, microcrystalline; contains scattered, thin beds of *Amphipora*; in recessive, yellow-grey weathering beds..........	3	791

Unit	Lithology	Thickness (feet)	Height above base (feet)
	SOUTHESK FORMATION (*cont.*)		
	Peechee Member (*cont.*)		
52	Dolomite, medium grey, medium crystalline; in cavernous, indistinct, light grey weathering beds	5	788
51	Unit partly talus covered, with scattered outcrops of dolomite, slightly argillaceous, dark grey to almost black, coarsely crystalline; contains a few thin beds with *Amphipora*; in thin 2″–4″ recessive, grey-weathering beds	26	783
50	Limestone, medium grey, a fine calcarenite with scattered tabular, microcrystalline fragments as long as ½″, average grain diameters 150 microns; contains unidentifiable fossil remains, calcispheres and ostracods; massive 2′–3′ resistant beds weather light grey	12	757
49	Dolomite, light grey, coarsely crystalline, good porosity in vuggy zones with preferred horizontal lineation of the vugs; thin, locally unaltered patches of medium brown-grey limestone occur sporadically; 4′ units with low amplitude, stylolitic bedding surfaces weather light grey	15	745
48	Limestone, slightly dolomitic, medium brown, microcrystalline, with scattered sparry calcite eyes and small isolated finely calcarenitic areas; numerous calcispheres and abundant unidentifiable fossil remains; resistant, 2′–3′ beds weather light grey	7	730
47	Dolomite, light brown, coarsely crystalline with fair to good intercrystalline porosity; in light grey weathering beds	7	723
46	Limestone, light brown, microcrystalline with irregularly shaped eyes of sparry calcite; in 1′–3′ resistant, light grey weathering beds	2	716
45	Dolomite, light brown, coarsely crystalline, texture partly sucrosic, fair porosity in fine, pin-point size vugs; forms light grey weathering beds	2	714
44	Limestone, light brown, microcrystalline, with eyes of sparry calcite; contains abundant calcispheres and unidentifiable fossil remains; 1′–3′ resistant beds weather light grey	2	712
43	Dolomite, light grey, coarsely crystalline, fair to good intercrystalline porosity; 1′–5′ recessive beds weather yellow-grey	3	710
42	Limestone, dolomitic, light brown, microcrystalline, finely laminated, with eyes of sparry calcite; dolomitization has effected the vesicular opening of numerous *Amphipora*; a few ostracods and abundant calcispheres; weathers light grey	1	707
	CAIRN FORMATION (706 feet)		
	Upper Member (570 feet)		
41	Dolomite, argillaceous, dark brown to almost black; abundant *Amphipora* throughout; recessive beds weather dark brown-grey	10	706
40	Dolomite, slightly argillaceous, dark brown, medium crystalline, a little porosity in small ⅛″ diameter vugs; weathers light grey	14	696
39	Dolomite, argillaceous, dark brown to almost black, medium crystalline, occurs as a persistent light grey weathering bed	3	682
38	Dolomite, light grey, medium crystalline, a little porosity in small ⅛″ diameter vugs; forms massive light grey weathering beds	4	679

Unit	Lithology	Thickness (feet)	Height above base (feet)
37	Dolomite, argillaceous, dark brown, finely and medium crystalline, scattered beds of numerous *Amphipora* and a few stromatoporoids; in moderately resistant, grey-weathering beds	41	675
36	Dolomite, medium grey, finely and medium crystalline with numerous, fine, calcite-filled fractures; a few thin beds of *Amphipora* and some globular stromatoporoids; in moderately resistant, grey-weathering beds	23	634
35	Dolomite, medium grey, medium crystalline, with fair porosity in ¼″ diameter vugs; a resistant light grey weathering bed	3	611
34	Dolomite, slightly silty, medium grey, finely crystalline, shows fine, horizontal laminations on fresh and weathered surfaces; in 2″–4″ recessive, brown-weathering beds	9	608
33	Dolomite, medium grey, medium crystalline, good intercrystalline porosity and in small ¼″ diameter vugs; many vugs partly filled with white sparry calcite; a few thin *Amphipora* beds; forms a resistant, light grey weathering unit	4	599
32	Dolomite, argillaceous, dark grey, finely crystalline, numerous *Amphipora*, a few solitary corals, some gastropods and brachiopods; forms recessive, grey-weathering beds	3	595
31	Dolomite, light grey, medium and coarsely crystalline, numerous globular stromatoporoids and scattered *Amphipora* in thin beds; cavernous, grey-weathering	61	592
30	Dolomite, slightly argillaceous, light to medium grey, medium crystalline; contains numerous *Amphipora*; forms a single, light grey weathering bed	2	531
29	Dolomite, slightly argillaceous, dark grey, finely crystalline; numerous fossil ghosts preserved, gastropods, brachiopods, small solitary corals, *Amphipora*, and other stromatoporoids; forms moderately resistant, brown-grey weathering beds	88	529
28	Dolomite, slightly argillaceous, trace of fine silt, grains 15 microns average diameter, light to medium grey, finely crystalline; resistant beds weather light grey	3	441
27	Dolomite, slightly argillaceous, dark brown to almost black, thin zones of numerous *Amphipora* and a few grey-weathering stromatoporoids; forms nodular, indistinct, dark grey weathering beds	35	438
26	Dolomite, argillaceous, trace of fine silt grains 15 microns average diameter, dark grey-brown, finely crystalline; numerous solitary corals and a few thin beds of *Amphipora*; forms alternating, well-bedded and nodular units about 5′ thick; grey-weathering	45	403
25	Dolomite, argillaceous, dark grey to almost black, finely and medium crystalline; a few thin *Amphipora* beds; distinct, 3″–6″ beds weather medium grey	42	358
24	Dolomite, brown-grey, finely crystalline, partly friable; forms indistinct moderately recessive, grey-weathering beds	23	316
23	Dolomite, slightly argillaceous, dark brown-grey, finely crystalline; numerous *Amphipora* throughout and many small ¼″ diameter, calcite-filled vugs, moderately well bedded; grey-weathering	25	293
22	Dolomite, slightly argillaceous, brown-grey, finely crystalline, occasional ½″ diameter calcite filled vugs; forms recessive 2″–4″ brown-grey weathering beds	24	268
21	Dolomite, argillaceous, dark brown-grey, medium and finely crystalline; numerous *Amphipora* throughout; in 2″–4″ grey-weathering beds	4	244

Unit	Lithology	Thickness (feet)	Height above base (feet)
	CAIRN FORMATION (*cont.*)		
	Upper Member (*cont.*)		
20	Dolomite, argillaceous, dark brown-grey, finely crystalline; in indistinct, nodular brown-weathering beds	20	240
19	Dolomite, very argillaceous with trace of fine silt, grains 15 microns average diameter, dark grey, finely crystalline; silty laminations frequently visible on weathered surfaces; in 4″–8″ brown-grey weathering beds	34	220
18	Dolomite, argillaceous, dark brown, medium crystalline; numerous silicified stromatoporoids and a few thin beds of *Amphipora*; in 2″–6″ resistant, grey-weathering beds	29	186
17	Covered interval	21	157
	Flume Member (136 feet)		
16	Dolomite, slightly argillaceous, medium brown, finely crystalline, with many calcite-lined, $\frac{1}{4}$″–$\frac{1}{8}$″ diameter vugs; numerous lenses and nodules of black and grey chert; weathers brown-grey	13	136
15	Dolomite, slightly argillaceous, dark grey to almost black, finely crystalline, abundant light grey weathering stromatoporoids as much as 8″ in diameter; nodular, resistant beds weather brown-grey	16	123
14	Dolomite, argillaceous, brown-grey, finely and medium crystalline; numerous lenses and nodules of black chert; in indistinct brown-weathering beds	12	107
13	Dolomite, slightly silty, medium brown, finely and medium crystalline; abundant black and grey chert; forms resistant brown-grey weathering beds	11	95
12	Dolomite, argillaceous, medium brown-grey, finely crystalline; abundant yellow-weathering chert in irregularly shaped blebs, and black-weathering chert in lenses and nodules; moderately resistant unit weathers brown-grey	14	84
11	Dolomite, argillaceous, traces of poorly sorted sand in grains as much as 150 microns in diameter, dark brown-grey, finely crystalline with numerous white dolomite-filled vugs; a few, thin lenses of black chert and a few small stromatoporoids; forms a recessive, grey-weathering unit	3	70
10	Dolomite, slightly argillaceous and silty and sandy; poorly sorted angular and subrounded grains as much as 150 microns in diameter, dark brown, finely crystalline; numerous silicified stromatoporoids and black chert lenses; a resistant, grey-weathering unit	6	67
9	Dolomite, argillaceous and silty, fine silt grains about 15 microns in diameter; dark grey, finely crystalline; silty laminations show on weathered surfaces; a few black chert nodules and lenses and a few *Amphipora*; forms thin, recessive, grey-weathering beds	8	61
8	Dolomite, slightly argillaceous, dark brown, finely crystalline; zones of numerous *Amphipora* and abundant $\frac{1}{2}$″–2″ diameter light grey weathering stromatoporoids; a moderately resistant, grey-weathering unit	5	53
7	Dolomite, argillaceous, brown, finely crystalline, numerous lenses and nodules of black and grey chert, a resistant, grey-weathering unit	6	48

Unit	Lithology	Thickness (feet)	Height above base (feet)
6	Dolomite, argillaceous, dark grey to almost black, finely crystalline, a few lenses of black chert; in ½″–2″ recessive, grey-weathering beds	7	42
5	Dolomite, argillaceous, dark brown, finely crystalline; a few silicified stromatoporoids; in resistant, grey-weathering beds	4	35
4	Dolomite, argillaceous, dark grey, finely crystalline; in resistant 1″–4″ recessive, light grey weathering beds	17	31
3	Dolomite, slightly silty and sandy, irregularly shaped, pitted and corroded quartz grains as much as 130 microns in diameter, medium grey, medium crystalline; forms a resistant, light grey weathering bed	2	14
2	Dolomite, argillaceous, trace of fine silt in grains 20 microns average diameter; dark brown, finely crystalline, numerous partly silicified stromatoporoids; a resistant grey-weathering unit	2	12
1	Dolomite, silty and argillaceous, coarse silt of subrounded, pitted, and corroded quartz grains 50 microns average diameter, some subrounded, non-corroded and unpitted grains as much as 200 microns in diameter, dark grey, finely crystalline; forms distinct 2″–6″ recessive, occasionally shaly, grey-weathering beds	10	10
	UPPER CAMBRIAN		
	Dolomite, silty, light brown, finely crystalline; forms massive, light yellow-grey weathering beds	17	

Section 6. Saracen Head (52°41′ N, 116°56′ W); measured on the cirque floor and a northeasterly facing ridge immediately to the northwest of Saracen Head, a prominent peak of Palliser Formation limestone situated on the northeast boundary of Jasper National Park. In this area, away from the margin of the carbonate complex, the Grotto Member is absent and the Southesk Formation consists of Peechee, Arcs, and overlying Ronde Members.

	PALLISER FORMATION		
63	Limestone, argillaceous and dolomitic, dark grey, microcrystalline; contains broken brachiopod remains; in resistant, cliff-forming, light grey weathering beds	25	1,426
	SASSENACH FORMATION (23 feet)		
	Upper Sandy Member (23 feet)		
62	Sandstone, dolomitic, light brown; of subrounded quartz grains 90 microns average diameter; shows fine crossbedding on weathered surfaces; some thin beds of intraformational conglomerate; weathers orange-yellow, recessive	20	1,401
61	Siltstone to fine sandstone, medium brown; of subrounded and subangular quartz grains 65 microns average diameter, a little authigenic quartz; forms recessive, orange-weathering beds	1	1,381
60	Dolomite, silty and sandy, medium brown, finely crystalline, silt grains as much as 75 microns in diameter, weathers orange-yellow	2	1,380

Unit	Lithology	Thickness (feet)	Height above base (feet)
	SOUTHESK FORMATION (714 feet)		
	Ronde Member (161 feet)		
59	Limestone, light brown, fine- to medium-grained calcarenite with coarse areas and laminae of dense microcrystalline calcite; contains thin 4″–6″ beds of silty dolomite; weathers light grey, resistant	20	1,378
58	Limestone, argillaceous, trace of fine silt as authigenic quartz and feldspar; small branching *Amphipora*, brachiopod remains, and finely comminuted skeletal fragments; forms resistant, light grey weathering beds	26	1,358
57	Dolomite, sandy, slightly calcareous, medium grey, finely crystalline; sandy element of subrounded and pitted quartz grains 90 microns average diameter; in recessive, 1″–2″ brown-weathering beds	13	1,332
56	Limestone, argillaceous, trace of fine quartz grains about 75 microns in diameter, dark grey, microcrystalline; resistant, light grey	5	1,319
55	Limestone, silty, dark grey, microcrystalline; silt occurs as subrounded and pitted 50-micron diameter quartz grains; forms thin, recessive, grey-weathering beds	3	1,314
54	Limestone, trace of authigenic quartz crystals as long as 0.4 mm; some authigenic feldspar and a little detrital quartz, dark grey; a medium-grained calcarenite; large, globular stromatoporoids as much as 8″ in diameter; weathers light grey	3	1,311
53	Dolomite, light brown, medium crystalline, sucrosic texture in part, cavernous weathering	7	1,308
52	Limestone, traces of silt and fine sand, dark grey, finely crystalline; sandy element occurs as extremely corroded quartz grains as much as 150 microns in diameter; some non-corroded authigenic quartz crystals; numerous small *Amphipora*; weathers light grey	5	1,301
51	Dolomite, slightly silty, light to medium brown, finely crystalline; as thin, recessive ½″–2″ yellow-grey weathering beds	2	1,296
50	Limestone, dolomitic, dark grey, microcrystalline; in 1′–3′ resistant, light grey weathering beds	3	1,294
49	Covered interval	74	1,291
	Arcs Member (107 feet)		
48	Limestone, light brown, microcrystalline; abundant calcispheres, ostracods, and unidentifiable fossil remains; well bedded; 1′–3′ units weather light grey	33	1,217
47	Limestone, slightly dolomitic, trace of excessively corroded, 40-micron diameter quartz silt, light to medium brown, microcrystalline, in part a medium-grained calcarenite; unidentifiable fossil remains; weathers light grey, resistant	25	1,184
46	Limestone, dolomitic, trace of authigenic quartz and feldspar, light brown, microcrystalline; dolomite as scattered, euhedral crystals; ostracods, brachiopods and unidentifiable fossil remains; massive 1′–3′ beds weather light grey	27	1,159
45	Limestone, dolomitic, light brown, microcrystalline, irregularly shaped eyes of sparry calcite; dolomite as scattered euhedral crystals and as local, completely dolomitized areas; resistant beds weather light grey	22	1,132

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Peechee Member (446 feet)		
44	Dolomite, trace of silt as angular chert shards, light brown, coarsely crystalline, good intercrystalline porosity, numerous fossil ghosts, possible *Amphipora*; in massive, light grey weathering beds..........	152	1,110
43	Dolomite, light brown, medium crystalline, with a little porosity in $\frac{1}{2}''$ diameter vugs; forms 1′–3′ resistant, light grey weathering beds	43	958
42	Dolomite, slightly silty, medium brown, medium crystalline, silt as detrital quartz grains 25 microns average diameter; 1′–2′ resistant beds weather light grey..........	18	915
41	Dolomite, medium to dark brown, fine and medium crystalline with a little porosity in small $\frac{1}{4}''$ diameter vugs; weathers medium grey	25	897
40	Dolomite, light grey to light brown, medium crystalline, fine, vuggy, and intercrystalline porosity; beds weather light grey, resistant....	41	872
39	Dolomite, argillaceous, dark brown to almost black, porous in $\frac{1}{4}''$–$\frac{1}{2}''$ diameter vugs; stromatoporoids and *Amphipora*; thin beds weather recessive, dark brown..........	8	831
38	Dolomite, light grey to light brown, medium crystalline, uniform texture throughout; 1′–4′ resistant, cliff-forming beds weather light grey..........	41	823
37	Dolomite, argillaceous, dark brown to black, finely crystalline, numerous, fine, white dolomite-filled fractures; recessive beds weather brown-grey..........	4	782
36	Dolomite, trace of fine 25-micron diameter silt; grey, medium crystalline; contains numerous *Amphipora* and a few corals in upper part of unit; well bedded, weathers light grey..........	4	778
35	Dolomite, argillaceous and slightly silty; silty element occurs as detrital and authigenic quartz and feldspar, dark brown to almost black, finely crystalline; *Amphipora* and stromatoporoids; weathers brown-grey, recessive..........	12	774
34	Dolomite, trace of fine 35-micron diameter silt, grey, medium and finely crystalline; in 1′–3′ resistant, light grey weathering beds......	17	762
33	Partly covered interval, dolomite, argillaceous, dark brown to almost black, finely crystalline; numerous colonial corals..........	15	745
32	Dolomite, medium to dark brown, finely and medium crystalline; well bedded, weathers light grey, resistant..........	14	730
31	Partly covered interval, dolomite, dark brown, finely and medium crystalline, numerous *Amphipora* and stromatoporoids..........	18	716
30	Dolomite, brown, medium and coarsely crystalline; good porosity in numerous $\frac{1}{4}''$–$\frac{1}{2}''$ diameter vugs; vaguely bedded, cavernous, weathers light grey..........	8	698
29	Dolomite, dark brown, finely to medium crystalline, well bedded, brown-grey weathering, resistant..........	5	690
28	Dolomite, light grey to light brown, medium crystalline, good intercrystalline and fine vuggy porosity; in 2′–4′ resistant, light grey weathering beds..........	21	685
	The Southesk/Cairn Formation contact is transitional over 167 feet. Intercalated beds of dark brown, argillaceous dolomite with numerous *Amphipora* and stromatoporoids occur to 831 feet.		

Unit	Lithology	Thickness (feet)	Height above base (feet)
	CAIRN FORMATION (664 feet)		
	Upper Member (594 feet)		
27	Dolomite, argillaceous, dark brown to almost black, finely crystalline; in thin, recessive, brown-grey weathering beds	2	664
26	Dolomite, argillaceous, dark brown to almost black, finely crystalline; numerous, large, solitary corals and a few brachiopods; vaguely bedded, weathers brown-grey	7	662
25	Dolomite, argillaceous, dark brown, medium crystalline; numerous *Amphipora* and light grey weathering stromatoporoids; many stromatoporoids leached away to leave cavities filled first with a layer of sparry dolomite, then by sparry calcite in the centre; beds weather brown-grey	5	655
24	Dolomite, medium brown, medium crystalline; thin beds of dark brown, finely crystalline, argillaceous dolomite containing numerous *Amphipora* and other stromatoporoids; weathers medium grey, moderately resistant	47	650
23	Dolomite, dark grey, finely and medium crystalline; forms distinct, 6″–2′ resistant, light grey weathering beds	14	603
22	Dolomite, argillaceous, dark brown to almost black, finely crystalline; numerous light grey weathering stromatoporoids and thin, ½″–2″ beds of abundant *Amphipora*; recessive beds weather brown-grey	15	589
21	Dolomite, argillaceous, dark brown to almost black, finely crystalline; a few *Amphipora*; well-bedded; forms resistant, brown-weathering beds	8	574
20	Dolomite, argillaceous, dark brown to almost black, finely crystalline; numerous *Amphipora*, scattered solitary corals, and a few gastropods; recessive beds weather brown-grey	24	566
19	Dolomite, light grey, medium crystalline; numerous vugs filled with white, sparry dolomite; resistant beds weather light grey	8	542
18	Dolomite, argillaceous, dark brown and black, finely and medium crystalline; contains *Amphipora*, small 2″ diameter stromatoporoids and solitary corals; some stromatoporoids replaced by sparry calcite and dolomite; moderately resistant beds weather grey	111	534
17	Dolomite, medium grey, finely crystalline; numerous globular stromatoporoids and many thin beds of *Amphipora*; cavernous beds weather light grey	30	423
16	Dolomite, argillaceous, dark grey to black, finely crystalline with scattered, thin beds of *Amphipora*; in brittle, extensively fractured, recessive, brown-grey weathering beds	102	393
15	Dolomite, argillaceous, dark brown, fine and microcrystalline; numerous thin beds of *Amphipora*, a few other stromatoporoids, some gastropods and large solitary corals; resistant beds weather light grey	3	291
14	Dolomite, dark brown, finely and medium crystalline; numerous *Amphipora* in thin beds and a few scattered globular stromatoporoids; moderately resistant beds weather light grey	19	288
13	Partly covered interval, dolomite, argillaceous, dark brown, finely crystalline; numerous *Amphipora*	39	269

Unit	Lithology	Thickness (feet)	Height above base (feet)
12	Dolomite, argillaceous, dark grey-brown, fine to microcrystalline; argillaceous laminae show on weathered surfaces; numerous small dolomite-lined vugs; resistant beds weather light brown.....	12	230
11	Dolomite, argillaceous, dark grey, microcrystalline; a few 3″ diameter stromatoporoids; thin 1″–2″ thick beds weather medium grey..........	40	218
10	Limestone, argillaceous, and dolomitic, dark grey, microcrystalline stromatoporoids and small brachiopods throughout (*Eleutherokomma reidfordi* (Crickmay), GSC loc. 48413); moderately resistant beds weather medium grey..........	40	178
9	Limestone, argillaceous and dolomitic, dark grey, microcrystalline; stromatoporoids, solitary corals, brachiopods and gastropods; in resistant, dark grey-weathering beds..........	14	138
8	Covered interval..........	29	124
7	Limestone, argillaceous, trace of authigenic quartz crystals and detrital quartz grains 50 microns average diameter, dark grey, microcrystalline; stromatoporoids, brachiopods (*Atrypa* cf. *A. multicostellata* Kottlowski, GSC loc. 48372) and gastropods; forms moderately resistant, grey-weathering beds..........	25	95
	Flume Member (70 feet)		
6	Dolomite, brown, finely and medium crystalline; numerous lenses of black chert and a few stromatoporoids; resistant brown-grey........	19	70
5	Dolomite, argillaceous, partly calcareous, dark grey, finely crystalline; numerous globular stromatoporoids and *Amphipora*; moderately resistant beds weather dark grey..........	25	51
4	Dolomite, argillaceous and calcareous, finely and microcrystalline, numerous thin lenses and beds of *Amphipora*; resistant beds weather medium grey..........	12	26
3	Limestone, argillaceous and slightly dolomitic, microcrystalline; numerous lenses and nodules of black chert, numerous fossil fragments and a few poorly preserved brachiopods; weathers light grey..........	11	14
2	Dolomite, argillaceous and calcareous, dark grey, finely crystalline; weathers medium grey..........	1	3
1	Limestone, argillaceous, silty and dolomitic, dark grey, microcrystalline; shows silty laminations on weathered surfaces; contains silicified stromatoporoids and *Amphipora*; resistant beds weather medium grey..........	2	2
	UPPER CAMBRIAN		
	Dolomite, silty and sandy, light to medium grey, forms massive, resistant, yellow-grey weathering beds 1′–3′ thick..........	35	

BULLETINS

Geological Survey of Canada

Bulletins present the results of detailed scientific studies on geological or related subjects. Some recent titles are listed below (Queen's Printer Cat. No. in brackets):

150 Geology of the New Quebec Crater, *by* K. L. Currie, $1.00 (M42-150)

151 Precambrian geology of Boothia Peninsula, Somerset Island, and Prince of Wales Island, District of Franklin, *by* R. G. Blackadar, $2.25 (M42-151)

152 Lower Cretaceous Bullhead and Fort St. John Groups, between Smoky and Peace Rivers, Central Rocky Mountain Foothills, Alberta and British Columbia, *by* D. F. Stott, $7.00 (M42-152)

153 Lower and Middle Devonian Trilobites of the Canadian Arctic Islands, *by* A. R. Ormiston, $5.50 (M42-153)

154 Deglaciation studies in Kamloops region, an area of moderate relief, B.C., *by* R. J. Fulton, $2.00 (M42-154)

155 Middle and Upper Triassic spiriferinid brachiopods from the Canadian Arctic Archipelago, *by* A. Logan, $2.00 (M42-155)

156 A standard for Triassic time, *by* E. T. Tozer, $4.00 (M42-156)

157 Lower Palaeozoic sediments of northwestern Baffin Island, *by* H. P. Trettin, $2.00 (M42-157)

158 Hettangian ammonite faunas of the Taseko Lakes area, B.C., *by* Hans Frebold, $2.00 (M42-158)

159 Study of pegmatite bodies and enclosing rocks, Yellowknife-Beaulieu region, District of Mackenzie, *by* R. Kretz, $3.00 (M42-159)

160 The geochemistry of silver and its deposits, *by* R. W. Boyle, $6.50 (M42-160)

161 Petrology and structure of Nakusp map-area, British Columbia, *by* D. W. Hyndman, $2.75 (M42-161)

162 The pyroxene granulites of the Mount Wright map-area, Quebec–Newfoundland, *by* R. A. Roach and Stanley Duffell, $2.50 (M42-162)

163 Contributions to Canadian palaeontology: Lower Cambrian faunas from Ellesmere Island, District of Franklin, *by* J. W. Cowie; a Middle Cambrian *Plagiura-Poliella* faunule from southwest District of Mackenzie, *by* B. S. Norford, $1.75 (M42-163)

164 Silurian cephalopods of James Bay lowland, with a revision of the family Narthecoceratidae, *by* R. H. Flower, $5.00 (M42-164)

165 Contributions to Canadian palaeontology: Conodonts and fish remains from the Stonehouse Formation, Arisaig, Nova Scotia, *by* J. A. Legault; Osteostraci from Somerset Island, *by* D. L. Dineley; A Devonian Osteolepidid fish from British Columbia, *by* H. Jessen, $2.50 (M42-165)

167 Magnetization direction in the Muskox Intrusion and associated dykes and lavas, *by* W. A. Robertson, $1.50 (M42-167)

168 Structure of the Northern Foothills and Eastern Mountain Ranges, Alberta and B.C., *by* E. J. W. Irish, $2.00 (M42-168)

169 Late upper Devonian (Famennian) rhynchonellid brachiopods from western Canada, *by* Paul Sartenaer, $8.00 (M42-169)

170 Middle Triassic (Anisian) ammonoids from northeastern B.C. and Ellesmere Island, *by* F. H. McLearn, $3.00 (M42-170)

171 Pre-Mississippian geology of northern Axel Heiberg and northwestern Ellesmere Islands, *by* H. P. Trettin, $2.00 (M42-171)

172 The contact metasomatic magnetite deposits of southwestern British Columbia, *by* D. F. Sangster, $2.00 (M42-172)

176 Ordovician and Silurian stratigraphy of the southern Rocky Mountains, *by* B. S. Norford, $2.75 (M42-176)

177 Geochemical prospecting for petroleum and natural gas in Canada, *by* A. H. Debnam, $1.00 (M42-177)

178 The Clearwater Complex, New Quebec, *by* H. H. Bostock, $2.00 (M42-178)

182 Contributions to Canadian paleontology, *by* B. S. Norford, *et al.*, $6.00 (M42-182)

183 Geology of Ordovician to Pennsylvanian rocks, M'Clintock Inlet, north coast of Ellesmere Island, Canadian Arctic Archipelago, *by* H. P. Trettin, $2.00 (M42-183)

184 Stratigraphy of the Devonian Southesk Cairn carbonate complex and associated strata, eastern Jasper National Park, Alberta, *by* W. S. MacKenzie, $2.00 (M42-184)

185 Barremian Textulariina, Foraminiferida from Lower Cretaceous beds, Mount Goodenough section, Aklavik Range, District of Mackenzie, *by* T. P. Chamney, $2.50 (M42-185)