

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/272167890>

Stratigraphy of the lower part of the Belt–Purcell Supergroup (Middle Proterozoic) in the Lewis thrust sheet of southern Alberta and British Columbia

Article in *Bulletin of Canadian Petroleum Geology* · January 1983

CITATIONS

9

READS

234

2 authors, including:



[Raymond A. Price](#)

Queen's University

325 PUBLICATIONS 6,467 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



GSC Map 2200A, Fernie, British Columbia [View project](#)



The Roles of the Geological Sciences in the International Geosphere-Biosphere Program – A Study of Global Change, IUGS April 1989 [View project](#)

STRATIGRAPHY OF THE LOWER PART OF THE BELT-PURCELL SUPERGROUP (MIDDLE PROTEROZOIC) IN THE LEWIS THRUST SHEET OF SOUTHERN ALBERTA AND BRITISH COLUMBIA

PETER R. FERMOR¹ AND RAYMOND A. PRICE²

ABSTRACT

Detailed mapping in the northern part of the Clark Range salient of the Lewis thrust sheet has led to a revision of stratigraphic correlations across the width of the thrust sheet, and has shown that marked facies changes occur within formations near the base of the Lewis thrust sheet. Strata immediately above the Lewis thrust, exposed around two windows through the Lewis thrust sheet in southeastern British Columbia, previously were correlated with the Waterton Formation, which had been considered the lowest unit within the thrust sheet. The strata immediately above the Lewis thrust are now shown to occupy a stratigraphic position below the Waterton Formation. Two new units, the Haig Brook Formation and the Tombstone Mountain Formation, are proposed for the stratigraphic interval between the Lewis thrust and the redefined base of the Waterton Formation. Strata in the hangingwall of the Lewis thrust that were penetrated by the Pacific-Atlantic Flathead No. 1 well, 20 km southeast of the windows, represent new units that are stratigraphically lower than the Tombstone Mountain and Haig Brook Formations, and comprise the lowest stratigraphic units known from the Clark Range salient of the Lewis thrust sheet.

STRATIGRAPHIE DE LA BASE DU SUPER-GROUPE BELT-PURCELL (PROTÉROZOÏQUE MOYEN) DANS LA
NAPPE LEWIS DU SUD ALBERTA ET DE LA COLOMBIE BRITANNIQUE

RÉSUMÉ

Dans la nappe Lewis, la cartographie détaillée de la partie nord du segment de la chaîne de Clark a conduit à réviser les corrélations stratigraphiques à l'intérieur de la nappe, et a permis de montrer que d'importants changements de faciès latéraux existent vers sa base. Dans le Sud-Est de la Colombie Britannique, les strates situées immédiatement au-dessus du contact de base sont exposées autour de deux fenêtres structurales. Ces strates, qui étaient précédemment corrélées avec la formation Waterton, considérée comme l'unité la plus inférieure de la nappe, apparaissent maintenant localisées sous cette formation. Deux nouvelles unités, la formation Haig Brook et la formation Tombstone Mountain, sont proposées pour cet interval stratigraphique entre le chevauchement et la base redéfinie de la formation Waterton. Vingt km au Sud-Est des fenêtres structurales, les strates qui furent traversées par le forage Pacific-Atlantic Flathead No. 1 à la base de la nappe sont aussi de nouvelles unités, stratigraphiquement inférieures aux formations Tombstone Mountain et Haig Brook.

Traduit par B. Collot

INTRODUCTION

The Belt-Purcell Supergroup is a thick succession of Middle Proterozoic sedimentary rocks that is exposed over wide areas of southwestern Alberta, southeastern British Columbia, and adjacent areas of Montana, Idaho, and Washington. In the Lewis Range in Montana and the Clark Range in Canada (Fig. 1), adjacent to the International Boundary, strata of the Belt-Purcell Supergroup form a major salient of the Lewis thrust sheet, an allochthonous mass underlain by the Lewis thrust fault.

The Lewis thrust fault is the dominant structure in the Cordilleran thrust and fold belt in the southernmost Canadian Rockies (Fig. 1). It extends some 225 km south and north from the International Boundary to its terminations in faulted hinge zones of anticlines in central Montana and the Rundle Range south of Banff, Alberta (Dahlstrom *et al.*, 1962; Bielenstein, 1969; Mudge and Earhart, 1980; and Spang *et al.*, 1981).

Near the International Boundary the sheet of Middle Proterozoic to Cretaceous sedimentary rocks overlying the Lewis thrust is up to 10 km or more thick and has been displaced at least 80 km northeastward relative to underlying Upper Cretaceous nonmarine, synorogenic, clastic deposits (Price, 1962; Mudge and Earhart, 1980). In this region the Lewis thrust sheet juts out over the western part of the Foothills belt in a large salient that extends from North Kootenay Pass in Canada to Marias Pass in Montana (Fig. 1). Beneath most of the salient, the Lewis thrust is essentially a bedding-parallel detachment surface relative to its hangingwall, because it lies within a relatively thin stratigraphic interval of the Middle Proterozoic Belt-Purcell succession, which makes up the bulk of the Lewis thrust sheet in this area. On the southeastern margin of this flaplike salient, the Lewis thrust sheet is offset by the Flathead fault (Price, 1962, 1965), a southwest-dipping listric normal fault that probably merges at depth with the Lewis thrust (Bally *et al.*, 1966).

¹Shell Canada Resources Ltd., P.O. Box 100, Calgary, Alberta T2P 2H5

²Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

This paper is based on part of an M.Sc. thesis by Peter R. Fermor, prepared under the supervision of Raymond A. Price and submitted to Queen's University in 1980. Tom Bryce, Paul Rauthwell, Gary Caldwell and Randy Toth provided able assistance in the field. Financial support was provided through the Department of Energy, Mines and Resources and the National Research Council. Shell Canada Resources kindly contributed the services of Barbara Wischniowski who drafted the illustrations, and Dianne Durante who typed the manuscript. Dr. Felix Frey and Dr. Robert McMechan reviewed an earlier version of the manuscript and gave helpful suggestions.

Copyright ©1983, Canadian Society of Petroleum Geologists

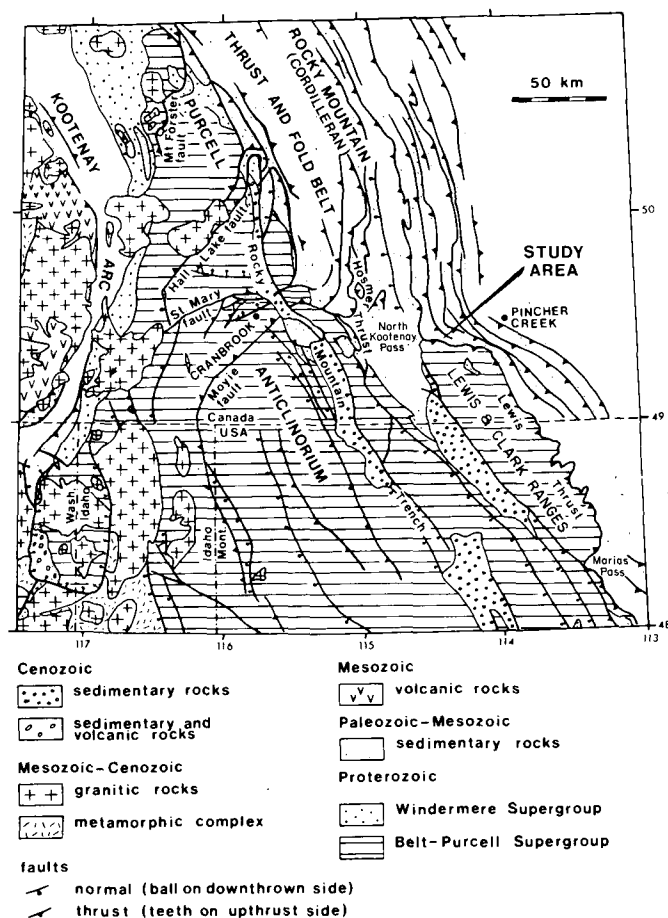


Fig. 1. Simplified geological map of the Rocky Mountain thrust and fold belt in the vicinity of the International Boundary, showing the regional setting of the Lewis and Clark Ranges salient of the Lewis thrust sheet. After McMechan (1981) and Price (1981).

The Cate Creek and Haig Brook windows in which Upper Cretaceous strata (Olsson and Caster, 1935) are exposed beneath the Lewis thrust, occur adjacent to the Flathead fault in southeastern British Columbia (Fig. 2). In the vicinity of the windows the Lewis thrust is folded along with overlying and underlying strata to form one of a series of northwest-trending, *en echelon* anticlinal culminations which extend the length of the west side of the salient (Clark, 1954; Price, 1958, 1959, 1962, 1965; Norris, 1959; Jones, 1969; and see Gordy *et al.*, 1977).

The lower part of the Lewis thrust sheet framing the windows is a layer up to 700 m thick that consists of imbricate, southwesterly dipping sigmoidal thrust-fault slices, comprising repetitions of several thin stratigraphic intervals from the deepest exposed levels of the Belt-Purcell Supergroup (Price, 1958, 1965; Dahlstrom, 1970). Above this imbricate zone stratigraphic units are relatively undeformed and can be projected easily across valleys and between peaks. The unravelling of the detailed structure of the zone of imbrication (Fermor, 1980) had led to a

re-interpretation of stratigraphic correlations in the lower Belt-Purcell Supergroup of the Clark Range.

The Lewis Series (Belt-Purcell Supergroup) was established in the Clark Range by Daly (1912) to encompass a series of units that had been established by Willis (1902) in the northern part of what is now Glacier National Park in Montana, and also a basal unit (the Waterton Formation) that may embrace beds older than those described by Willis. Hume (1933) and Hage (1943) extended this sequence to include younger rocks in the central and northern Clark Range that are overlain unconformably by Middle Cambrian rocks. In the Clark Range the Belt-Purcell Supergroup consists of 3400 to 6000 m (Table 1) of shallow marine and intertidal clastics and carbonates, that thicken toward the southwest (Price, 1964). The lower part of this sequence is the subject of the following discussion.

The Waterton Formation, as established by Daly (1912, p. 50-56) and amended by Douglas (1952; and in Gordy *et al.*, 1977), forms the base of the Lewis thrust sheet in southeastern Clark Range. More than 180 m of the Waterton Formation occur in Waterton Lakes National park (in Waterton map-area) in the vicinity of lower Cameron Creek (Fig. 2) and Belly River (Douglas, 1952). In this area, the Waterton Formation consists of a sequence of alternating units of red, grey and greenish grey dolomite and of interbedded banded, streaked and laminated grey dolomite and limestone with argillite. A green argillite unit, 11 m thick, occurs near the bottom of this sequence (Fig. 3). The base of the formation is unknown because the lowest exposed beds are underlain by a splay fault from the Lewis thrust fault.

In the same area, the overlying Altyn Formation (Willis, 1902) has been divided by Douglas (1952) into three units. The lower unit consists of thinly bedded, finely laminated, light-buff-weathering dolomite; varies in thickness from about 80 to 240 m; is moderately resistant to erosion and is in gradational contact with the Waterton Formation. The middle unit consists of 60 to 120 m of cliff-forming, massive-bedded, sandy, gritty and conglomeratic dolomite; and white-weathering stromatolitic dolomite. In the upper unit, which is 30 to 60 m thick and moderately resistant, black argillite is interbedded with sandy, gritty and laminated dolomite, and algal dolomite (Fig. 3), and is overlain by argillite and quartz sandstone of the Appekunny Formation.

CORRELATION OF LOWER BELT-PURCELL STRATA FROM WATERTON LAKES TO NORTHERN CLARK RANGE

A similar succession of homotaxial strata exposed along the leading edge of the Lewis thrust sheet in northeastern Clark Range, near West Castle River (Figs. 3, 4 and Appendix 1), was assigned to the Waterton and Altyn Formations by Norris (1959). At West Castle River the basal 120 m of the stratigraphic succession in the hangingwall of the Lewis thrust can be assigned to the Waterton Formation on the basis of lithological aspect and stratigraphic

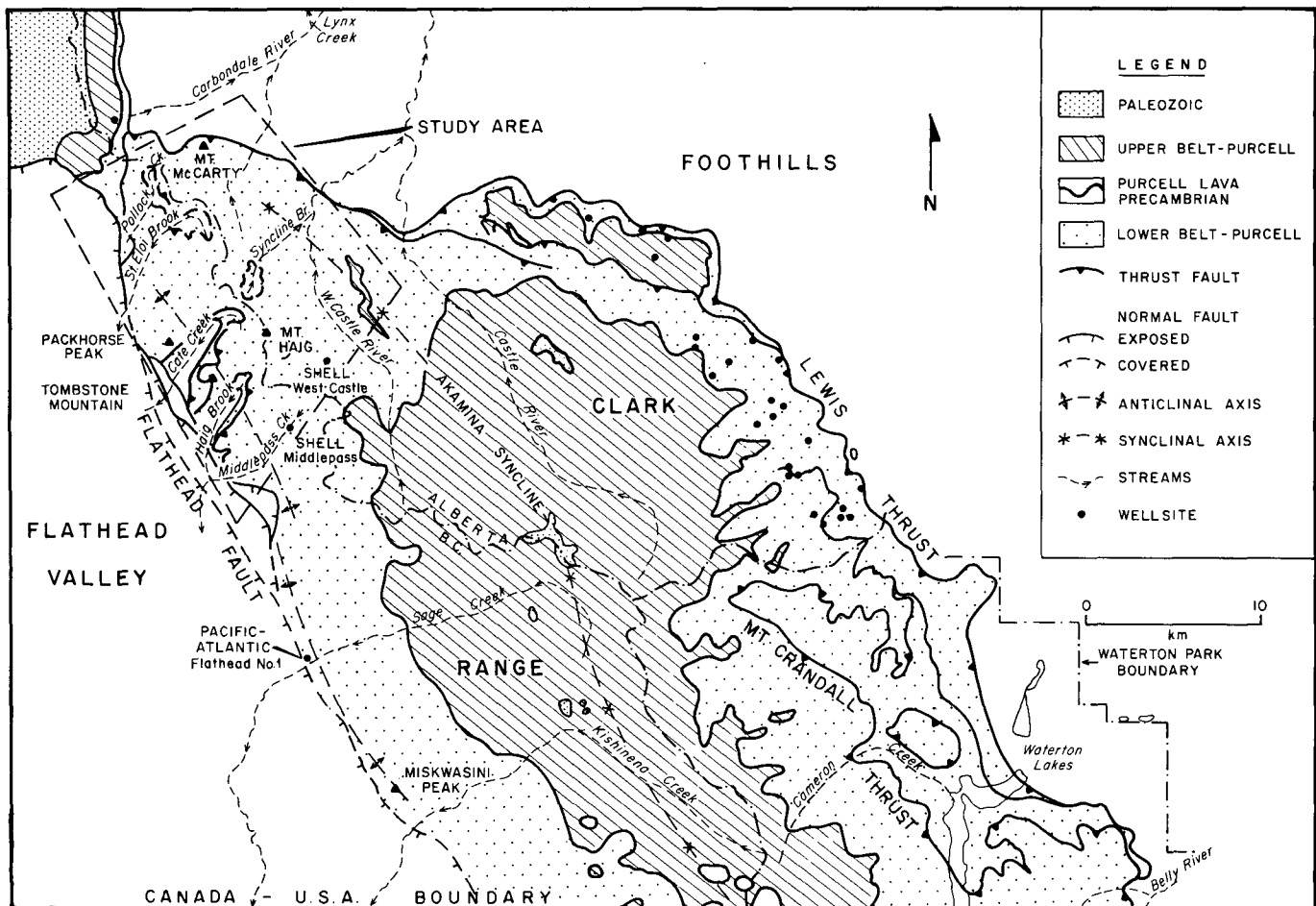


Fig. 2. Location map for Clark Range, Alberta and British Columbia.

position. It consists of varicoloured, banded and streaked weathering micritic, argillaceous limestone and dolomite; shale; light grey silty dolomite; dolomite with distinctive elliptical "nodules" of finely laminated grey limestone that are aligned with the bedding and probably comprise algal stromatolites; dark limestone and shale; and distinctive dark-red-weathering dolomite, which is concentrated in two bands near the top of the formation (Fig. 3 and Appendix 1).

The overlying succession, which can be assigned on the same basis to the Altyn Formation, contains at its base about 30 m of light green, grey-green and grey-red argillite or shale, with subordinate dolomitic siltstone and silty dolomite. Thick-bedded, light-brown-weathering, very resistant sandy and gritty dolomite and dolomitic quartz-sandstones make up most of the overlying 75 m (Fig. 3 and Appendix 1). Light pink-grey and green-grey columnar stromatolites occur in several beds near the base of this unit. The uppermost 40 m of the Altyn Formation at West Castle River consists of sandy dolomite interbedded with black argillite and dolomitic quartz sandstones; the last become more common toward the top of the unit, where they are interbedded with quartz sandstone and recessive-

weathering sandy argillite. The contact with the overlying Appekunny Formation is gradational and is placed at the base of the first bed of green argillite (Norris, 1959). At least one bed of sandy dolomite occurs in the lower part of the Appekunny Formation, which consists mainly of green argillite and siltstone, and light grey and white quartzitic sandstone.

The Altyn and Waterton Formations are truncated against the underlying Lewis thrust fault to the northwest and southeast from West Castle River. At West Castle River, however, they lie in the northeast limb of the Akamina syncline, a broad regional fold that extends along the entire length of the Lewis and Clark Ranges salient of the Lewis thrust sheet (Fig. 2). The Altyn and Waterton Formations can be correlated on the basis of lithologic aspect and stratigraphic succession with homotaxial units that are exposed in the opposite limb of the Akamina syncline in the valley of Syncline Brook. These units can be traced or projected westward across the Continental Divide from the headwaters of Syncline Brook in Alberta to the valleys of Cate Creek and Haig Brook in British Columbia, where they frame the windows that have been eroded through the Lewis thrust sheet. In the upper part of the valley of

Unit Name	Thickness (m)	Lithology
Roosville Formation	0-600	Green argillite, siltstone and sandstone; light grey argillaceous and stromatolitic dolomite.
Phillips Formation	150-170	Red sandstone, siltstone, and argillite.
Gateway Formation	350-900	Argillite, argillaceous siltstone; dolomite, dolomitic argillite and sandstone; red, grey and green.
Sheppard Formation	45-270	Light-coloured quartzitic and dolomitic sandstone and dolomitic argillite, dark red micaceous mudstone, siltstone and sandstone, dark green andesite locally.
Purcell Lava	70-150	Dark green, reddish or purplish chloritized andesite and amygdaloidal andesite flows; pillowed andesite.
Siyeh Formation Upper Member	30-180	Green siltstone and fine-grained sandstone intercalated with green argillite and some beds of red argillite and siltstone.
Siyeh Formation Middle Member	300-600	Dolomitic limestone, limestone, and dolomite, grey argillite and sandstone. Resistant, cliff-forming, grey-weathering.
Siyeh Formation Lower member	10-150	Interbedded grey dolomite, quartz sandstone, green and black argillite.
Grinnell Formation	106-520	Red argillite interbedded with green argillite and white and red quartz sandstones.
Appekunny Formation	330-600	Green argillite and white quartz sandstone with interbedded sandy dolomite and red argillite in the east.
Altyn Formation/Dolomitic Argillite Unit of Appekunny Formation	140-340	Sandy dolomite, dolomite and argillite, dolomitic argillite, argillaceous dolomite and argillite; light grey and greenish grey.
Waterton Formation	200?-247	Limestone and dolomite, argillaceous limestone and dolomite; grey and locally red; grey to green argillite, medium to light greenish grey, silty dolomite and dolomitic siltstone.
Tombstone Mountain Formation (new name)	175	Argillite and argillaceous dolomite and limestone, dark grey.
Haig Brook Formation (new name)	150 +	Grey dolomite and limestone, some weathering banded and streaked; grey, red and green argillaceous limestone and dolomite.
Lower Units from Pacific-Atlantic Flathead No. 1 well		
Unit 1 Dark Argillite	107	Dark argillite, calcareous and dolomitic and black argillite.
Unit 2 Argillaceous Dolomite	314	Light brownish grey to medium grey argillaceous dolomite; black argillite; red and green dolomite toward base.
Unit 3 Varicoloured Limestone and Dolomite	219	Light grey, green, red and white very fine and cryptocrystalline dolomite and limestone.
Unit 4 Grey Dolomite	217	Medium to dark grey, dense, argillaceous dolomite.

Table 1. Stratigraphic table of the Belt-Purcell Supergroup in Clark Range.

Syncline Brook, strata assigned to the Waterton Formation form a resistant, cliff-forming unit, 250 m thick, that is composed of silty and argillaceous micritic limestone and dolomite. Distinctive ellipsoidal "nodules" of finely laminated, grey (weathered and fresh surfaces) limestone in a light-brown-weathering, grey dolomite matrix are common in the lower parts of this unit. These "nodules" are similar to those that occur in the Waterton Formation in the opposite limb of the syncline. Red dolomites also occur along Syncline Brook in the southwest limb of the Akamina Syncline, but they disappear to the southwest. A 15-m-thick argillite unit, which changes in weathering colour from green in the northeast to black in the southwest, occurs about 40 m above the base of the Waterton Formation. It overlies "concretionary" or "nodular" limestone and dolomite, and quartzose and arenaceous grey dolomite, all of which form the basal strata of the Waterton Formation.

Strata assigned to the Altyn Formation in the southwest limb of the Akamina syncline, along Syncline Brook, com-

prise about 130 m of interbedded sandy dolomite, dolomite, dolomitic quartz sandstone and green and black argillite. These beds were assigned to the Appekunny Formation by Norris (1959) and Price (1958, 1959), who assigned the underlying "nodular" limestone and dolomite unit to the upper part of the Altyn Formation rather than to the Waterton Formation. Green argillites and interbedded green and grey quartzitic sandstones and siltstones that overlie the dolomitic beds clearly belong to the Appekunny Formation, and were mapped as the "middle part of the Appekunny Formation" by Norris (1959). Older strata, which lie below the dolomite unit with "nodules" of laminated grey limestone that marks the base of the Waterton Formation, comprise distinct stratigraphic units lower than any of those that occur along the hangingwall of the Lewis thrust to the east, in Alberta.

Around the Cate Creek and Haig Brook windows the uppermost beds of the Waterton Formation are gradationally overlain by 120 to 150 m of dolomite, green dolomitic

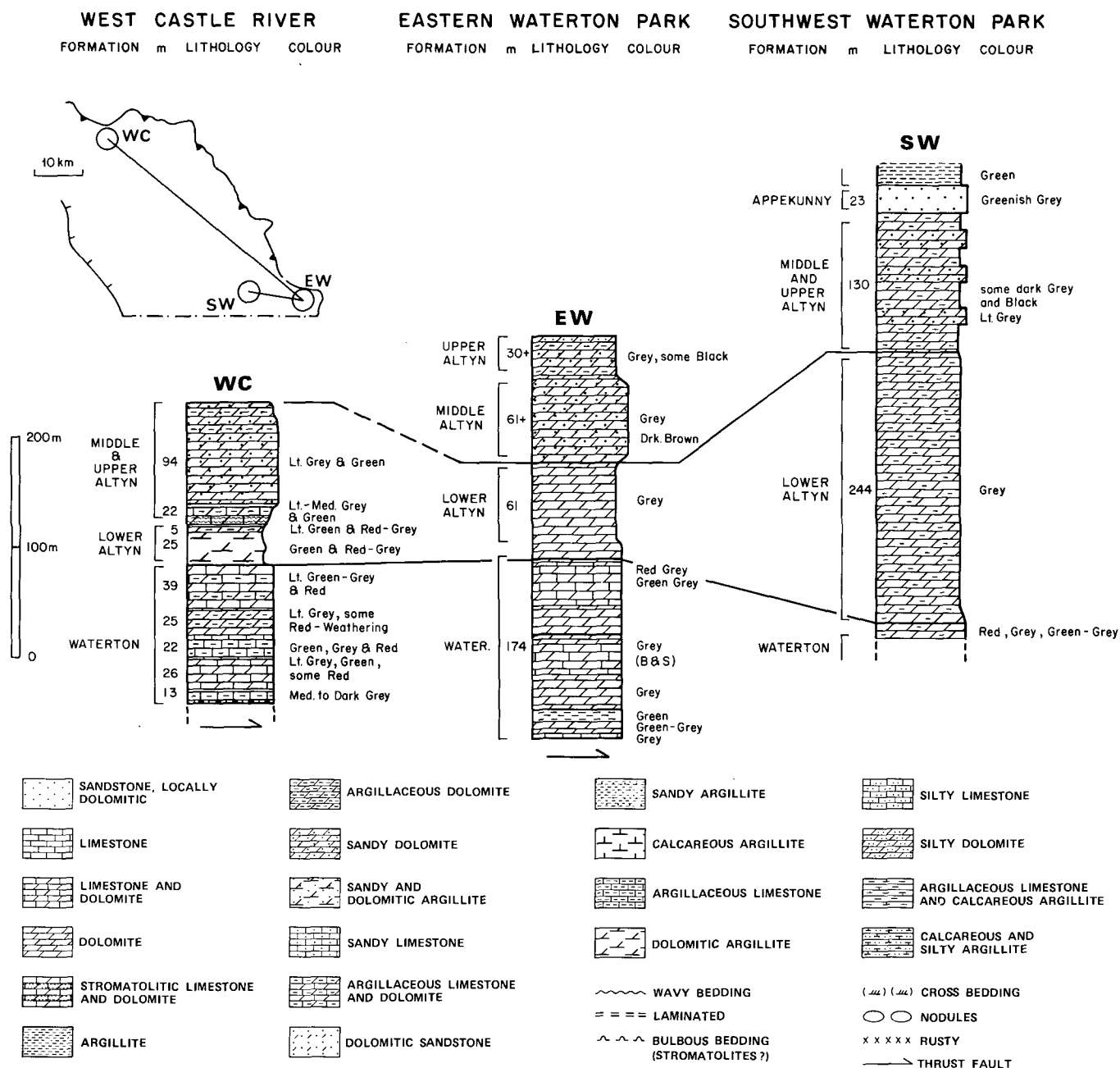


Fig. 3. Stratigraphic correlations along eastern Clark Range from West Castle River to eastern and southwestern Waterton Park, showing past correlations, as indicated by the names assigned to the units and solid tie lines, and tentative correlations of Altn Formation sections between West Castle River and Waterton Lakes as indicated by dashed tie line. Thicknesses of individual stratigraphic units are shown to the left of the column (in metres). See legend for lithology and other stratigraphic symbols.

argillite, and green and black argillite with thin quartz sandstone interbeds (section by D.U. Wise, *in* Price, 1965, p. 143; R.A. Price and D.U. Wise field notes of 1957 and 1958; see this paper, Appendix 2). This unit, which will be referred to informally as the "dolomitic argillite unit", is the lateral equivalent of the Altn Formation, as developed near West Castle River, but it resembles the Appekunny Formation and has been mapped as part of the Appekunny Formation by Price (1958, 1959, 1965) and Norris (1959), a practice that will be followed here (Fig. 5).

At the headquarters of St. Eloi Brook (Figs. 2, 5) the lowest beds in the "dolomitic argillite unit" are platy, green argillite and dolomite and dolomitic argillite that weather either light grey or black and rusty, and form a recessive-weathering interval about 13 m thick. These are succeeded by medium green, argillitic dolomite; medium-brown- and greenish-brown-weathering dolomitic argillite, and argillite in massive beds 0.3 to 1.0 m thick alternating with platy beds. Interbeds of coarse-grained and very coarse grained sandy (quartz) dolomite and dolomitic quartz

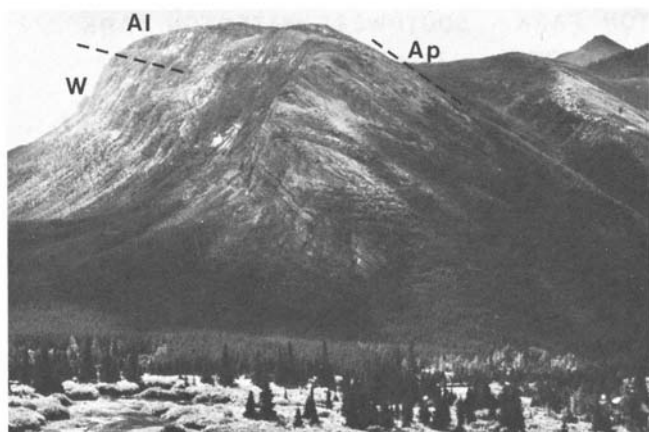


Fig. 4. View of mountain front, south side of West Castle River looking south. Lowermost cliffs in upper part of Waterton Formation (W). Slight break in slope underlain by argillites of "lower Altyn." Upper part of cliff formed by remainder of Altyn Formation (AI). Saddle on ridge on skyline marks approximate position of top of Altyn Formation, base of Appekunny Formation (Ap).

sandstone occur near the base. About 102 m above the base the "dolomitic argillite unit" becomes less dolomitic and beds 0 to 2 m thick or more of arenaceous argillite and coarse-grained, white, quartz sandstone appear. Distinct beds of sandstone appear to become more common toward the top of the unit. The overlying sequence is about 125 m thick and consists of alternating green argillite and prominent thick quartzitic sandstone. This last unit forms a distinctive marker in the western Clark Range, and its importance will be discussed in a later section of this paper.

The discovery, during this study, that the Altyn Formation grades westward across northern Clark Range into strata that have been assigned to the base of the Appekunny Formation (Clark, 1954; Price, 1958, 1964, 1965; Norris, 1959) implies that a series of distinct stratigraphic units in western Clark Range, mapped as the Altyn and Waterton Formations by Price (1958, 1965) and Norris (1959), and described by Price (1964), are really lateral equivalents of

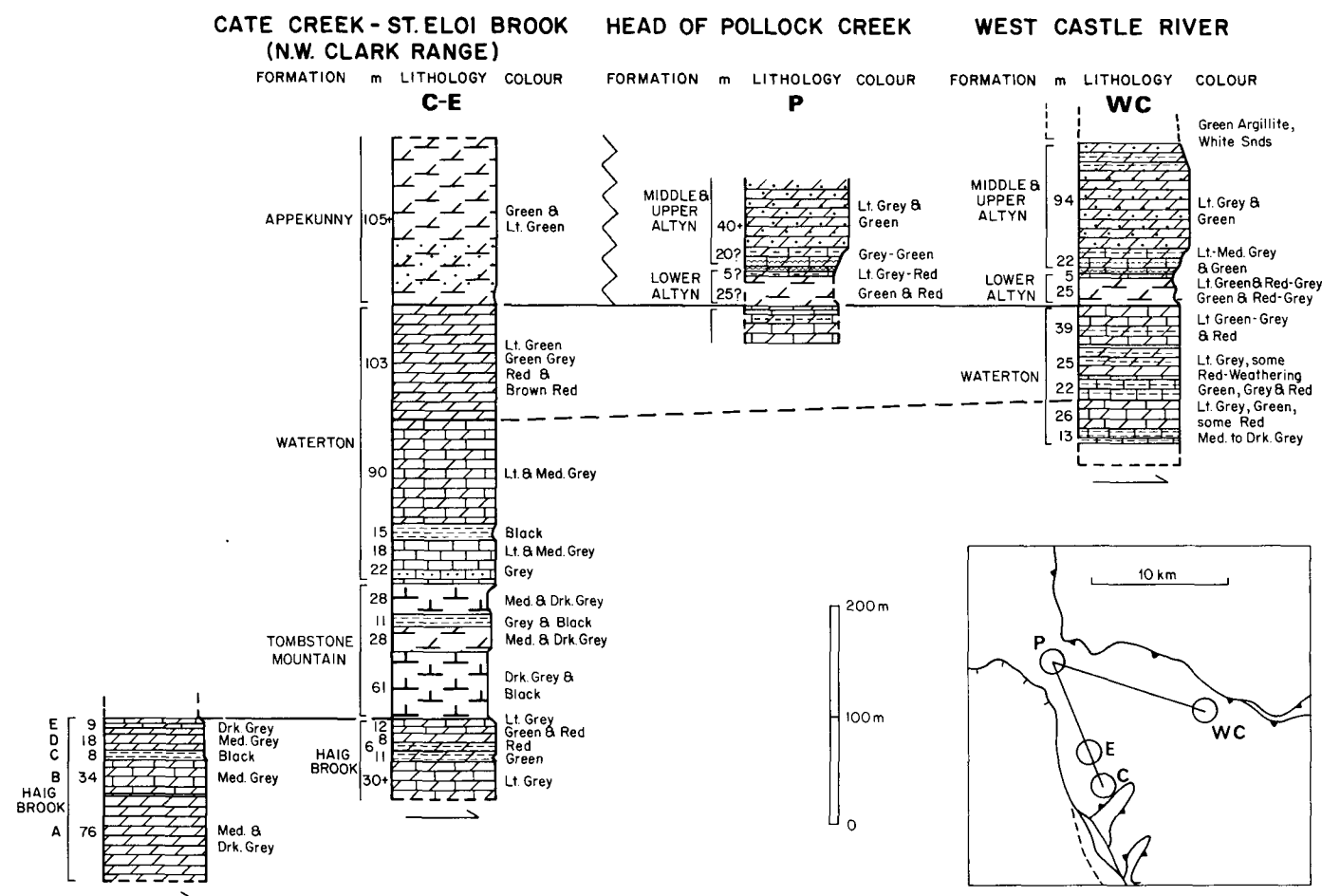


Fig. 5. Stratigraphic correlations across northern Clark Range from Cate Creek and St. Eloi Brook to the head of Pollock Creek and to West Castle River. Refer to Figure 3 for legend. The figure illustrates the new correlations established across northern Clark Range, and shows the stratigraphic positions of the Tombstone Mountain and Haig Brook Formations. The complete column of the Haig Brook Formation in the lower left corner is representative of the Cate Creek area; the C-E column is derived from outcrops between Cate Creek and Haig Brook. Column P represents outcrops exposed at the head of Pollock Creek, and column WC the exposures at the leading edge of the Lewis thrust sheet on the north side of the West Castle River. The dashed tie line represents a tentative correlation within the Waterton Formation.

the Waterton Formation and older strata. Therefore, the Altyn Formation needs to be redefined in terms of its stratigraphic relationship to the Appekunny Formation.

The sequence of strata assigned to the Waterton Formation in northwestern Clark Range is thicker and contains stratigraphically lower units than those exposed in Waterton map-area. The stratigraphic units that underlie the Waterton Formation in northwestern Clark Range form two distinct sequences, one a recessive and argillaceous sequence that immediately underlies the Waterton Formation, and underneath it a resistant cliff-forming carbonate unit that forms the hangingwall of the Lewis thrust around the Cate Creek and Haig Brook windows (Fig. 6). These units are lithologically distinct from the Waterton Formation, well exposed, and easily mapped throughout northwestern Clark Range; therefore the base of the Waterton Formation also needs to be redefined.

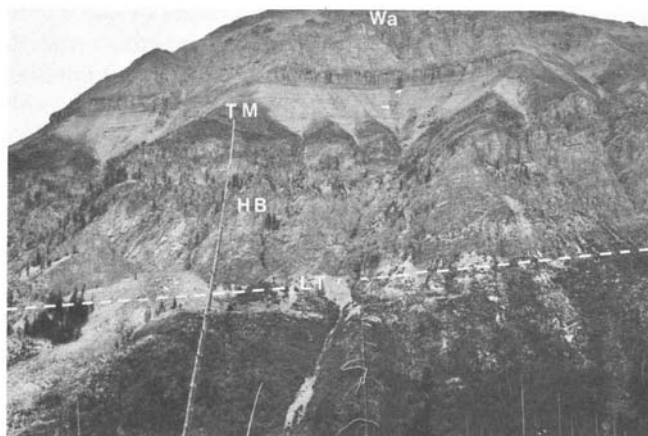


Fig. 6. Exposures of lower Belt-Purcell strata on west side of Cate Creek valley (see Fig. 2 for location). Upper cliffs are formed in resistant carbonates of the Waterton Formation (Wa). Note "dark argillite" forming a faint dark band near the base of these cliffs. Underlying slopes are formed from argillaceous carbonate and argillite of Tombstone Mountain Formation (TM): new name; see below. Lower cliffs are cut into carbonate of the Haig Brook Formation (HB): new name; see below. The strata of the Haig Brook Formation are repeated on many small, imbricate thrust faults that splay from the Lewis thrust (LT), which occurs at the base of the cliffs. The lower slopes, beneath the Lewis thrust, are underlain by Cretaceous sandstone and shale. Photo by R. Toth.

ALTYN FORMATION

The Altyn Formation (Willis, 1902; Daly, 1912; Douglas, 1952) has been defined as the sequence of sandy dolomite, dolomitic sandstone, dolomite and argillite that overlies the silty carbonates of the Waterton Formation and underlies the green argillites and quartz sandstones of the Appekunny Formation in northeastern Glacier National Park, Montana and Waterton Lakes National Park, Alberta. As redefined here it grades westward across northern Clark Range into argillite, dolomitic argillite and quartz sandstone that are included in the base of the Appekunny Formation. The type locality is on Appekunny Mountain,

near the locality of Altyn, in northeastern Glacier National Park, Montana (Willis, 1902). Daly (1912) and Fenton and Fenton (1937) extended the use of the formation designation into southeastern Waterton Lakes National Park and, on the basis of his studies in that area, Douglas (1952) revised the Altyn Formation to eliminate the effects of fault repetitions that were not recognized by Willis (1902), Daly (1912) and Fenton and Fenton (1937).

The Altyn Formation changes significantly from east to west in the Waterton map-area. In the western part of the map-area the massive sandy dolomites of the middle part of the type Altyn Formation are replaced by a less resistant interval that consists of argillite and dolomite with a few 15-20-m-thick, resistant beds of sandy dolomite (Fig. 7). This is a transitional facies where the 130-m-thick middle and upper parts of the Altyn Formation grade westward into a sequence assigned to the Appekunny Formation. The lower part of the Altyn Formation is made up of thinly bedded, finely laminated dolomite throughout the map-area.

The Altyn Formation is recognized from the vicinity of Marias Pass, Montana (Ross, 1959; Childers, 1963; Mudge *et al.* in Gordy *et al.*, 1977; Fig. 1) northward along the leading edge of the Lewis thrust sheet in eastern Lewis and Clark Ranges, almost as far as North Kootenay Pass at the northern end of the Clark Range (Fig. 2). Over most of this distance the Lewis thrust fault occupies bedding glide zones in the Altyn Formation; thus the preserved stratigraphic thickness of the Altyn Formation depends on the exact stratigraphic horizon followed by the Lewis thrust. In the Waterton map-area, where the full thickness of the Altyn Formation is preserved above the Lewis

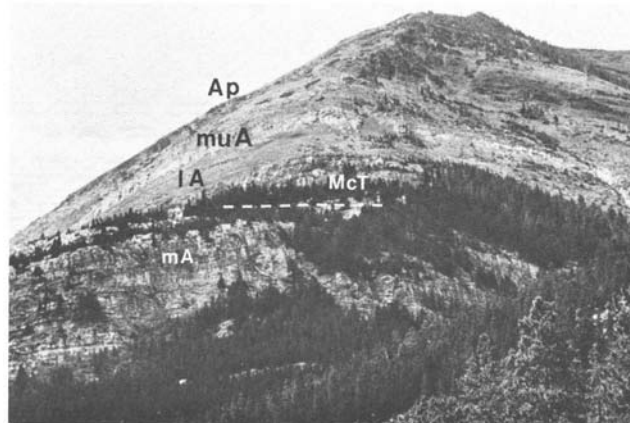


Fig. 7. View of the northwest side of Cameron Creek valley, western Waterton Lakes Park, Alberta. Cliff-forming sequence below tree line is the middle part of the Altyn Formation (mA). The Mount Crandall thrust fault is close to the tree line (MCT). The lower part of the Altyn Formation (IA) immediately overlies the thrust, forming the recessive interval. The middle and upper parts of the Altyn Formation (muA) are represented by the interval showing the resistant, white-weathering rib. The Appekunny Formation (Ap) forms the uppermost, dark-weathering slopes. Note the contrast in the appearance of the middle part of the Altyn Formation between the footwall and hangingwall of the Mount Crandall thrust.

thrust, Douglas (1952 and in Gordy *et al.*, 1977) reported that the Altyn Formation varies in thickness from 150 m to 425 m from east to west across Waterton map-area. Most of this variation is attributed to thickness changes in the lower part of the Altyn Formation (from 60 to 250 m). Norris (1959) reported a thickness of 146 m for the Altyn Formation at West Castle River in northeast Clark Range, where the thickness does not appear to change significantly along the leading edge of the Lewis thrust sheet as far as the northernmost exposures of the Altyn Formation near North Kootenay Pass.

The contact with the Waterton Formation is conformable and distinct. It is placed where red, grey and greenish grey dolomites of the Waterton Formation grade upward, in southeastern Clark Range, into thick-bedded, buff-weathering, green to greenish grey dolomites of the lowermost part of the Altyn Formation (Douglas, in Gordy *et al.*, 1977). In northeastern Clark Range light green-grey micritic limestone of the uppermost Waterton Formation grades upward into light green-grey silty and dolomitic argillite at the base of the Altyn Formation.

The contact with the Appekunny Formation is gradational and not as distinct as the contact with the Waterton Formation. In southeastern Clark Range, in eastern Waterton map-area, the contact is placed where black argillite, interbedded with sandy, gritty and laminated dolomite, gives way to argillaceous, greenish grey, quartzitic sandstone and interbedded green argillite (Douglas, *pers. comm.* to Price, 1964). In northeastern Clark Range, near West

Castle River, the contact is placed at the base of the first bed of green argillite (Norris, 1959). Some sandy dolomite occurs in the lower part of the Appekunny Formation.

The Altyn Formation is considerably thicker at Waterton Lakes than at West Castle River, and it may be that the Altyn Formation at West Castle River is equivalent to only a part of the Altyn Formation at Waterton Lakes (Fig. 8). The sandy dolomite beds that occur in the lower part of the Appekunny Formation near West Castle River may be equivalent to beds forming part of the Altyn Formation in the Waterton area. Alternatively, it is possible that the difference is due to internal stratigraphic thickening.

WATERTON FORMATION

The Waterton Formation is redefined here as the distinctive sequence of grey, green and red silty and argillaceous carbonate rocks and argillites that overlies the dark grey argillites and argillaceous carbonate rocks of the Tombstone Mountain Formation (new name; see below) in northwestern Clark Range. It is exposed in the immediate hangingwall of the Lewis thrust in northeastern and southeastern Clark Range. The formation underlies dolomites and argillites of the Altyn Formation in eastern Clark Range, but in the northwestern Clark Range argillite, dolomitic argillite and quartz sandstone of the Appekunny Formation overlie the Waterton Formation.

The type locality of the Waterton Formation (Daly, 1912; Douglas, 1952) is in Waterton Lakes National Park

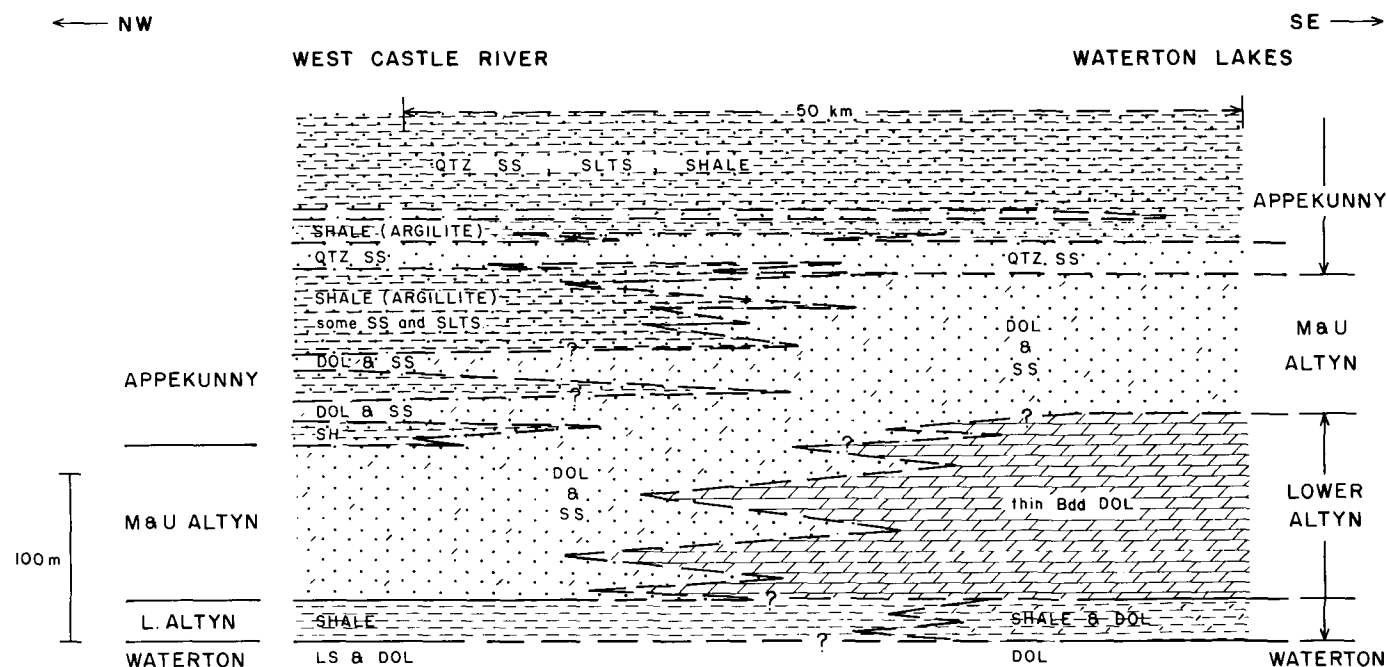


Fig. 8. Speculative stratigraphic correlations along eastern Clark Range, showing possible correlations of relatively thin Altyn Formation section at West Castle River with thicker Altyn Formation section in Waterton Lakes area. The Altyn Formation at West Castle River is shown as equivalent to only a part of the Altyn Formation at Waterton Lakes: alternatively the difference in thickness may be accommodated by internal stratigraphic thickening of the Altyn Formation from West Castle River to Waterton Lakes, or by the top of the Waterton Formation having been picked at a higher stratigraphic level at West Castle River.

in southeast Clark Range, but the base of the formation is not exposed there. A complete section of the Waterton Formation, however, is well exposed in northwestern Clark Range (see Price, 1965, p. 143; this paper, Fig. 5 and Appendix 2). These strata, which formerly were assigned to the "upper part of the Altyn Formation", can serve as a principal reference section for the Waterton Formation, now expanded to include beds below the lowest exposed at the type section in Waterton Lakes Park. This reference section is located on the south side of St. Eloi Valley near the headwaters of St. Eloi Brook. It is accessible from the British Columbia Forest Service Road in the Flathead Valley at the mouth of Pollock Creek by way of St. Eloi Valley.

Price (1958, 1959) described the following five subdivisions of the Waterton Formation (which he called the "upper part of the Altyn Formation"), from base to top:

1. Sandy limestone — quartzose calcarenite and silty limestone that grades into both the underlying argillaceous sequence (the Tombstone Mountain Formation, see below) and the overlying lower "concretionary" beds; some "concretionary limestone" occurs near the base of this 21-m-thick unit.
2. Lower "concretionary" beds — light and medium grey, finely crystalline argillaceous limestone and dolomite, finely laminated in part and containing few to abundant ellipsoidal calcareous "concretions" (which are probably algal stromatolites) 2.5 to 15 cm long and less than 5 cm thick (Fig. 9), that are aligned with the plane of the bedding and have laminations more widely spaced than in the surrounding rock. Unit about 18 m thick.
3. Dark argillite that changes northeastward from recessive, black platy argillite to medium to dark grey and then to light green and grey argillite. Unit about 18 m thick.
4. Upper "concretionary" beds — light and medium grey, finely crystalline "concretionary" argillaceous limestone and dolomite similar to the lower "concretionary" beds. Unit about 90 m thick.



Fig. 9. Calcareous "concretions" in upper part of Waterton Formation, east side of Syncline Brook valley. Encompassing rock is silty and argillaceous dolomite.

5. Upper transition beds — mainly light grey, greenish grey, finely crystalline argillaceous dolomite with lesser amounts of dolomitic siltstone or mudstone. Beds of red argillaceous dolomite occur in zones 3 to 9 m thick and become more abundant to the northeast. In northernmost Clark Range two prominent red-weathering bands appear in the upper part of this unit. Unit about 104 m thick.

In addition to the area around Waterton Lakes, in southeastern Clark Range (Daly, 1912; Douglas, 1952), and the West Castle River area in northeastern Clark Range (Norris, 1959), the Waterton Formation has been traced without interruption over an area of about 150 km² in northwestern Clark Range, from north of Pollock Creek to the south side of Middlepass Creek (Figs. 2, 10). No significant changes in thickness are evident in northwestern Clark Range. The only significant facies variations occur on the south side of Middlepass Creek, at the southernmost edge of the exposures of the Waterton Formation in northwestern Clark Range. There, medium to dark grey, colour-laminated argillite, that weathers light grey and rusty, appears to represent a stratigraphic level equivalent to the middle part of the Waterton Formation. Below these rocks are platy-weathering, dark-coloured dolomite, limestone and argillite, which appear to be part of the underlying Tombstone Mountain Formation. The Waterton Formation is less resistant on the south side of Middlepass Creek, and it appears to grade southward into argillite in west-central Clark Range (see page 184).

Stratigraphic relationships established in the correlation of the Waterton Formation across northern Clark Range provide a basis for reviewing correlations from northern Clark Range to the Waterton map-area. The "dark argillite", which forms a distinctive marker within the lower part of the Waterton Formation in northwestern Clark Range, changes gradually northeastward from black to dark grey argillite at St. Eloi Brook (Figs. 2, 10) to light green, platy dolomitic argillite at Syncline Brook (Figs. 2, 10) and is about 15 m thick throughout this area. It may be correlative with the 11.5-m-thick, massive green argillite unit that occurs near the base of the exposed portion of the Waterton Formation in Waterton map-area (Fig. 3).

The interval between the argillite unit and the top of the Waterton Formation is 147.6 m thick at Waterton Lakes and 196 m thick at St. Eloi Brook. Tentative correlations of other parts of the Waterton Formation also can be made between the stratigraphic sections at Waterton Lakes and St. Eloi Brook, and in the West Castle River area, by simply taking the proportions of these thicknesses (Fig. 5). The strata that underlie the argillite in northwestern Clark Range have no exact equivalent at Waterton Lakes, where massive to thick-bedded dolomite underlies the green argillite unit (Douglas, 1952).

The contact of the Waterton Formation with the underlying Tombstone Mountain Formation (see definition below) is conformable and distinct. It is placed where recessive,

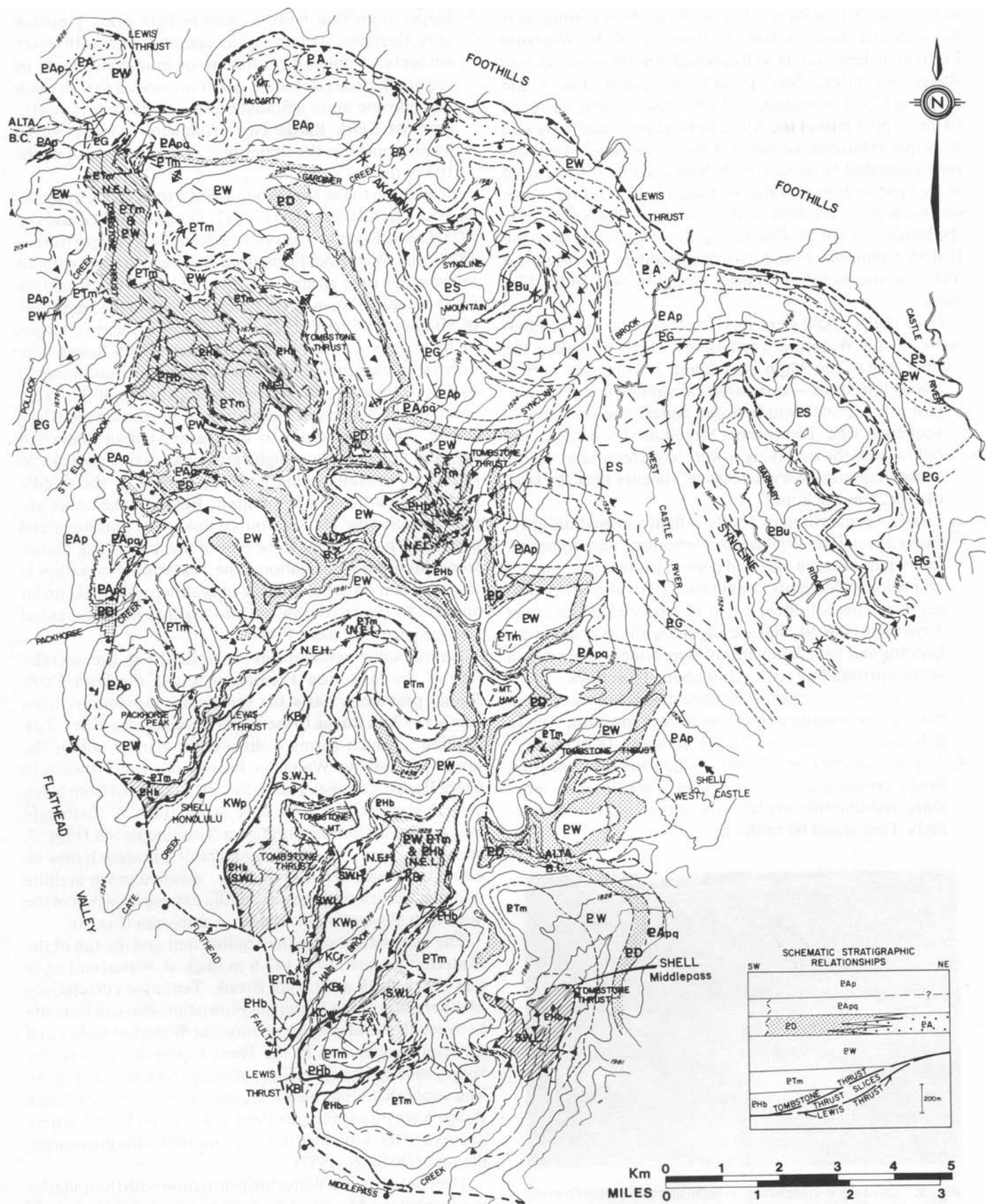


Fig. 10. Geology of northern Clark Range, British Columbia and Alberta (after Fermor, 1980).

LEGEND

CRETACEOUS		BELT – PURCELL SUPERGROUP	
UPPER CRETACEOUS			
MESOZOIC	 BELLY RIVER FORMATION	 UPPER BELT – PURCELL SUPERGROUP	
	ALBERTA GROUP	 SIYEH FORMATION	
	 WAPIABI FORMATION	 GRINNELL FORMATION	
	 CARDIUM FORMATION	 APPEKUNNY FORMATION	
	 BLACKSTONE FORMATION	 QUARTZ SS. UNIT OF APPEKUNNY FORM	
	LOWER CRETACEOUS	 ALTYN FORMATION/ DOLOMITIC ARGILLITE UNIT	
	 CROWSNEST FORMATION	 WATERTON FORMATION	
	 BLAIRMORE GROUP	 TOMBSTONE MOUNTAIN FORM	
		 HAIG BROOK FORMATION	
CONTACT			
(approximate, assumed)			
(mappable limit of unit)			
BEDDING (inclined)			
THRUST FAULT (defined, approximate, assumed)			
TRANSVERSE FAULT (defined, approximate, assumed)			
NORMAL FAULT (defined, approximate, assumed)			
ANTICLINE (approximate)			
CONTOURS (interval 500 feet (153 meters))			
SYNCLINE (approximate)			
PROVINCIAL BOUNDARY			

NOTE

-  NORTHEAST LENS: fault slices of PHb, ETm and EW
-  SOUTHWEST LENS: fault slices of PHb
-  NORTHEAST HORSE: fault slices of rocks of unknown stratigraphic position
-  SOUTHWEST HORSE: fault slices of rocks of unknown stratigraphic position

argillaceous, dark grey limestone and dolomite or dolomite and limy argillite of the Tombstone Mountain Formation give way upward to lighter grey, resistant, cliff-forming silty limestone or dolomite of the Waterton Formation. The contact with the Altyn Formation in eastern Clark (see previous discussion) and with the Appekunny Formation in northwestern Clark Range is conformable and distinct, although gradational over a thicker interval in western Clark Range. In northwestern Clark Range medium grey, greenish grey and dull reddish brown argillaceous dolomites form the highest beds of the Waterton Formation and grade upward into green dolomitic argillites at the base of the "dolomitic argillite unit" of the Appekunny Formation.

TOMBSTONE MOUNTAIN FORMATION (NEW NAME)

The Tombstone Mountain Formation is defined as the sequence of dark grey argillite, dolomitic and calcareous argillite, and argillaceous dolomite and limestone that underlies the light-coloured silty and argillaceous carbonates of the Waterton Formation and overlies light-coloured carbonate rocks of the Haig Brook Formation (new name, see below) in northwestern Clark Range.

The type section (Fig. 11 and Appendix 3) is located approximately 4.5 km northeast of the confluence of Middlepass Creek and Haig Brook, on a shoulder of the ridge that forms the northwest side of Middlepass Creek Valley. The shoulder leads up to the most southerly prominent summit on the ridge. The section is approximately 54 km southeast of Fernie, British Columbia, and can be reached via the road to the Shell Middlepass wellsite from the Flathead forestry road. The formation is also well exposed on Tombstone Mountain, 4 km northwest of the type section.

At the type section the Tombstone Mountain Formation consists of dark grey to black argillaceous and/or silty limestone or dolomite and argillite, with all gradations between these lithotypes. Black, rusty-weathering argillite occurs as interbeds near the top at the type section and forms a thin marker bed near the base of the formation throughout northwestern Clark Range. Fine colour-laminations are common on the weathered surfaces throughout the formation. The more carbonate-rich beds commonly display wavy bedding surfaces, with an amplitude of 1 or 2 cm. These waves resemble the structures that occur below in the mixed limestone and dolomite beds of the underlying Haig Brook Formation and are presumed to be algal stromatolites.

The Tombstone Mountain Formation becomes less argillaceous, more dolomitic and calcareous, and less recessive in over-all aspect in northeasterly exposures. At St. Eloi Brook and Syncline Brook (Fig. 10) the lowermost portion consists of about 60 m of recessive, dark grey, argillaceous limestone and dark grey to black argillite. A distinct resistant, rusty-weathering, laminated black argillite,

1 m thick, occurs 8 m above the base. The overlying 20 to 25 m consists of grey, yellowish-brown-weathering, argillaceous limestone or dolomite which appears to become moderately resistant to the northeast. Higher strata include an 11-m-thick unit of black argillite and grey, argillaceous, grey-weathering limestone that appears to change north-eastward to a 28-m-thick unit of banded and streaked yellowish brown and grey-weathering argillaceous dolomite and limestone, and medium to dark grey, fissile, recessive, argillaceous limestone and argillite (Price, 1965, p. 144).

The Tombstone Mountain Formation is recognized from the northern end of Clark Range around the headwaters of Pollock Creek (Figs. 2, 10), southward through western Clark Range to the south side of Middlepass Creek. It may be exposed at Sage Creek, and this question is discussed below. There is no marked change in the thickness of this unit over the area in which it is exposed, and the thickness of 175 m measured at the type section appears to be representative. There may be some thickness decrease northwestward toward the St. Eloi Brook - Cate Creek - Haig Brook area. A stratigraphic section measured near the headwaters of St. Eloi Brook (Price, 1965, p. 144) probably contains repetitions due to thrust faults and therefore cannot be used as a detailed reference section.

The contact with the underlying Haig Brook Formation is gradational. It is placed where banded and streaked limestone and dolomite of the Haig Brook Formation grade upward, over a few metres, into a dark-grey-weathering argillaceous limestone and dolomite interbedded with dark grey to black argillite of the Tombstone Mountain Formation. The contact with the Waterton Formation has been described above.

HAIG BROOK FORMATION (NEW NAME)

The Haig Brook Formation is defined here as the resistant, light-coloured, cliff-forming sequence of dolomite, banded and streaked limestone and dolomite, and minor argillite that underlies the dark-coloured limestone, dolomite and argillite of the Tombstone Mountain Formation. This sequence forms the hangingwall of the Lewis thrust fault around the Cate Creek and Haig Brook windows. These beds occur in a series of sigmoidal, imbricate, southwesterly overlapping thrust-fault slices that are bounded below by the Lewis thrust and above by the Tombstone thrust (see Fermor and Price, 1976). Although a complete section has not been observed in any single thrust slice, a composite stratigraphic type section has been established on the basis of stratigraphically overlapping partial sections in individual fault slices. The sections are exposed in cliffs on the northwest side of Haig Brook Valley about 1.5 km southwest of the summit of Tombstone Mountain (Figs. 2, 10) and about 50 km southeast of Fernie, British Columbia. The sections are accessible from the Flathead forestry road, via a seismic trail, and the access road to the abandoned Shell Middlepass wellsite.

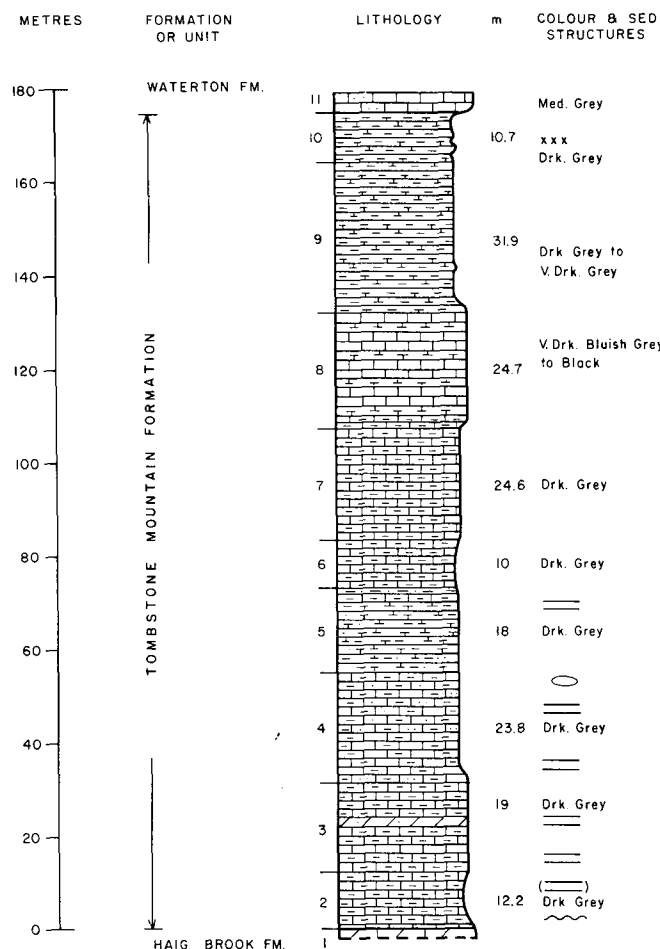


Fig. 11. Graphic plot of the type section of the Tombstone Mountain Formation. Refer to Figure 3 for legend and Appendix 3 for detailed description. Numbers of units correspond to those in Appendix 3.

The Haig Brook Formation can be subdivided into five distinct units. They are informally labelled A to E from lowest to highest, following Fermor and Price (1976) — who incorrectly referred these strata to the “Waterton Formation”. The following description for the type section (see also Fig. 12 and Appendix 4) is applicable only to the immediate Cate Creek - Haig Brook area.

Unit A consists mainly of resistant, medium to dark grey, finely crystalline, light-yellowish-brown-weathering dolomite. Beds are 0.15 m to 1 m thick near the base, but decrease in thickness upward, and the upper part of the unit is platy-weathering. Banded yellow- and grey-weathering, medium grey dolomite and limestone occur in units up to 2 m thick. Locally the dolomite is laminated. Interbeds of dark grey to black, dark-weathering argillite, 0.1 to 2 m thick, occur in the lowest 10 m. The base of the exposed portion of unit A is a bedding glide-zone of the Lewis thrust. The interval immediately below the thrust is recessive-weathering and generally covered; thus the thickness of Unit A is difficult to determine. The part of Unit A

that occurs above the Lewis thrust is probably not more than 80 m thick, and may be slightly less.

Unit B comprises 34 m of very resistant, banded and streaked bluish-grey and yellowish-brown-weathering, very finely crystalline limestone and dolomite. The carbonates are a uniform light to medium grey on fresh surfaces, but show fine details of intermixed dolomite and limestone bands on weathered surfaces (Fig. 13). Intraformational flat-pebble conglomerate and prelithification fold structures are fairly common. Cross bedding is also common and is outlined by yellow-brown silt and very fine sand-size grains of dolomite in a matrix of grey-weathering limestone. Broad bulbous structures up to 1 m wide and less than 0.15 m high, possibly of stromatolitic origin, are fairly common. Interbeds of dolomite up to 2 m thick occur throughout the unit.

Unit C is 8 m thick and has an abrupt contact with Unit B but grades upward into Unit D. The lower part of Unit C consists of black, distinctly laminated, fissile, recessive argillite. It grades upward into dark grey, platy, dolomitic argillite which in turn merges upward into argillaceous dolomite at the base of Unit D.

Unit D comprises 18 m of resistant, platy-weathering, medium grey, very finely crystalline dolomite and argilla-

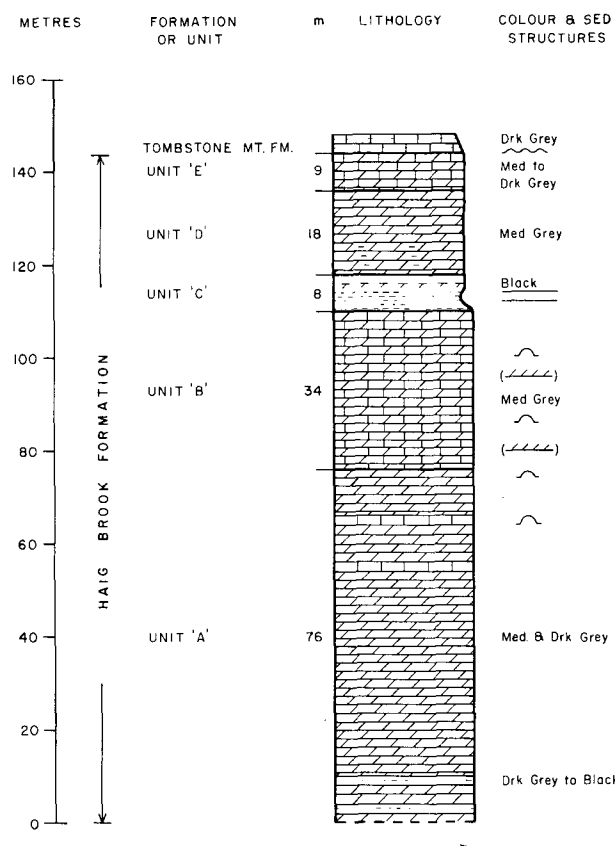


Fig. 12. Graphic plot of the (composite) type section of the Haig Brook Formation. Refer to Figure 3 for legend and Appendix 4 for written description.



Fig. 13. Intermixed dolomite and limestone bands on weathered surfaces in Unit B.

ceous dolomite. It weathers medium brown and locally red-brown, and commonly is partly covered by yellow lichen. In southwesterly exposures light- and dark-grey colour bands, approximately 0.5 cm thick, are common on fresh surfaces.

Unit E, 9 m thick, comprises banded and streaked, slightly argillaceous, finely crystalline, medium to dark grey, resistant limestone and dolomite. The lower contact is abrupt, but the upper contact is gradational over 1 to 2 m into argillaceous limestones and argillites of the overlying Tombstone Mountain Formation. Unit E is very similar to Unit B, but darker in colour, probably because it is more argillaceous.

These lithostratigraphic units were initially identified in the vicinity of Cate Creek and Haig Brook, and then were traced southward to Middlepass Creek, northward to St. Eloi Brook and eastward to Syncline Brook. It is important to emphasize that even very thin units maintain their identities over the entire area of exposure, and the changes that do occur are gradational and systematic. In general there is a progressive northeasterly decrease in the proportion of argillaceous material in units B, C, D and E, and colour changes in Units B, C and D from rocks that on fresh surfaces are various shades of grey, to green, red, cream and white rocks.

There are a number of specific lateral changes that are noteworthy (Fig. 14). The darkest-weathering beds in Unit C occur above the Tombstone thrust near its southwestern limit of exposure (Fig. 10). The equivalent beds in the imbricate fault slices below the Tombstone thrust, which originally were in a relatively more northeasterly position, are distinctly lighter-grey-weathering. In the southwest portion of the valley of St. Eloi Brook the dark-weathering beds of Unit C can be distinguished from the base of Unit D, but in the northeast portion Unit C can be recognized only as a more argillaceous, platy-weathering interval at the base of Unit D.

Northeastward to St. Eloi and Syncline Brook equivalents of Unit D become brighter-coloured. The sequence

begins with 11 m of platy, brown-weathering, moderately resistant, predominantly green, argillaceous dolomite with a more argillaceous interval at the base (*i.e.*, the equivalent of Unit C). These are overlain by 6 m of resistant, platy, red- and yellow-weathering, dull red, cream, and minor green, colour-laminated argillaceous dolomite; in turn overlain by 8.5 m of resistant, yellow- brown- and red-weathering, green and red colour-laminated, argillaceous dolomite.

The banded and streaked limestone and dolomite of Unit E becomes progressively less argillaceous and correspondingly lighter grey, and thickens from about 9 m to 12 m or more to the north and northeast. The thickness change is probably at the expense of the overlying Tombstone Mountain Formation.

The Haig Brook Formation is exposed in fault slices from St. Eloi Brook (Figs. 2, 10) southeast to Syncline Brook and southward to Middlepass Creek. Throughout this area the base, where exposed, is a bedding glide-horizon forming the hangingwall of the Lewis thrust. In the light of the variations in lithology described above, however, the formation and its subunits appear to be relatively constant in thickness, with the greatest thickness, about 150 m, occurring above the Lewis thrust at Haig Brook and Cate Creek.

The contact with the overlying Tombstone Mountain Formation is described in a previous section. The lower contact is not exposed, but may have been identified in the subsurface in the Pacific-Atlantic Flathead No. 1 well at Sage Creek (Fig. 2), where the Haig Brook Formation appears to be underlain by dark argillites that comprise a new unit (see below).

STRATIGRAPHIC CORRELATIONS FROM CATE CREEK AND HAIG BROOK WINDOWS TO SAGE CREEK

The "dolomitic argillite" beds that overlie the Waterton Formation around Cate Creek and Haig Brook, and are the lateral stratigraphic equivalents of the Altyn Formation beds along West Castle River, are overlain by a sequence about 125 m thick of alternating green argillites and prominent, thick, quartzitic sandstones referred to previously. The thick, white, quartzitic sandstones form good markers, easily visible on vertical air photographs. This argillite-sandstone unit, which comprises the "middle part of the Appekunny Formation" as mapped by Norris (1959) in the southwest limb of the Akamina syncline, can be recognized throughout northern Clark Range (1957 field notes of R.A. Price and D.U. Wise). It can be traced on vertical air photographs as far south as the north side of Commerce Creek (Fig. 2), and intermittent exposures of the prominent white quartz sandstones appear to be present on the western slopes of Commerce Peak (R.D. McMechan, *pers. comm.*, 1980), within 4 km of Sage Creek (see also Fig. 15).

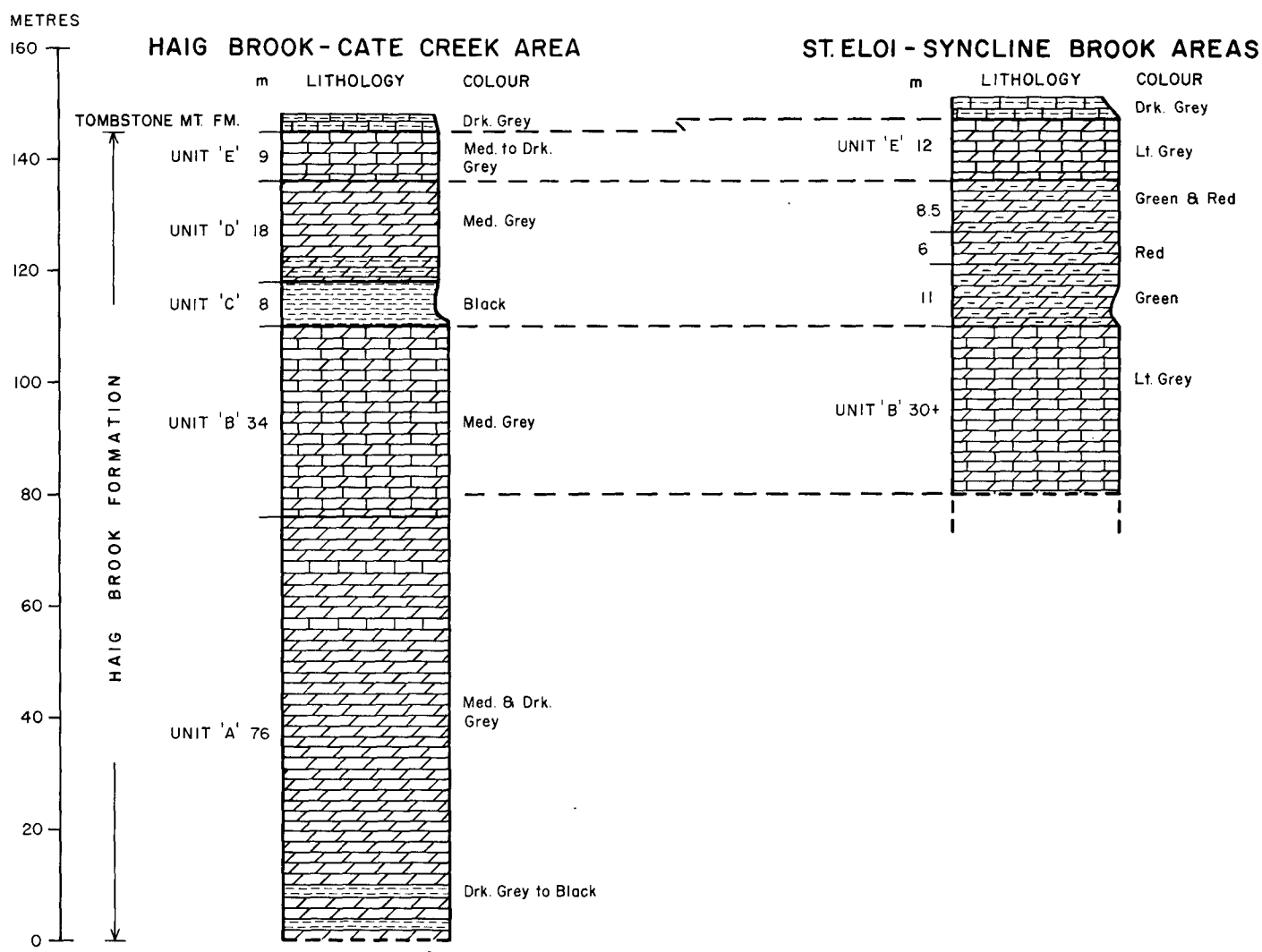


Fig. 14. Diagram of stratigraphic relationships in the Haig Brook Formation across N. Clark Range.



Fig. 15. Two prominent white-weathering dolomitic quartz sandstone marker units on south side of Commerce Creek, midway between Sage and Middlepass Creeks. Underlying cliffs are dolomitic argillite unit, overlying slopes are argillite and sandstones of Appekunny Formation. Photo by R.D. McMechan.

Three prominent resistant beds of white quartz-sandstone and dolomitic quartz-sandstone occur at Sage Creek (Fig. 16, column S), where they are interbedded with argillaceous, quartzitic and dolomitic siltstone; green and grey argillite; dolomitic green argillite, and very light grey and greyish green, dolomitic, fine-grained quartz-sandstone (see stratigraphic section, Fig. 16, Appendix 5 and Fig. 2). These beds form a unit 122 m thick. This unit, which was assigned to the lower part of the Appekunny Formation at this locality by Price (1962), appears to be the lateral equivalent of the quartzitic sandstone marker unit identified in northern Clark Range.

South of Middlepass Creek the uppermost beds of the Waterton Formation, and the overlying beds in the "dolomitic argillite unit" (a facies equivalent of the beds assigned to the Altyn Formation at West Castle River) form a series of alternating, more or less resistant beds above a recessive interval comprising the middle part of the Waterton Formation. These upper Waterton and dolo-

Furthermore, the strata penetrated in the well consist of a sequence of distinct units that are unlike higher stratigraphic units in the Belt-Purcell succession (see Table 1). On this basis, it must be concluded that the major part of the Belt-Purcell stratigraphic section penetrated in the well consists of stratigraphic units older than any exposed on the surface in northwestern Clark Range. Because the units are known only from chip samples from one well, no comments can be made about their lateral extent and correlation, and they will be referred to here, informally, as units 1 to 4 from top to bottom.

Unit 1

Unit 1 is a sequence of black argillite, black calcareous and dolomitic argillite, and dark argillaceous dolomite and limestone (see Appendix 6 and Fig. 16). It is present between 155 and 262 m (107 m thick) in the Pacific-Atlantic Flathead No. 1. well. It underlies Haig Brook carbonates. At the type section of the Haig Brook Formation, argillites occur in the basal beds, suggesting a transitional contact with the argillites of Unit 1.

Unit 2

Unit 2 is a sequence of argillaceous dolomite and black argillite between 262 and 576 m (314 m thick) in the Pacific-Atlantic Flathead No. 1. well.

It contains three subdivisions. The upper 235 m consists of light brownish grey to medium grey, very finely crystalline to cryptocrystalline, argillaceous dolomite, in part colour-laminated. A middle subdivision of 42 m of black, argillaceous dolomite and black argillite overlies a lower division that consists of 37 m of varicoloured argillaceous dolomite with minor black argillite (see Appendix 6 and Fig. 16).

The upper contact with Unit 1 is abrupt, and is marked by a change from dark grey to black argillite to grey argillaceous dolomite within a single sample interval. The slightly greenish argillaceous dolomite at the base of Unit 2 marks a gradational transition to the varicoloured dolomites of Unit 3.

Unit 3

Unit 3 is a sequence of varicoloured limestone and dolomite between 576 and 795 m in the Pacific-Atlantic Flathead No. 1 well. It underlies the argillaceous dolomites and argillites of Unit 2 and overlies the grey argillaceous dolomites of Unit 4.

The principal lithotypes of Unit 3 are white, light grey, light greenish grey, and red-brown dolomite interbedded with white and light grey limestone; all very finely crystalline to cryptocrystalline (see Appendix 6 and Fig. 16). A white limestone at the base forms a useful marker. Parts of this unit were penetrated a second time in a lower thrust-fault slice. The lithological details vary between the two sections, but the white limestone unit can be recognized in both, and the range of lithotypes remains the same.

As noted above, the upper contact is transitional. The lower, transitional contact is placed at the change from grey argillaceous dolomite of Unit 4 to light grey and white limestone at the base of Unit 3 (Appendix 6).

Unit 4

Unit 4 is a sequence of medium- to dark-grey, in part light grey, dense, very finely crystalline, argillaceous dolomite present between 795 and 1012 m in the Pacific-Atlantic Flathead No. 1 well (Fig. 16 and Appendix 6). In the well, the base of Unit 4 is a thrust fault that repeats part of the section penetrated higher in the well, but no beds older than those encountered above the fault were penetrated before the well encountered the Lewis thrust and the Paleozoic rocks that lie beneath it.

STRATIGRAPHIC CORRELATIONS ACROSS SOUTHERN CLARK RANGE

Precise correlations between the Sage Creek area and the Waterton map-area are difficult to establish at levels below the top of the Appekunny Formation. The resistant quartzitic sandstone unit of northwestern Clark Range can be traced on vertical air photographs as far south as Miskwasini Peak, just north of Kishenina Creek in western Clark Range near the British Columbia - Montana boundary (Fig. 2). However, no quartzitic sandstone unit with the same lateral continuity has been reported from northeastern Clark Range by Norris (1959), although beds of quartz sandstone do occur near the base of the Appekunny Formation in this area. Three quartz sandstone and sandy dolomite beds occur in the lower 150 m of the Appekunny Formation in Waterton map area. Two grade laterally into argillite toward the southwest, but one of these, a quartz sandstone unit at the base of the Appekunny Formation, apparently persists throughout the Waterton map area (Douglas, 1952).

As noted above, the "middle" part of the Altyn Formation in western Waterton map-area consists of two or three resistant, white-weathering beds of sandy dolomite, each 15 to 20 m thick, in an interval of interbedded dolomite muds, dark shales and siltstone about 130 m thick (which may include beds equivalent to the upper part of the Altyn Formation in eastern Waterton map-area) and is overlain by a quartz sandstone at the base of the Appekunny Formation. The lower part of the Altyn Formation persists as a sequence of thin-bedded, finely laminated grey dolomite. These sequences resemble, and may be the lateral equivalents of, the quartzitic sandstone and dolomitic argillite units, respectively, of southwestern Clark Range.

CONCLUSIONS

The strata that occur in the hangingwall of the Lewis thrust fault around the Cate Creek and Haig Brook windows in northwest Clark Range, and formerly were corre-

lated with the Waterton Formation, are overlain by strata correlative with the Waterton Formation and comprise two new units of an earlier age, the Tombstone Mountain and Haig Brook Formations. Furthermore, the strata penetrated by the Pacific-Atlantic Flathead No. 1 well at Sage Creek appear to underlie the Haig Brook Formation, and to comprise the lowest stratigraphic levels known from the Lewis thrust sheet.

Thickness and facies changes in the lower part of the Belt Purcell Supergroup indicate that the shape of the northern part of the Clark Range salient of the Lewis thrust sheet appears to be controlled by the shape of the basin in which the Belt-Purcell Supergroup accumulated (see McMechan, 1981). The thinnest and most condensed sections occur near the north and northeast margins of the Clark Range salient. Distinctive sedimentary facies such as red and green dolomite, columnar stromatolites, banded and streaked limestone and dolomite and sandy dolomite appear relatively abruptly near the margins of the salient, whereas more argillaceous facies, perhaps indicative of a deeper-water depositional environment, make up equivalent stratigraphic horizons away from the margins.

REFERENCES

- Bally, A. W., Gordy, P. L., and Stewart, G. A. 1966. Structure, seismic data, and orogenic evolution of southern Canadian Rocky Mountains. *Bulletin of Canadian Petroleum Geology*, v. 14, p. 337-381.
- Bielenstein, H. U. 1969. The Rundle Thrust Sheet, Banff, Alberta. Unpublished Ph.D. thesis, Queen's University, Kingston, Ontario.
- Childers, M. O. 1963. Structure and stratigraphy of the southeast Marias Pass area, Flathead County, Montana. *Geological Society of America Bulletin*, v. 74, p. 141-164.
- Clark, L. M. 1954. Cross-section through the Clark Range of the Rocky Mountains of southern Alberta and southern British Columbia. *Alberta Society of Petroleum Geologists, Guidebook, 4th Annual Field Conference*, p. 105-109.
- Dalstrom, C. D. A. 1970. Structural geology in the western margin of the Canadian Rocky Mountains. *Bulletin of Canadian Petroleum Geology*, v. 18, p. 332-406.
- , Daniels, R. E. and Henderson, G. G. L. 1962. The Lewis thrust at Fording Mountain, British Columbia. *Bulletin of Canadian Petroleum Geology*, v. 10, p. 373-395.
- Daly, R. A. 1912. *Geology of the North American Cordillera, at the Forty-ninth Parallel*. Geological Survey of Canada, Memoir 38.
- Douglas, R. J. W. 1952. Preliminary map, Waterton, Alberta. Geological Survey of Canada, Paper 52-10.
- 1977. Waterton Lakes National Park. In: Gordy, P. L. et al. (Eds.), *Geological Guide for the Canadian Society of Petroleum Geologists, Waterton - Glacier Park Field Conference*.
- Fenton, C. L. and Fenton, M. A. 1937. Belt Series of the north: stratigraphy, sedimentation, paleontology. *Geological Society of America Bulletin*, v. 48, p. 1837-1970.
- Fermor, P. R. 1980. Structural and Stratigraphic Analysis of Rocks Adjacent to the Lewis Thrust Fault Around the Cate Creek and Haig Brook Windows, British Columbia and Alberta. Unpublished M.Sc. thesis, Queen's University, Kingston, Ontario.
- and Price, R. A. 1976. Imbricate structures in the Lewis thrust sheet around the Cate Creek and Haig Brook windows, southeastern British Columbia. *Geological Survey of Canada, Paper 76-1B*, p. 7-9.
- Gordy, P. L., Frey, F. R. and Norris, D. K. 1977. Geological guide for the Canadian Society of Petroleum Geologists 1977 Waterton - Glacier Park Field Conference. *Canadian Society of Petroleum Geologists*.
- Hage, C. O. 1943. Beaver Mines, Alberta. *Geological Survey of Canada, Map 739A*.
- Hume, G. S. 1933. Waterton Lakes - Flathead Valley Area, Alberta and British Columbia. *Geological Survey of Canada, Summary Report, 1932, Part B*, p. 1-20.
- Jones, P. B. 1969. Tectonic windows in the Lewis thrust, southeastern British Columbia. *Bulletin of Canadian Petroleum Geology*, v. 17, p. 247-251.
- McMechan, M. E. 1981. The Middle Proterozoic Purcell Supergroup in the southwestern Rocky and southeastern Purcell Mountains, British Columbia and the initiation of the Cordilleran Miogeocline, southern Canada and adjacent United States. *Bulletin of Canadian Petroleum Geology*, v. 29, p. 583-621.
- Mudge, M. R., Earhart, R. L., Cobban, W. A. and Rice, D. D. 1977. Glacier National Park and areas to the south and east. In: Gordy et al. (Eds.), *Geological Guide for the Canadian Society of Petroleum Geologists 1977 Waterton - Glacier Park field conference*.
- and Earhart, R. L. 1980. The Lewis thrust fault and related structures in the Disturbed Belt, northwestern Montana. *United States Geological Survey, Professional Paper 1174*.
- Norris, D. K. 1959. Carbondale River, Alberta - British Columbia. *Geological Survey of Canada, Map 5-1959*.
- Olsson, A. A. and Caster, K. E. 1935. Occurrence of *Baculites ovatus* zone of Upper Alberta shales in southeastern British Columbia. *American Association of Petroleum Geologists Bulletin*, v. 19, p. 295-299.
- Price, R. A. 1958. Structure and Stratigraphy of the Flathead North Map-area (East Half), British Columbia and Alberta. Unpublished Ph.D. thesis, Princeton University, New Jersey.
- 1959. Flathead, British Columbia and Alberta. *Geological Survey of Canada, Map 1-1959*.
- 1962. Fernie map-area, east half, Alberta and British Columbia, 82G east half. *Geological Survey of Canada, Paper 61-24*.
- 1964. The Precambrian Purcell System in the Rocky Mountains of southern Alberta and British Columbia. *Bulletin of Canadian Petroleum Geology*, v. 12, p. 399-426.
- 1965. Flathead map-area, British Columbia and Alberta. *Geological Survey of Canada, Memoir 336*.
- 1981. The Cordilleran foreland thrust and fold belt in the southern Canadian Rocky Mountains. In: McClay, K. R. and Price, N. J. (Eds.), *Thrust and Nappe Tectonics*: Geological Society of London.
- Ross, C. P. 1959. *Geology of Glacier National Park and the Flathead Region, northeastern Montana*. United States Geological Survey, Professional Paper 296.
- Spang, J. H., Brown, S. P., Stockmal, G. S. and Moffat, I. 1981. Structural Geology of the Foothills and Front Ranges west of Calgary, Alberta. In: Thompson, R. I. and Cook, D. G. (Eds.), *Field Guides to Geology and Mineral Deposits, Calgary*. 1981 Geological Association of Canada, Mineralogical Association of Canada, Canadian Geophysical Union.
- Willis, B. 1902. Stratigraphy and structure, Lewis and Livingstone Ranges, Montana. *Geological Society of America Bulletin*, v. 13, p. 305-352.

APPENDIX 1

Succession above Lewis thrust at West Castle River

Location: Northeast flank of Syncline Mountain along ridge trending northwest from West Castle road toward Suicide Creek; 50 km southeast of Fernie, British Columbia. N.T.S. Fernie 82-G/B - U.T.M. Grid no. 688 000 m E, 5470 m N, Zone 11. Stratigraphic section measured July 1976 by R.A. Price and J.M. Dixon. Top of exposure-dip slope.

Unit	Description	Thickness (m)	Height Above Base (m)
ALTYN FORMATION			
60	Quartz sandstone: conglomeratic, dolomitic, very light grey, grains well rounded; in part quartz granule conglomerate; beds 0.3-3.0 m thick; weathers yellow and light red-brown; grains etched in relief.	5.5	194.8
59	Quartz sandstone: as in unit 60, but fine-grained.	3	189.3
58	Covered interval, probably as in unit 59.	0.46	186.3
57	Sandstone and siltstone: dolomitic, light grey, lenses and stringers of granules and coarse-grained to very coarse grained well-rounded quartz sand; weathers light red-brown, grains etched in relief.	2.5	181.7
56	Quartz sandstone: calcareous, light to medium grey, stringers of coarse-grained to very coarse grained well-rounded grains and some granules of quartz, weathers light blue-grey, platy. Grades down into unit 55.	1.3	179.2
55	Quartz sandstone and fine-grained sandstone: dolomitic, light to medium grey; stringers of coarse-grained sand and granules of rounded quartz; beds 15 cm - 1.6 m thick; weathers light red-brown; with quartz etched in relief; lower 1.3 m stromatolitic.	3.6	177.9
54	Dolomite: silty and argillaceous, light to medium grey, platy to shaly. Interbeds of light to medium grey dolomitic siltstone and fine-grained sandstone.	5.5	174.3
53	Dolomite: light pink-grey; stromatolitic; upright columns 8-15 cm wide, matrix of dolomitic coarse-grained quartz sandstone; grading up to light yellow-grey dolomitic argillite. Flat-pebble conglomerate 8 cm thick at base.	1.3	168.8
52	Siltstone and fine-grained sandstone: dolomitic, light yellow-grey. Interbedded with light yellow-grey, argillaceous dolomite beds, 15 cm to 0.6 m thick. Siltstone beds, 0.3 to 0.6 m thick, weather light yellow-brown, with laminations in the siltstone etched in relief.	4	167.5
Shift along strike to east.			
51	Dolomite: as in unit 53 without flat-pebble conglomerate at base. Infilling of dolomitic siltstone between stromatolite columns.	0.6	163.5
50	Siltstone: dolomitic, light green-grey, weathers light red-brown, with silty and sandy laminations etched in relief. Interbeds of green-grey, argillaceous dolomite, and light grey dolomitic quartz sandstone. Beds 5-25 cm thick.	4.5	162.9
49	Stromatolitic limestone? or dolomite?: columnar stromatolites up to 0.3 m tall at base, in matrix of green-grey dolomitic shale; grade up into spherical and elliptical stromatolites at top.	1.6	158.4
48	Light green-grey, argillaceous dolomite: platy; weathers yellow-brown.	0.3	156.8
47	Argillaceous dolomite: light green-grey, micritic, partly stromatolitic, partly finely laminated. Flat-pebble conglomerate in basal 0.3 m. Weathers light grey.	1	156.5
Shift along strike to east.			
46	Stromatolitic limestone? or dolomite?: columns inclined updip (to northeast); columns are up to 25 cm high, 10 cm wide; matrix is dolomitic argillite; weathers light grey-pink.	2.2	155.5
45	Dolomitic siltstone and shale: light to medium grey, platy; weathers red-brown.	1	153.3
44	Stromatolitic limestone? or dolomite? as in unit 46.	0.6	152.3
"Lower Altyn"			
43	Dolomitic siltstone and shale: light green-grey siltstone grades to fine-grained sandstone; beds up to 0.3 m thick. Shale partings up to 7.5 cm thick, weathers light yellow-brown and red-brown. A few interbeds up to 15 cm thick of flat-pebble, dolomite clast conglomerate.	2.2	151.7
42	Shaly, silty dolomite: light red-grey, brown-grey; platy; grades down into unit 41.	3.0	149.5
41	Shale: light grey-green and grey-red; thin interbeds of siltstone.	8.5	146.5

Unit	Description	Thickness (m)	Height Above Base (m)
Shift along strike to east.			
40	Shale or argillite: light green-yellow-grey, platy to fissile. Thin interbeds of silty argillite near top.	15.3	138
Shift along strike to east.			
39	Argillite: silty, dolomitic, light green-grey; weathers yellow-brown; platy; grades down into unit 23.	2.2	122.7
	Measured (partial) thickness of Altyn Formation.	74.3	
WATERTON FORMATION			
38	Limestone: light green-grey, micritic; thin (up to 5 cm) lenses and nodules in a light green calcareous shale matrix; weathers light grey and green-grey banded and streaked (B & S) with reddish patches; grades down into unit 37.	6	120.5
37	Limestone: argillaceous and silty, medium grey and green-grey, platy; weathers medium grey and brown-grey with laminations etched in relief; grades to argillite at base.	6	114.5
36	Limestone: light grey and green-grey, dense micritic, thin beds and lenses in light yellow-grey shaly matrix; weathers banded and streaked with laminations etched in relief.	5.6	108.5
35	Limestone: light grey, micritic, disseminated quartz silt; weathers light grey with silty laminations etched in relief. Flat-pebble conglomerate at top.	0.3	102.9
34	Limestone: light green-grey, argillaceous and silty; thin beds and lenses in matrix of light green-grey calcareous shale.	2.5	102.6
33	Limestone: light green-grey, silty and sandy; grades to dolomitic quartz siltstone and sandstone.	0.6	100.1
32	Limestone: as in unit 34.	4.5	99.5
Shift along strike to east.			
31	Limestone: argillaceous, grey-red, platy, dense micritic.	1	95
30	Limestone: argillaceous, dense micritic, light green-grey, in part silty and shaly; weathers light yellow-brown with laminations etched in relief; in part cross bedded.	3.6	94
29	Shale: light green-grey with lenses of light green-grey micritic limestone.	0.6	90.4
28	Limestone: argillaceous, micritic, light green-grey and yellow-grey; finely laminated; nodular and platy; weathers light yellow-grey.	1	89.8
27	Limestone: argillaceous, micritic, grey-red, nodular and shaly; finely laminated.	1	88.8
26	Limestone: argillaceous, light grey-green, silty, micritic; weathers banded and streaked, grey and light yellow-brown; laminations etched in relief.	1.6	87.8
25	Dolomite and dolomitic siltstone: micritic, silty; light grey; beds 7.5 cm to 30 cm thick; weathers yellow-brown, platy, with laminations etched in relief. Thin lenses and beds of light green-grey limestone at base.	8	86.2
24	Limestone: medium grey-red, argillaceous, micritic; shale partings.	0.6	78.2
23	Limestone: micritic, light grey and green-grey; lenses and thin beds in a matrix of argillaceous and silty limestone. Weathers banded and streaked light green-grey and yellow-brown, platy.	1.3	77.6
22	Dolomite: micritic, silty; light grey; weathers red-brown; laminations etched in relief. Interbeds of quartz sandstone and siltstone, dolomitic. Contains lenses and thin interbeds of light-grey-weathering limestone toward base.	3.6	76.3
21	Dolomite and sandstone: as in unit 22.	9.7	72.7
20	Limestone: as in unit 23.	0.6	63
19	Limestone: very light grey and green-grey, micritic; lenses and beds up to 5 cm thick in medium grey-red argillaceous matrix; weathers banded and streaked white and red.	2.5	62.4
18	Limestone: micritic, light grey-pink lenses and beds up to 5 cm thick in a green-grey argillaceous limestone matrix.	6	59.9
17	Limestone: as in unit 19; in part with minor green argillaceous matrix.	6	53.9
16	Limestone: as in unit 18 but green.	1.6	47.9
15	Limestone: as in unit 19 but red.	3.6	46.3
14	Limestone: silty, dense; medium red, weathers red-brown, rubbly.	1.6	42.7
13	Limestone: light grey and light green-grey, micritic, argillaceous and silty; weathers light grey and light yellow-brown, banded and streaked; platy.	2	41.1
12	Limestone: medium grey-red, argillaceous and shaly interbeds; platy, laminations etched in relief.	2	39.1

Unit	Description	Thickness (m)	Height Above Base (m)
11	Limestone: very light grey and green-grey, dense, micritic; occurs as thin beds and nodules intermixed with argillaceous, light green-grey dolomite. Weathers banded and streaked very light grey and light yellow. Becomes dominantly green-grey argillite at base.	12	37.1
10	Limestone: light grey, micritic; occurs as thin lenses and nodules in a matrix of argillaceous and silty, light grey limestone. Weathers banded and streaked light grey and light yellow-grey, platy.	2.3	25.1
9	Quartz siltstone: light green-grey, dolomitic; weathers yellow-brown, laminations etched in relief.	0.6	22.8
8	Limestone: as in unit 10.	1.6	22.2
7	Quartz siltstone: as in unit 9.	1.6	20.6
6	Argillite: light grey, calcareous, platy.	0.3	19
5	Siltstone: as in unit 9.	3	18.7
4	Argillite: dolomitic and silty; thin bands of light grey, micritic limestone.	2.7	15.7
3	Limestone: dark grey, micritic; beds 5 cm to 30 cm thick. Interbeds of dark grey calcareous shale up to 0.5 m thick.	2.5	13
2	Dolomite: silty and argillaceous, medium to dark grey; weathers light yellow-brown, laminations etched in relief.	3	10.5
1	Limestone: medium to dark grey, argillaceous and silty; thin bands and lenses in matrix of medium grey calcareous or dolomitic shale. Interbedded with silty dolomite (similar to unit 2). Becomes predominantly shale towards the base.	7.5	7.5

Base of Exposure.

APPENDIX 2

Principal reference section of the Waterton Formation

Location: On the south side of St. Eloi Valley near the headwaters of St. Eloi Brook, 45 km southeast of Fernie, British Columbia. N.T.S. Fernie 82-G/7; U.T.M. Grid no. 681 500 m E, 5467 000 m N, Zone 11. Measured by D.U. Wise for R.A. Price, 1958.

Unit	Description	Thickness (m)	Height Above Base (m)
APPEKUNNY FORMATION			
9	Argillite and dolomitic argillite: medium green, weathers medium brown and greenish brown, platy to blocky; massive beds 0.3 m to 1 m thick alternate with platy beds. Toward top becomes less dolomitic. Thin beds of arenaceous (very coarse quartz sand) argillite and coarse-grained sandstones and pebble conglomerates occur locally in upper part; first prominent, coarse-grained, white quartzite band occurs 102.1 m above base.	102.1	353.3
	Measured thickness of Appekunny Formation.	102.1	
WATERTON FORMATION			
8	Dolomite: argillaceous, medium grey and medium greenish grey, dull reddish brown in zones 3 m to 9.1 m thick, weathers light yellowish brown, locally dull red; a few elliptical concretions (stromatolites?), finely crystalline; beds 2.5 cm to 10 cm thick. Top of highest red dolomite is marked by a slight recessive zone with green dolomitic argillites of Appekunny above; contact transitional.	102.1	251.2
7	Dolomite: argillaceous, dull red, with light-grey-weathering elliptical concretions (stromatolites?) 2.5 cm thick and 10 cm long; weathers dull red, platy; finely crystalline. This unit is the lowest bed of red dolomite.	1.2	149.0
6	Limestone and dolomitic limestone: argillaceous (?), finely crystalline; beds 1.2 cm thick near base, 5 to 7.5 cm thick near top. Elliptical grey-weathering concretions (stromatolites?) 2.5 cm thick and 15 cm long, elongated parallel with bedding; local fine laminations are continuous through concretions, spacing of laminae increasing abruptly at their periphery to give closer spacing in matrix and wider spacing in concretion. Beds pinch and swell. Weathers light yellowish brown, platy, cliff-forming.	93.0	147.8
5	Argillite: black, colour-laminated in part, 3 mm laminae; becomes dark grey toward top; weathers black to dark grey at base, medium to grey at top; platy. Grades into overlying unit; sharply defined against underlying unit.	15.2	54.9

Unit	Description	Thickness (m)	Height Above Base (m)
4	Limestone: medium grey, finely crystalline, weathers light yellowish brown, platy. Abundant elliptical concretions (stromatolites?) 5 cm thick and 15 cm long which weather light grey. Beds 60 to 10 cm thick with faint textural laminations that pass through concretions and are compressed adjacent to them.	18.2	39.6
3	Limestone: medium grey, finely crystalline, arenaceous (medium-grained quartz sand), beds 2.5 to 10 cm thick; finely laminated; weathers medium brown with gritty surface, blocky.	4.6	21.3
2	Limestone: medium grey, finely crystalline; angular quartz sand locally present; weathers banded light grey and yellowish light brown; laminations; a few local, grey-weathering elliptical concretions.	16.7	16.7
	Thickness of Waterton Formation	251.2	
TOMBSTONE MOUNTAIN FORMATION			
1	Limestone: argillaceous, medium to dark grey, finely crystalline; 3 mm colour laminations; weathers medium grey, fissile, recessive.		

APPENDIX 3

Type section of the Tombstone Mountain Formation

Location: Approximately 4.5 km northeast of the confluence of Middlepass Creek and Haig Brook on a shoulder leading up to the most southerly prominent summit on the ridge which forms the northwest side of Middlepass Creek Valley, 54 km southeast of Fernie, British Columbia; N.T.S. Fernie 82-G/1; U.T.M. Grid no. 685 800 m E, 5456 800 m N, Zone 11. Measured by P. Fermor and G. Caldwell, 1981.

Unit	Description	Thickness (m)	Height Above Base (m)
WATERTON FORMATION			
11	Limestone: very finely crystalline, medium grey, silty, resistant buff-brown weathering; prominent cliff.		
TOMBSTONE MOUNTAIN FORMATION (174.9 m)			
10	Limestone: argillaceous, dark grey, very platy weathering. Interbeds of black, rusty-weathering calcareous argillite.	10.7	174.9
9	Limestone: argillaceous, dark grey, very platy weathering, with prominent unit of very dark grey limestone and calcareous argillite, 2 m thick, at 141.1 m.	31.9	164.2
8	Limestone: argillaceous, relatively resistant, black to very dark bluish grey, in beds about 0.5 m thick; interbedded with very platy brown and dark-grey-weathering limestone or limy argillite.	24.7	132.3
7	Limestone: argillaceous, platy-weathering, thin-bedded (<2.5 cm), dark grey.	24.6	107.6
6	Mainly covered: appears to be mainly dark grey argillaceous limestone. Some open folds with amplitudes of 1-2 m apparent. Grades downward into Unit 5.	10	33
5	Argillite: calcareous and silty, dark grey; interbedded with dark grey limestone; weathers to dark brown with fine colour laminations on weathered surface; medium brown and dark grey laminations; dark grey laminations absent below 70 m; grades downward into Unit 4.	18	73
4	Limestone: argillaceous, silty, platy-weathering; laminated dark grey; very finely crystalline; over-all brown-weathering aspect compared with dark grey of unit 3; laminations 1 mm (or less) to 0.5 cm thick; beds about 0.3 m thick.	23.8	55
3	Limestone: argillaceous; dark grey with many brown-weathering interbeds, which are laminated on the weathered surface and appear to be silty dolomite and/or silty limestone; beds about 3 cm thick weather to a dark, slightly bluish grey; forms a relatively prominent unit.	19	31.2
2	Limestone: very dark grey, cryptocrystalline to very finely crystalline, some beds with very fine laminations weathering dark grey and light brown; laminated beds have regular bedding, but other bedding surfaces are wavy and rough, similar in morphology to beds of banded and streaked limestone and dolomite of the underlying Haig Brook Formation. All limestone appears argillaceous, but platy beds are probably calcareous siltstone or calcareous argillite. Grades downward into Haig Brook Formation.	12.2	12.2
HAIG BROOK FORMATION: UNIT E			
1	Limestone and dolomite: banded and streaked yellow and grey on weathered surface, dark grey on fresh surface.		

APPENDIX 4

Composite type section of the Haig Brook Formation

Location: Approximately 1.5 km southwest of the summit of Tombstone Mountain on the cliff faces that form the northwest boundary of Haig Brook Valley, about 50 km southeast of Fernie, British Columbia; N.T.S. Fernie 82-G-1; U.T.M. Grid no. 683 800 m E, 5458 000 m N, Zone 11. This composite section was established from observations of a number of incomplete stratigraphic sections in overlapping thrust-fault slices. The thicknesses have been estimated from some measurements and from graphic estimates based on oblique air photographs of cliff faces.

Unit	Description	Thickness (m)	Height Above Base (m)
TOMBSTONE MOUNTAIN FORMATION			
6	Limestone: argillaceous, very finely crystalline, dark grey. Dark grey, argillite interbeds.		
HAIG BROOK FORMATION			
5	Limestone and dolomite: banded and streaked yellow and grey on weathered surface, dark grey on fresh surface.	9	145
	UNIT D		
4	Dolomite and argillaceous dolomite: medium grey, resistant but platy-weathering; weathers medium brown and locally red-brown, and commonly is partly covered by yellow lichen.	18	136
	UNIT C		
3	Dolomitic argillite and argillite: dark grey, platy. Argillite: black, laminated and fissile; recessive.	8	118
	UNIT B		
2	Limestone and dolomite: light to medium grey, banded and streaked bluish-grey- and yellowish-brown-weathering, very finely crystalline. Flat pebble conglomerates: prelithification fold structures; cross bedding outlined by dolomite grains in a limestone matrix, and bulbous structures (stromatolites?) occur throughout.	34	110
	UNIT A		
1	Dolomite: medium to dark grey, finely crystalline, weathers light yellowish brown, very resistant; beds 0.15 m to 1 m thick near base; platy-weathering near top. Argillite, dark grey to black, dark-grey-weathering; occurs as 0.1- to 2-m-thick interbeds near base. Banded-and-streaked-weathering limestone and dolomite facies occurs as interbeds.	76-80	76
Lewis Thrust Fault			
	Sandstone, siltstone, shale (Cretaceous) underlie the thrust plane.		

APPENDIX 5

Belt-Purcell Succession at Sage Creek, British Columbia

Location: Approximately 64.5 km southeast of Fernie, British Columbia; N.T.S. Fernie 82-G/1; U.T.M. Grid no. 689 000 m E, 5445 000 m N, Zone 11. The following summary section embraces strata from the lower part of the Purcell Supergroup measured by D.L. Scott for R.A. Price along the north side of the valley of Sage Creek. The description has already been published by Price (1964) but some additional unpublished details from the notes of D.L. Scott are included. In addition, the correlation of the units in this section has been re-interpreted.

Unit	Description	Thickness (m)	Height Above Base (m)
GRINNELL FORMATION			
1	Siltstone: argillaceous, red; thin lenses of quartz sandstone; grades downward through a few feet of laminated and banded red and green argillaceous siltstone into Appekunny Formation.		
APPEKUNNY FORMATION			
2	Siltstone: argillaceous and quartzitic. Argillite: in part silty, pale green, massive to platy; mud cracks occur locally. Lenses and thin interbeds of light grey and greenish grey quartzitic quartz sandstone, in part cross-bedded, grades locally to intraformational conglomerate consisting of plates and chips of argillite and siltstone in a quartz sandstone matrix; weathers light green.	85	1077.4

Unit	Description	Thickness (m)	Height Above Base (m)
3	Argillite, dolomitic argillite, silty argillite and argillaceous siltstone: pale green and greenish grey, faintly laminated; becomes very finely and distinctly laminated light and dark greenish grey toward base; weathers light green with rusty patches toward base.	135	992.4
4	Covered.	14	857.4
5	Argillite and argillaceous, quartzitic siltstone: light to medium-dark grey and greenish grey; in part very finely and distinctly laminated and banded; weathers light greenish grey, platy to massive.	63	843.4
6	Siltstone; argillaceous and quartzitic. Argillite, in part dolomitic; light greenish grey to medium grey; in part very finely and distinctly laminated and banded; weathers light greenish grey, platy and flaggy.	72	780.4
QUARTZ-SANDSTONE MARKER UNIT (of Appekunny Formation)			
7	Sandstone: quartzitic quartz arenite: white to very light grey and brownish grey, fine-grained, dense; locally contains chips of greyish green argillite; bedding commonly obscure; weathers very light grey to white, massive, resistant.	34	708.4
8	Siltstone: argillaceous and quartzitic, in part dolomitic, medium to greenish grey and greyish green; weathers medium to dark greyish green, massive to platy and flaggy.	24	674.4
9	Sandstone: quartzitic quartz arenite; grey to white, medium- to coarse-grained; locally contains chips of argillite; interbedded with dark greenish grey argillite; beds 7.5 cm to 15 cm thick; weathers light grey and brown.	6	650.4
10	Sandstone: quartzitic quartz arenite, in part dolomitic; white to very light grey, fine-grained, beds from 10 cm to 1 m thick, cross-bedded; weathers very light grey, resistant.	8	644.4
11	Argillite and silty argillite: light greenish grey to dark grey, very finely and distinctly laminated; interbeds of very light grey and greyish green, quartzitic and dolomitic, fine-grained quartz sandstone that locally contains chips of argillite; weathers light greenish grey to dark grey, platy.	5	636.4
12	Siltstone: argillaceous and quartzitic; light greenish grey in part dolomitic; interbeds of light grey, fine-grained, dolomitic and quartzitic quartz arenite at the top; weathers dark green to brown, resistant.	4.5	631.4
13	Argillite: in part dolomitic and silty; light greenish grey and medium dark grey; mainly finely and distinctly laminated and banded; weathers light greyish green, part rusty weathering, platy to blocky.	32.5	626.9
14	Sandstone: quartz arenite, quartzitic and dolomitic; light grey and greenish grey; very fine grained; interbedded with silty, dolomitic, light greyish green argillite; weathers brown, massive, resistant.	11	594.4
DOLOMITIC ARGILLITE UNIT of Appekunny Formation (lower part may be equivalent to upper part of Waterton Formation)			
15	Dolomite: silty and argillaceous; gradational to silty argillite; medium to light grey with slight greenish hue; weakly to strongly colour-laminated; weathers dark to medium grey, platy to blocky with some massive units.	210	583.4
WATERTON FORMATION EQUIVALENT			
16	Dolomite: silty, medium to greenish grey with lighter-coloured laminations. Upper 110 m is platy-weathering and largely covered. Lowest 60 m is in part platy-weathering. Lowest 6 m contains zones of laminated white limestone 2.5 to 7.5 cm thick.	170	373.4
17	Covered.	26	203.4
TOMBSTONE MOUNTAIN FORMATION			
18	Argillite: in part silty and micaceous; light to medium grey; very finely laminated; laminae in part disturbed by pre-lithification slumping (?); weathers medium grey with rusty stain.	13.7	177.4
19	Covered.	13.7	163.7
20	Siltstone: argillaceous, calcareous, dense; medium to dark grey; grades to laminated silty argillite; weathers light brownish grey.	13.5	150.0
21	Covered.	17.5	136.5
22	Argillite: medium to dark grey; very finely and distinctly laminated; weathers medium grey and rusty, platy.	19	119.0
23	Covered (graphic estimate of covered interval to the top of the sequence in the Pacific-Atlantic Flathead No. 1 well).	75-100	100

APPENDIX 6

Log of Pacific-Atlantic Flathead No. 1 (D-34-E 82-G-1) well, Sage Creek, British Columbia, based partly on published and unpublished descriptions by Price (1964) and R.J.W. Douglas. Sample log not adjusted to radioactivity logs.

Unit	Description	Thickness (m)	Depth Below K.B. (m)
HAIG BROOK FORMATION (?)			
1	Diorite: very finely crystalline to finely crystalline (may be cavings or till).	6.1	33.5-39.6
2	Dolomite: argillaceous; finely crystalline; medium to light grey. Rare beds of medium to light grey, finely crystalline, argillaceous limestone. Also rare dark grey dolomitic argillite. Some diorite chips (cavings?).	64	39.6-103.6
3	Limestone: very light grey to light grey, finely crystalline.	9.1	103.6-112.8
4	Dolomite: argillaceous, medium grey, finely crystalline.	12.2	112.8-125.0
5	Dolomite; medium to dark grey; argillaceous at top of interval grading to entirely argillaceous dolomite at 134.1 m depth (this interval marks the beginning of the downward transition to the dark argillites of Unit 1).	15.2	125.0-140.2
UNIT 1 (dark argillite)			
6	Argillite: dolomitic, black to dark grey.	6.1	140.2-146.3
7	Limestone: medium to dark grey; minor argillaceous black dolomite. In part silty and sandy in basal 12.2 m.	15.2	146.3-161.5
8	Argillite: black; partly dolomitic and calcareous; fissile in part.	61	161.5-222.5
9	Argillite: partly micaceous (transition to Unit 2 occurs at 262 m sample).	39.6	222.5-262.1
UNIT 2 (argillaceous dolomite)			
10	Dolomite: argillaceous; medium grey, partly light and dark grey; very finely crystalline to cryptocrystalline.	9.1	262.1-271.3
11	As above, but light yellowish grey and pale pink dolomite make up about 5% of the sample.	9.1	271.3-280.4
12	Samples as above from 262-271.3 m, very monotonous. Gamma log indicates highly radioactive interval from 320 to 326 m. Two cores were taken in this interval, from 345.4-348.4 m and 498-500m. Both are described as cherty argillaceous dolomite and mudstone (<i>i.e.</i> , argillite) in Shell Canada Resources well evaluation report (anonymous).	201.2	280.4-493.8
13	Argillite and argillaceous dolomite: black. At 524.3 m, larger chips show laminations on mm scale. At 539.5 m samples are 95% dark grey to black argillite, and 5% medium grey, very finely crystalline dolomite.	45.7	493.8-542.5
14	Dolomite: argillaceous; very finely crystalline; dark to medium grey, with minor light brown, light reddish brown, and greyish green. Some black argillite. The base of this interval has a gradational contact with Unit 3. At 576 m the sample is dolomite, of which 70% is silty and medium grey-green, 25% is dark grey, and 5% is light grey to white. The contact between the units is judged to occur within this sample interval.	33.5	542.5-576.0
UNIT 3 (varicoloured limestone and dolomite)			
15	Dolomite: grey and light greenish grey, dark brownish red and grey green, finely crystalline to cryptocrystalline; dominantly greenish grey and light grey toward base of interval; red is most abundant at 585.2 m. Some chips exhibit extremely fine laminations. Intimate mixing of different colours over a wide interval suggests beds with rapidly varying colours. Some white limestone and black argillite.	30.5	576.0-606.5
16	Limestone and dolomite: white to light grey, light greenish grey in part; cryptocrystalline; minor dark grey and black argillite (may be cavings).	42.7	606.5-649.2
17	Dolomite and limestone: various shades of green dominant, some white, some honey-coloured, minor dark red to pale reddish brown; cryptocrystalline; colour laminations visible on some chips.	18.2	649.2-667.5
18	Dolomite (may be limestone in part): very pale grey, slight greenish hue, dark red at 667.5 m, some pink; cryptocrystalline.	21.3	667.5-688.8
19	Dolomite (probably limestone in part): dark red to pale green; cryptocrystalline.	6.1	688.8-694.9
20	Dolomite: pale green, minor red; cryptocrystalline.	6.1	694.9-701.0
21	Dolomite: cryptocrystalline; pale green, red and minor light grey to white. Proportions of the colours vary from sample to sample, presumably indicating interbedding.	18.2	701.0-719.3
22	Dolomite: cryptocrystalline; light green and minor red; minor white limestone.	6.1	719.3-725.4
23	Dolomite: cryptocrystalline to very finely crystalline; dark purple-red and light green, in about equal amounts with minor white, grading to dominantly dark red and reddish green at base; colour laminations.	15.2	725.4-740.7
24	Dolomite: cryptocrystalline to very finely crystalline; light greenish grey with minor red at 750 m.	15.2	740.7-755.9

Unit	Description	Thickness (m)	Depth Below K.B. (m)
25	Dolomite: cryptocrystalline; dark purplish red and pale green, becoming predominantly red at base.	9.1	755.9-765.0
26	Dolomite: cryptocrystalline; predominantly medium to light greenish grey, minor white and red.	21.3	765.0-786.4
27	Limestone: pale green-white to white, partly pale greenish grey; cryptocrystalline.	9.1	786.4-795.5
UNIT 4 (argillaceous dolomite)			
28	Dolomite: light grey to medium grey, becoming progressively darker downward through interval; cryptocrystalline to very finely crystalline. Gradational upper contact.	45.7	795.5-841.2
29	Dolomite: argillaceous; dark grey; very finely crystalline; apparently interbedded with light to medium grey dolomite (as above), may contain some limestone and brown chert.	33.5	841.2-874.8
30	Dolomite: cryptocrystalline; light to medium grey.	9.1	847.8-883.9
31	Dolomite: argillaceous; dark grey; interbedded with light grey, cryptocrystalline dolomite; rare chert.	21.3	883.9-905.3
32	Dolomite: very finely crystalline; medium to dark grey, minor light grey and white; partly pink and brownish pink in interval from 920.5 to 963.2 m; partly green-grey in sample at 957 m. Radioactivity logs indicate an increase in clay content from 923.5 to 935.7 m. Grey chert occurs in the interval from 963.2 m to 1108.9 m. Fault indicated at 1011.9 m by character of samples and radioactivity logs. Strata in footwall of fault appear to be a repetition of Unit 3.	106.7	905.3-1011.9
UNIT 3 (varicoloured limestone and dolomite)			
33	Dolomite: light green, finely crystalline.	18.3	1011.9-1030.2
34	Dolomite: dominantly dark red, with pink and light green; finely crystalline.	45.7	1030.2-1075.9
35	Dolomite: green, and dark red; finely to very finely crystalline.	24.3	1075.9-1100.3
36	Limestone: white and light grey; cryptocrystalline to very finely crystalline. (See above for interval 27 at 786.4-795.5 m.)	9.1	1100.3-1109.5
UNIT 4 (argillaceous dolomite)			
37	Dolomite: very finely crystalline; light grey with splotches of medium grey, grading downward to dominantly medium grey; minor dark grey, very finely crystalline dolomite; local minor dark grey argillite; grey and brown chert in argillitic interval.	103.6	1109.5-1213.1
38	Dolomite: light grey; very finely crystalline to cryptocrystalline. Fault (?) to near base of Unit 2.	30.5	1213.1-1243.6
UNIT 2 (argillaceous dolomite)			
39	Argillite: dolomitic; dark grey to medium grey; very finely crystalline; minor black argillite at 1268 m.	33.5	1243.6-1277.1
40	Dolomite: very finely crystalline. Black argillite in part. Grades downward to black, very finely to finely crystalline, argillaceous dolomite	36.6	1277.1-1313.7
UNIT 3 (?) (varicoloured limestone and dolomite)			
41	Dolomite: very finely crystalline; light grey, light yellowish grey, light greenish grey, silty. May represent top of Unit 3.	9.1	1313.7-1322.8
42	As above with pink and red also. Fault?	6.1	1322.8-1328.9
UNIT 2 (?) (argillaceous dolomite)			
43	Dolomite: finely crystalline; light to medium grey; grades down to medium to dark grey argillaceous dolomite and black argillite. Slickensides on samples at base. Lewis Thrust Fault. Overturned section of carbonate rocks of the Livingstone Formation (Mississippian).	12.2 12.2	1328.9-1341.1 1328.9-1341.1