STRATIGRAPHY OF THE LOWER ROCKY MOUNTAIN SUPERGROUP IN THE SOUTHERN CANADIAN ROCKY MOUNTAINS

by

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FACULTY OF GRADUATE STUDIES

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DOCTOR OF PHILOSOPHY

of

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M.Sc., The University of British Columbia, 1959

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COMMITTEE IN CHARGE

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ABSTRACT

The lower Rocky Mountain Supergroup of Pennsylvanian age contains five formations which in ascending order are: Todhunter, Tyrwhitt, Storelk, Tobermory and Kananaskis. All except the Kananaskis are new formations that are equivalent to the Tunnel Mountain Formation. The Todhunter, Tyrwhitt and Tobermory consist mainly of brown weathering, dolomitic and quartzitic, very fine- to fine-grained, pure, quartz-chert sandstones with some interbedded, locally fossiliferous, sandy dolomite. The Storelk is quartzitic, very fine- to medium-grained, very massive, cross-bedded, white wheathering quartz-chert sandstone. All these formations contain varying amounts of scattered medium and coarse sand. The Kananaskis consists of sandy and cherty, dense, microcrystalline, grey dolomite. The Todhunter, Tyrwhitt and Storelk Formations are interpreted as being Early Pennsylvanian (Morrowan) in age, and the Tobermory and Kananaskis Formation, which regionally may be facies equivalents, as early Middle Pennsylvanian (Atokan) in age. The contact between the lower Rocky Mountain and the underlying Etherington Formation (Late Mississippian Chesterian) is conformable and locally gradational. Contacts between the Todhunter and Tyrwhitt, and between the Storelk and Tobernory are unconformable, whereas that between the Tyrwhitt and Storelk may be conformable or unconformable. The lower Rocky Mountain is unconformably overlain by Permian, Triassic or Jurassic strata.

The lower Rocky Mountain sediments were deposited in a structural basin which may have been partially isolated from adjacent basins to the north, west and south by low barrier arches. Individual formations in the succession thin in a northwesterly and southwesterly direction towards the basin flanks, where as little as 160 feet of the five formations was deposited and remains, whereas at least 1,175 feet of equivalent strata is preserved in the central part. The quartz sand was probably transported by rivers and longshore marine currents from a source lying to the east within the continental interior.

Chert and phosphorite fragments ranging up to pebble size were probably locally derived. The strata of Chesterian and Morrowan age represent a regressive sequence. After Morrowan time, gentle warping, emergence, and erosion caused truncation of Lower Pennsylvanian and Upper Mississippian strata towards the east. Angular truncation, and local conglomerates composed of chert, phosphorite, sandstone and dolmite granules and pebbles mark this unconformity. Strata of Atokan age thicken westward and represent a transgressive sequence which onlaps and truncates the underlying strata.

The Pennsylvanian sandstones are a potential source of pure silica sand.

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part. The quartz sand was probably transported by rivers and longshore marine currents from a source lying to the east within the continental interior. Chert and phosphorite fragments ranging up to pebble size were probably locally derived. The strata of Chesterian and Morrowan age represent a regressive sequence. After Morrowan time, gentle warping, emergence, and erosion caused truncation of Lower Pennsylvanian and Upper Mississippian strata towards the east. Angular truncation, and local conglomerates composed of chert, phosphorite, sandstone and dolomite granules and pebbles mark this unconformity. Strata of Atokan age thicken westward and represent a transgressive sequence which onlaps and truncates the underlying strata.

The Pennsylvanian sandstones are a potential source of pure silica sand.

J.V. Ross

Acknowledgments

I wish to express my indebtedness to the Geological Survey of Canada for providing the opportunity to undertake a stratigraphic analysis of the late Paleozoic succession in the southern Canadian Rocky Mountains, and for allowing this information to be used for a Doctoral Thesis.

I greatly appreciate the assistance and supervision given by Dr. R. A. Price of the Geological Survey, who granted me time from his 1960 field season to initiate the present study, and for the considerable amount of time and effort spent by him attending to all the details necessary to the planning and equipping of my field parties in 1961 and 1962. I am further grateful for his many lengthy discussions and suggestions pertaining to particular problems, for critical reading of the manuscript, and for his palinspastic reconstructions of stratigraphic section localities. I wish also to acknowledge the assistance of Dr. E. W. Bamber of the Geological Survey of Canada who painstakingly dissolved out and identified the many fossils collected during the past three years. Additional thanks are due other members of the Geological Survey, particularly R. J. W. Douglas, T. P. Chamney, R. Proctor, and J. Aiken who discussed specific problems with me.

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INTRODUCTION

General Statement

The upper Paleozoic strata in the southern Canadian Rocky Mountains belong to two large groups, the Rundle Group of Mississippian age, and the Rocky Mountain Group of Pennsylvanian and Permian age. The lower parts of the Rundle Group are rather well known because they contain important hydrocarbon reservoirs in the Eastern Foothills and Interior Plains. The upper part of the Rundle Group and the Rocky Mountain Group however, are absent in the easternmost Foothills and Interior Plains, and accordingly fewer data relating to these strata have become available until recently when intensive studies of the Rocky Mountain Group were begun in the Rocky Mountains.

The stratigraphic relationships of the Rocky Mountain Group have been the subject of considerable controversy. For many years these rocks were simply designated Permo-Carboniferous or Permo-Pennsylvanian and were as poorly known and understood as this vague term suggests. The term Rocky Mountain simply referred to the siliceous beds at the top of the Paleozoic succession. It was fully 30 years after P. S. Warren (1927) concluded that the Rocky Mountain was Pennsylvanian in age and perhaps Permian at the top, that this was confirmed when Forbes and McGugan (1959) discovered Permian fusulinids in laterally equivalent strata at Wapiti Lake, and later Pennsylvanian fusulinids in the type section of the Norquay Formation of the Rocky Mountain Group at Banff (McGugan and Rapson 1960). Since this time there has been considerable interest in the Rocky Mountain Group, mainly as a result of the analyses and surprising discoveries made by McGugan and Rapson in the upper (Middle Pennsylvanian and Permian) part of the Rocky Mountain Group.

The lower Rocky Mountain has perhaps been the most seriously misinterpreted part of the succession. This has resulted in part from inadequate observational data and premature conclusions regarding lithostratigraphic correlations. The confused picture that has resulted is also in part due to the innaccurate lithologic description of the type section of the lower part (Tunnel Mountain Formation), facies changes within the underlying uppermost Mississippian rocks, and imperfect knowledge about mid-Carboniferous marine invertebrate fossils.

The information presented here is the result of field investigations conducted during 1961 and 1962 as part of a detailed stratigraphic project for the Geological Survey of Canada. This project involved the analysis of both the upper part of the Rundle Group and the Rocky Mountain Group in the southern Canadian Rocky Mountains. This thesis however, deals primarily with the Rocky Mountain part of the succession, and the upper Rundle strata are treated only briefly.

Location and Access of the Study Area

The area selected for this study contains the type sections of both the Rocky Mountain Group and Etherington Formation of the Rundle Group, and lies mainly within the subdivision of the Rocky Mountains known as the Front Range Sub-province, but also in adjacent parts of the Foothills Sub-province (North and Henderson 1954). Within this region strata were examined between the Crowsnest Pass area in the south and Bow Valley-Panther River area in the north. The eastern and western boundaries of the study area were determined by the quality of exposures of stratigraphic sections and accessibility of the sections (Figure 1). The eastern boundary is formed by the most easterly exposures of Paleozoic strata, and the western boundary is formed by large thrust faults along which older Paleozoic strata have overidden the Permo-Carboniferous formations. In the

southern part of the outcrop area strata were examined from the eastern to the western boundaries of present exposure, but towards the north the study area narrows, so that at the north end only sections near the middle of the outcrop belt were examined (Figure 1).

Access to sections throughout the region is for the most part good. The two most important routes of access are the north-south Elk Valley road and the Kananaskis-Coleman Highway. In addition, two transverse routes, the Trans-Canada Highway in the north and the Southern Trans-Provincial Highway through Crowsnest Pass in the south, complete a grid that provides ready access to nearly all sections.

Method of Study

Stratigraphic sections were measured with a Jacobs Staff and thicknesses were recorded to the nearest foot, except for very distinctive beds less than 1 foot thick. This mode of measurement probably involves errors of up to 10% in total thicknesses, but this is considered inconsequential in view of the rapid changes in thickness of individual beds that are known to occur within short distances. Rock specimens were collected from each bed, and depending upon thickness and internal variability of the beds, 1 to 5 specimens were taken. Very thick units were sampled at 5 to 10 foot intervals. Collections from all fossil-bearing beds were made and these are accurately located within the stratigraphic sections.

Field observations included such features as gross lithology, stratification, weathering colours, topographic expression, sedimentary structures, contact relationships, the occurrence of any fossils, and the thickness of individual beds. Detailed textural and lithological descriptions of every specimen collected were made later in the laboratory using a binocular microscope. A binocular microscope was found to be adequate for

determining grain size, degree of sorting, cementation and general textural features. Angularity of the smaller sand grains, and the composition and percentage of heavy mineral accessories were determined from thin sections of typical lithologic types from each formation.

The composition of the sandstones was determined by employing the hydrofluoric acid-sodium cobaltinitrate method (Gabriel and Cox 1929) which selectively stains feldspar and leaves quartz unaffected. The percentage of chert in the sands was estimated from thin section. Enough specimens were stained and examined in thin section to establish the general composition of the sandstones. To determine the composition of the cementing material in the sandstones, 5% hydrochloric acid was used. Phosphatic grains were identified by utilizing the nitric acid-ammonium molybdate method which stains phosphate yellow (Berry and Mason 1959, p. 266).

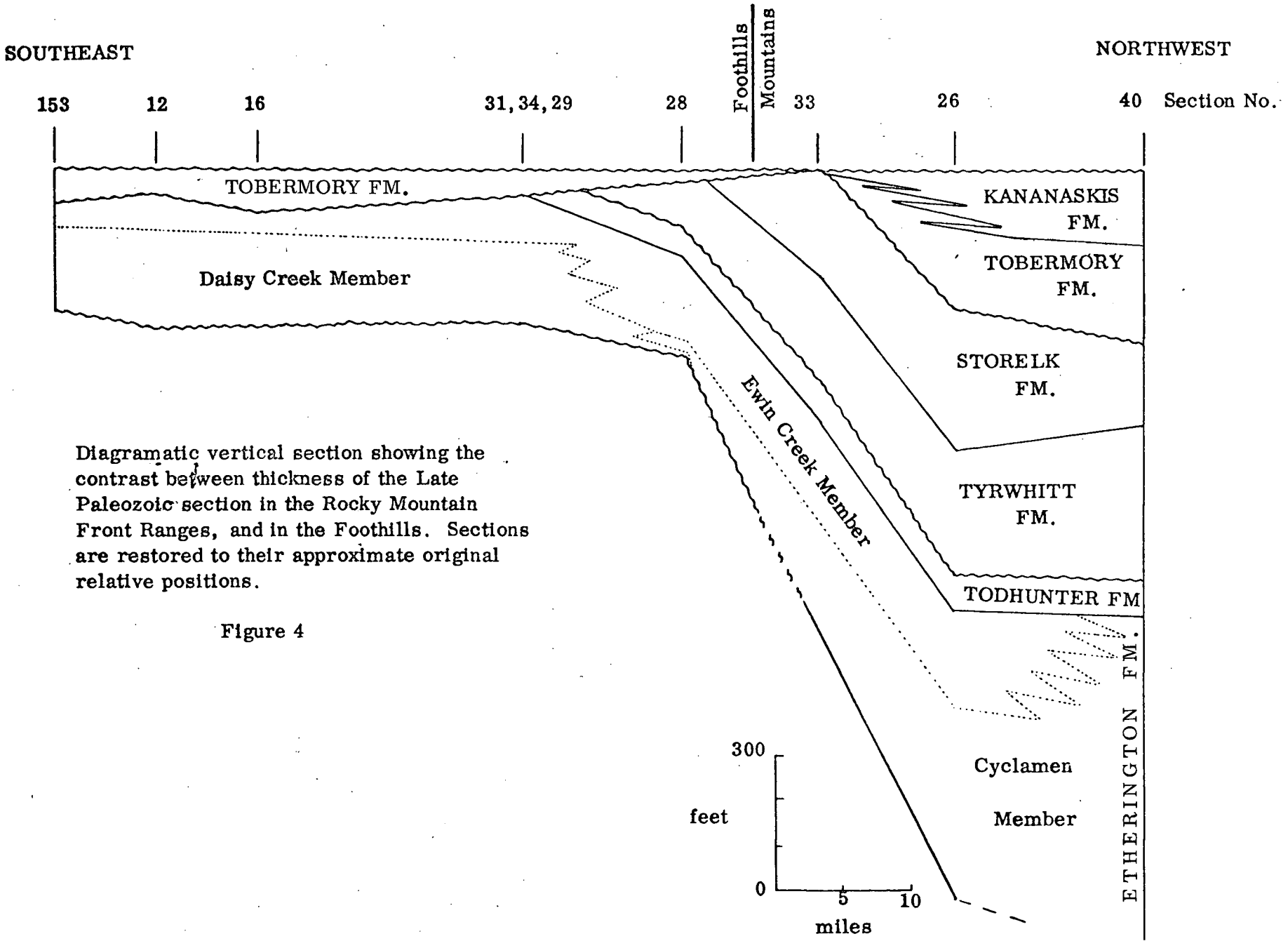
From the lithological descriptions, strip logs of each stratigraphic section were constructed at scales of 1 inch = 50 feet, 1 inch = 30 feet, or 1 inch = 20 feet, depending upon the thickness of the stratification. Finally two large vertical stratigraphic cross-sections (Figures 2 and 3) were constructed by equating beds or larger units believed to be lateral equivalents or approximate equivalents. In Figures 2 and 3 the stratigraphic column immediately below each section number (with the exception of the upper half of sections 13 and 21) is the slightly generalized section actually measured. The correlation of beds between the sections as portrayed is largely diagrammatic, particularly in the upper part of the Etherington Formation, and this rather complex pattern should be interpreted by the reader as a diagrammatic representation of the type of interfingering that probably exists, rather than what actually does exist. These cross-sections represent an interpretation, based entirely upon the writers own observations.

STRATIGRAPHY

Geologic Setting

The southern Canadian Rocky Mountains occupy the position of the former Cordilleran miogeosyncline which existed in this region throughout the Paleozoic. The eastern margin of the miogeosyncline appears to have been situated near the present mountain front and subparallel to it during middle Carboniferous time. At this time the structural boundary between miogeosyncline and the stable shelf or craton to the east may have been a hinge line situated within the present study area, just east of the present position of Flathead-High Rock-Misty Ranges, Mount Rundle, and Cascade Mountain. Evidence for the existence of this postulated hinge area comes from thickness and facies changes within the late Mississippian and Pennsylvanian sediments within the study area, after the effects of tectonic foreshortening have been taken into account (Figure 4). Similarly, the thickness of the total Paleozoic succession in the Rocky Mountains, over 30,000 feet, and in the Interior Plains, less than 10,000 feet, reflects the presence of a zone near the eastern margin of the deformed belt, to the west of which the rate of subsidence appears to have greatly exceeded that to the east of the zone.

In the area under investigation, sedimentation was intermittent from Cambrian to Tertiary time, and more of this interval is represented by hiatuses than by rock. In this area of the Rocky Mountains, the Phanerozoic strata are divisible into two major lithologic sequences: one a carbonate sequence ranging in age from early Paleozoic to Mississippian; and the second, a predominantly clastic sequence ranging in age from Pennsylvanian through to Tertiary. It is the strata occurring at the base of the clastic sequence that forms the subject of this thesis.



Diagramatic vertical section showing the contrast between thickness of the Late Paleozoic section in the Rocky Mountain Front Ranges, and in the Foothills. Sections are restored to their approximate original relative positions.

Figure 4

Historical Review of the Rocky Mountain Group

The evolution of concepts and nomenclature relating to the Carboniferous and Permian stratigraphy of the southern Canadian Rocky Mountains has been well summarized by Moore (1958) and by McGugan and Rapson (1962), so that with the aid of the accompanying correlation charts (Tables I-VII) only a brief mention of the more significant contributions need be given.

D. B. Dowling formally named the Rocky Mountain Quartzite in 1907. The exposures on Pigeon Mountain (section 42) in Bow Valley were referred to as typical, but no exact type section was designated.

The first important contribution to detailed knowledge of the Rocky Mountain Group was made by P. S. Warren in 1927. He assigned a Pennsylvanian age to the Rocky Mountain and suggested that the uppermost beds might be Permian. Unfortunately Warren believed that dolomite was the principal rock type in the formation, whereas sandstone is actually the main rock type. Later in 1947 Warren proposed the first formal subdivision of the Rocky Mountain into two members (Table I). The type section of these members was established on the south side of Tunnel Mountain at Banff, the section which has now come to be regarded as type for the Rocky Mountain Group (Plate X). Warren in 1956 described the lithology of the type Norquay Mountain and Tunnel Mountain Members, confirmed the Permian affinities of the Norquay Mountain fauna, and the Pennsylvanian age of the Tunnel Mountain Member. As previously, the Tunnel Mountain strata were defined as sandy dolomite, which, strictly speaking, invalidates the use of the term for sandstones presently bearing this name. The Tunnel Mountain as defined by Warren (1956) appears to include strata here defined as uppermost Etherington Formation which consists of sandy, microcrystalline dolomite.

The next report to influence thought on the Rocky Mountain was published

TUNNEL MOUNTAIN, BANFF

Warren 1947, 1956			This Thesis				
Tr.	SPRAY RIVER FM.		Tr.	SPRAY RIVER FM.			
Permian		Norquay Mountain Mbr.	Permian	SUPERGROUP		ISHBEL GROUP	
Pennsylvanian			Mid. Penn. (Atoka)			KANANASKIS FM.	
						TOBERMORY FM.	
		Tunnel Mountain Mbr.	E. Pennsylvanian (Morrowan)	ROCKY MOUNTAIN		STORELK FM.	
Lower?						TYRWHITT FM.	
						TODHUNTER FM.	
Mississippian		RUNDLE FORMATION	Late Mississippian (Chesterian)	RUNDLE GROUP	ETHERINGTON FORMATION	Ewin Creek Mbr.	
						Cyclamen Mbr.	

TABLE I

TUNNEL MOUNTAIN, BANFF

Beales 1950			This Thesis			
	SPRAY RIVER FM.		Tr.	SPRAY RIVER FM.		
Permian & (?) Pennsylvanian	ROCKY MOUNTAIN FORMATION	upper 240 ± feet	Permian	ROCKY MOUNTAIN SUPERGROUP	ISHBEL GROUP	
			Mid. Penn. (Atokan)		KANANASKIS FM.	
		sandstone and dolomite			TOBERMORY FM.	
		intermediate beds	E. Pennsylvanian (Morrowan)		STORELK FM.	
					TYRWHITT FM.	
		lower 140 feet			TODHUNTER FM.	
Mississippian	RUNDLE FORMATION		Late Mississippian (Chesterian)	RUNDLE GROUP	ETHERINGTON FORMATION	Ewin Creek Mbr.
						Cyclamen Mbr.

TABLE II

MOUNT ARETHUSA, MISTY RANGE

Raasch 1956, 1958				This Thesis			
Tr.	SPRAY RIVER FM.			Tr.	SPRAY RIVER FM.		
Permian	ROCKY MOUNTAIN GROUP	STORM CREEK FM.		E. Pennsylvanian (Morrowan)	ROCKY MOUNTAIN SUPERGROUP	STORELK FM.	
		NORQUAY FM.	Member No. 1			TYRWHITT FM.	
			Member No. 2			TODHUNTER FM.	
			Member No. 3	Late Miss. (Chesterian)	RUNDLE GROUP	ETHERINGTON FM.	Ewin Creek Mbr.
Mississippian	RUNDLE GROUP	TUNNEL MOUNTAIN FM.					Cyclamen Mbr.
							?
				Meremecian		MT. HEAD FM.	Carnarvon Mbr.
		MT. HEAD FM.					

TABLE III

BEEHIVE PASS, HIGH ROCK RANGE

Norris 1957			This Thesis			
Tr.	SPRAY RIVER FM.		Tr.	SPRAY RIVER FM.		
Pennsylvanian (?) & Permian	ROCKY MOUNTAIN FORMATION	upper unit	Mid. Penn. (Atokan)	ROCKY MOUNTAIN SUPERGROUP	KANANASKIS FM.	
					TOBERMORY FM.	
			E. Pennsylvanian (Morrowan)		STORELK FM.	
					TYRWHITT FM.	
		?				
		Todhunter Mbr.			TODHUNTER FM.	
L. Miss. (Chesterian)	RUNDLE GROUP	ETHERINGTON FM.	L. Miss. (Chesterian)	RUNDLE GROUP	ETHERINGTON FM.	Ewin Creek Mbr.
						Cyclamen Mbr.
						?
			Meremec		MT. HEAD FM.	Carnarvon Mbr.

TABLE IV

LIVINGSTONE-HIGHWOOD RANGE

Douglas 1958				This Thesis			
Tr.	SPRAY RIVER FM.			Tr.	SPRAY RIVER FM.		
Pennsylvanian?				Permian			
				Mid. Penn. (Atokan)	ROCKY MT. SUPERGROUP	TOBERMORY FM.	
	ROCKY MOUNTAIN FM.			E. Pennsylvanian (Morrowan)			
Miss. (Chesterian)	GROUP	ETHERINGTON FM.	upper middle lower ?	Miss. (Chesterian)	GROUP	ETHERINGTON FM.	Ewin Creek Mbr. Daisy Creek Mbr.
Meremecian	RUNDLE	MT. HEAD FM.	Carnarvon Mbr.	Meremecian	RUNDLE	MT. HEAD FM.	Carnarvon Mbr.

TABLE V

BOW VALLEY AREA

McGugan & Rapson 1961			This Thesis			
Tr.	SPRAY RIVER GROUP		Tr.	SPRAY RIVER FM.		
Permian	GROUP	ISHBEL FM.	Permian	SUPERGROUP	ISHBEL GROUP	
M. Pennsylv.	GROUP	KANANASKIS FM.	Mid. Penn. (Atokan)	SUPERGROUP	KANANASKIS FM.	
Chesterian to Lower Pennsylvanian	ROCKY MOUNTAIN	TUNNEL MOUNTAIN FM.	Mid. Penn. (Atokan)	ROCKY MOUNTAIN	TOBERMORY FM.	
			E. Pennsylvanian (Morrowan)	ROCKY MOUNTAIN	STORELK FM.	
			E. Pennsylvanian (Morrowan)	ROCKY MOUNTAIN	TYRWHITT FM.	
			E. Pennsylvanian (Morrowan)	ROCKY MOUNTAIN	TODHUNTER FM.	
Chesterian	RUNDLE GROUP	ETHERINGTON FM.	L. Miss. (Chesterian)	RUNDLE GROUP	ETHERINGTON FM.	Ewin Creek Mbr.
			L. Miss. (Chesterian)	RUNDLE GROUP	ETHERINGTON FM.	Cyclamen Mbr.
			Meremecian	RUNDLE GROUP	MT. HEAD FM.	? Carnarvon Mbr.

TABLE VI

COMPOSITE SECTIONS, SOUTHERN CANADIAN ROCKY MTS.

McGugan & Rapson 1963			This Thesis				
Tr.	SPRAY RIVER GROUP		Tr.	SPRAY RIVER FM.			
Permian	ISHBEL GROUP		Permian	SUPERGROUP	ISHBEL GROUP		
M. Penn.	SPRAY LAKES GROUP	KANANASKIS FM.	Mid. Penn. (Atokan)	ROCKY MOUNTAIN	KANANASKIS FM.		
Early Pennsylvanian (Morrowan)		TUNNEL MOUNTAIN FM.			TOBERMORY FM.		
			E. Pennsylvanian (Morrowan)		STORELK FM.		
					TYRWHITT FM.		
					TODHUNTER FM.		
Late Miss. (Chesterian)	RUNDLE GROUP	ETHERINGTON FORMATION	Late Miss. (Chesterian)	RUNDLE GROUP	ETHERINGTON FM.	Ewin Creek Mbr.	
						Cyclamen Mbr.	
			Meremecian		MT. HEAD FM.	? Carnarvon Mbr.	

TABLE VII

by Raasch in preliminary form in 1954, and expanded later in 1956 and 1958 (Table III). Unfortunately many mis-correlations were made that have since created considerable confusion regarding the stratigraphic relationships of the Rocky Mountain, however this work provided a needed stimulus for other workers study these strata in more detail. Raasch raised the Rocky Mountain to group rank (1956) and thus the Tunnel Mountain and Norquay to formation rank.

D. K. Norris in 1957 suggested an alternative to Raasch's correlations (Table IV). Norris noted the similarity in gross lithology between sections at Highwood Pass and Beehive Pass, and proposed the name Todhunter Member for a distinctive lithostratigraphic unit at the base of the Rocky Mountain Formation sequence at Beehive Pass. Equivalent strata were recognized in Raasch's Highwood Pass section, and the overlying beds in both sections were considered to be stratigraphic equivalents. Norris proposed that the Beehive Pass and Highwood Pass sections were correlative with the sandstone succession in Warren's Tunnel Mountain Member. He also suggested the equivalence of the cherty dolomites at the top of the Paleozoic succession at Beehive Pass with the Norquay Mountain Member (the dolomite part of which is named Kananaskis Formation, see McGugan and Rapson 1961).

The first intensive study of the Rocky Mountain was recently begun by McGugan and Rapson (1960, 1961, 1962, 1963a). They subdivided the Rocky Mountain Group into three formations, the Tunnel Mountain, the Kananaskis, and the Ishbel (Table VI). They have restricted the definition of the Tunnel Mountain Formation to include only sandstone, so that now there are now at least three different connotations of the name in the literature.

The most recent contribution by McGugan and Rapson (1963b) has been the proposal to discard the name Rocky Mountain Group, to raise the Ishbel Formation to Group rank, and to apply the name Spray Lakes Group to the

Kananaskis and Tunnel Mountain Formations (Table VII).

The present study of Late Mississippian (Chesterian) and Early-Middle Pennsylvanian strata in the southern Canadian Rocky Mountain Front Ranges and Foothills has resulted in the formal recognition of eight distinct, widespread lithostratigraphic units, three of which are new, and several of which have heretofore been only informally recognized. For the purpose of discussing the local and regional stratigraphic relationships of these units it is most convenient to assign formal names to them. The most practical stratigraphic classification is one which involves a minimum of new formal subdivisions, yet one that is still compatible with the longer established, though less clear nomenclature. Any new classification should also be flexible enough that units can be grouped or reclassified with a minimum of redefinition at some future time.

As a result of this study it is suggested that the term Rocky Mountain be retained and not abandoned as suggested by McGugan and Rapson (1963b). However, the group rank of the Rocky Mountain is now invalidated by the recently defined Ishbel Group (McGugan and Rapson 1963b, p. 55) which it formerly contained. Therefore, in order to retain the term Rocky Mountain it must be raised to the rank of Supergroup, and in this thesis it will be used in this sense (Table VIII). It is desirable to retain the term Rocky Mountain because it is not only deeply ingrained in the literature, but it is useful for referring to the Permo-Pennsylvanian clastic sediments in this area. In this thesis the term lower Rocky Mountain Supergroup will refer to the Kananaskis Formation and underlying Pennsylvanian sandstone formations, and the upper Rocky Mountain Supergroup will refer to the Permian Ishbel Group.

Another long established term, Tunnel Mountain Formation, requires

revision in the light of new data presented in this thesis. The presence of two unconformities (one of which involves angular truncation) within the Tunnel Mountain as presently defined by McGugan and Rapson requires that this term be abandoned, or elevated to group rank. Unfortunately, considerable confusion surrounds the name Tunnel Mountain, in part because the type Tunnel Mountain includes dolomite at the base which is now known to belong to the Etherington Formation, and because the contacts of the type Tunnel Mountain are very poorly defined. Also premature correlations and definitions based upon inadequate observational data in the past have masked the simple stratigraphic relationships that seem to exist. At the present time there are several widely accepted usages of the term Tunnel Mountain, and retention here of the name would involve yet another definition. For the above reasons it might be most desirable to abandon the name altogether. On the other hand, the now commonly accepted definition of the term for sandstones between the Etherington and Kananaskis Formations (Table VI) is, in view of the present data, a reasonable and acceptable definition. For the present however, it seems most practical to refrain from prematurely proposing any rigid definition of the Tunnel Mountain until more data is available.

In the place of the presently defined Tunnel Mountain Formation (restricted of McGugan and Rapson 1961 which includes the Todhunter Member at the base) three new formally designated lithostratigraphic units are here recognized (Table VIII). Each of these units, together with the Todhunter at the base are here assigned formation rank. These four formations, which in ascending order are Todhunter, Tyrwhitt, Storelk, and Tobermory, appear to be equivalent to the Tunnel Mountain (restricted) sandstone formation. In view of this, the Tunnel Mountain could be raised to group rank to include the four formations newly defined in this thesis.

Type Section of the Tyrwhitt, Storelk, and Tobermory Formations

Complete and well exposed sections of Late Mississippian and Pennsylvanian strata occur throughout High Rock Range and Elk Mountains near the Alberta-British Columbia provincial boundary. Most sections in this area are typical of the Etherington through Kananaskis formations, and many different sections could be designated as a type. Accessibility being an important consideration however, a type section for the newly recognized Tyrwhitt, Storelk and Tobermory formations has been selected in Elk Mountains on the southwest corner of Mount Storelk (section 26) (Figures 1, 2; Plate VIII), township 18, range 8, section 14. The section is exposed in a narrow canyon (here referred to as Storelk Canyon), on the southwest side of Mount Storelk, 1 mile east 32° north from the mouth of Tobermory Creek, and 4 miles east 20° south from Lower Elk Lake. A conspicuous large, low, alluvial fan composed of cobbles and boulders and covered with low vegetation marks the mouth of Storelk Canyon.

The names of the formations are derived from Mount Tyrwhitt and Mount Storelk in the Elk Mountains range, and from Tobermory Creek which flows along the west side of the range.

DESCRIPTION OF FORMATIONS

RUNDLE GROUP

ETHERINGTON FORMATION

The Etherington Formation of Late Mississippian (Chesterian) age is a lithologically heterogenous unit composed primarily of limestone and dolomite with lesser amounts of sandstone, siltstone and shale. It thickens from a minimum of 180 feet in easternmost exposures to at least 690 feet in westernmost exposures (Table IX). Rhythmic and cyclic alternations of beds of many different textures and compositions, together with an east-west facies change add to the lithologic complexity.

The lower part of the Etherington embraces two very different sequences of strata belonging to two lithofacies, herein referred to as the eastern dolomite-shale facies of less than 100 to about 230 feet in thickness, and the western limestone facies of 225 to 475 feet thickness. Overlying both facies and also grading laterally into each is a regionally persistent dolomite-sandstone unit that ranges from 144 to 275 feet in thickness.

The eastern dolomite-shale facies or Daisy Creek Member (here named from Daisy Creek which flows along the west side of Livingstone Range where the facies is typically developed) outcrops in the easternmost Rocky Mountain Front Ranges and Foothills and is composed of dolomite, limestone, sandstone, siltstone, shale, and locally solution collapse-breccias composed of the same lithic elements. These various lithologic types have been shown to alternate cyclically by Douglas (1958). Colours range from tan through grey to pale greenish grey to maroon, and the shales are both green and maroon. The shale occurs mainly in the lowermost part, where beds as much as 20 to 30 feet thick occur, and decrease in amount upwards.

Numerous breaks of short duration in sedimentation are recorded in some sections by very thin intraformational breccias and conglomerates composed of chert, siltstone, sandstone, limestone or dolomite. Locally in the upper part are one or two thick zones (12 to 22 feet) of coarse breccia which probably originated through collapse after the solution of interbedded evaporite beds (Figure 3). The basal contact with the Mount Head Formation (of Meramecian age) also may represent a brief period of either non-deposition or possibly even slight emergence and subaerial erosion. This is suggested by a local 2 foot thick claystone conglomerate (Plate IA), absence of the top bed of the upper cycle of the underlying Carnarvon Member of the Mount Head (Douglas 1958, p. 59), and apparent truncation of the Carnarvon Member by the Etherington in the subsurface to the east (Douglas 1958, p. 59).

The western limestone facies or Cyclamen Member (here named from Cyclamen Ridge which lies just east of High Rock Range in which the member is typical) is exposed in the mountains west of the surface trace of the Lewis Thrust, Misty Fault and Rundle Fault. Its thickness ranges between 300 and 475 feet (Table IX), but thicker sections may be present farther west. The variation in thickness is partly due to the nature of the upper boundary, which although a natural boundary between skeletal limestones and dense, microcrystalline dolomite (the Ewin Creek Member), is not a single, regionally persistent horizon because the secondary dolomitization processes seem to have penetrated and altered the limestones variable distances below the top in different areas.

The Cyclamen Member consists predominantly of skeletal limestone (echinoderm calcarenite) but pseudoolite and oolite are very abundant in some sections. Thin beds of very fine-grained quartz sandstone are common. Echinoderm ossicles and bryozoan fragments form the bulk of the skeletal

grains, and fragments of calcareous algae, brachiopods and foraminifera are in general subordinate in amount. Brachiopods and locally solitary and colonial corals are the most abundant fossils, and foraminifera are very numerous in some beds, especially the better sorted pseudoolite and oolite calcarenites.

The limestones of the Cyclamen Member are readily grouped into six distinct microfacies which, together with thin beds of sandstone and dolomite alternate in a complex manner. Each microfacies seems to have been related among other factors to current strength, water depth and distance from shore. Hence the alternations of the various microfacies are interpreted as reflecting minor variations in sea-level that may be referred to as transgressive and regressive pulses of shallow, marine, shelf seas.

The upper part of the Etherington Formation almost everywhere consists of grey, microcrystalline, highly sandy and cherty dolomite (Figures 2 and 3; Plate IB) with some interbedded very fine-grained sandstone that tends to become more abundant towards the top in some sections. This division is designated the Ewin Creek Member (after Ewin Creek which flows westward from Beehive Pass in the middle part of High Rock Range) and it overlies both the Daisy Creek and Cyclamen Members of the lower part of the formation, besides grading laterally into them. Above the Daisy Creek Member it is less than 100 feet thick (due perhaps to a combination of erosional truncation at the top and lateral facies change towards the east), but above the Cyclamen Member it is locally more than 200 feet thick. Towards the west the Ewin Creek dolomites grade laterally into limestones of the Cyclamen Member, one of the zones of transition occurring in Elk Mountains. On the basis of this lateral change, together with internal

textural features in the Ewin Creek Member, the dolomite is interpreted as having originated mainly through the penecontemporaneous dolomitization (in part through the process of dolomitization by seepage refluxion, see Adams and Rhodes 1960) of lime muds and skeletal sands which accumulated in a restricted lagoonal environment, bounded on the west by temporary barrier bars, banks and shoals of calcareous sediment, and on the east by beaches and coastal dunes composed of quartz sand. Locally, in highly restricted areas characterized by evaporitic conditions, anhydrite or gypsum was apparently deposited (indicated by solution collapse-breccias at Mount Ptolemy). Westward of the lagoons and barrier banks, an open marine shelf appears to have persisted during the time of dolomitization, and the calcareous sediment deposited in this environment was in many areas completely unaffected by the dolomitization processes.

Towards the end of Mississippian time increasing amounts of quartz sand began drifting into the area, possibly from the east and northeast. Since there was not a corresponding increase in the rate of subsidence of the depositional site, the eastern shore lines, together with associated near shore terrigenous clastic sediments, migrated westward in a regressive trend of sedimentation. Periodically, widespread layers of sand blanketed the carbonate sediments in latest Mississippian time (causing carbonate sedimentation to cease temporarily). Eventually, by the beginning of early Pennsylvanian time, clastic sediment dominated the area that was formerly the site of carbonate sedimentation, burying all of the dolomite and limestone of the Etherington Formation.

ROCKY MOUNTAIN SUPERGROUP

TODHUNTER FORMATION

General Statement

The Todhunter Member was defined in 1957 by D. K. Norris as a succession of "interbedded grey and very pale orange, resistant sandstones and dolomites, and greyish red and greyish orange pink, recessive shales and siltstones." It was designated the basal division of the Rocky Mountain Formation at Beehive Pass where it is 88 feet thick. The unit is herein recognized as a valid and useful rock unit, although the uppermost beds are missing in many areas.

The name Todhunter, here raised to formation rank, refers to a sequence of marine sandstones, dolomites, siltstones and very minor amounts of green and maroon shale that form three groups of beds informally designated the lower, middle and upper divisions (Figure 5). The lower and upper divisions consist of sandstone and siltstone, and the middle part consists of two units of dolomite (or limestone where undolomitized) called the upper and lower Spirifer tongues which are separated by commonly cherty sandstone with local siltstone beds. The Spirifer tongues characteristically contain abundant silicified brachiopods except in the Bow Valley region.

The three divisions of the formation are present in Flathead (section 10 and 157), High Rock (sections 13, 18) and Kananaskis Range (section 40), at Cummings Creek (section 5) and at Mount Hosmer (section 24). Elsewhere, as in Misty (32,33) and Highwood Ranges (28) and the Bow Valley region (41,44), the upper division and part of the middle division appear to be missing. Furthermore, in the Bow Valley region and farther north there is little to distinguish the Todhunter from the overlying Tyrwhitt Formation

GENERALIZED COLUMNAR SECTION
OF THE TODHUNTER FORMATION

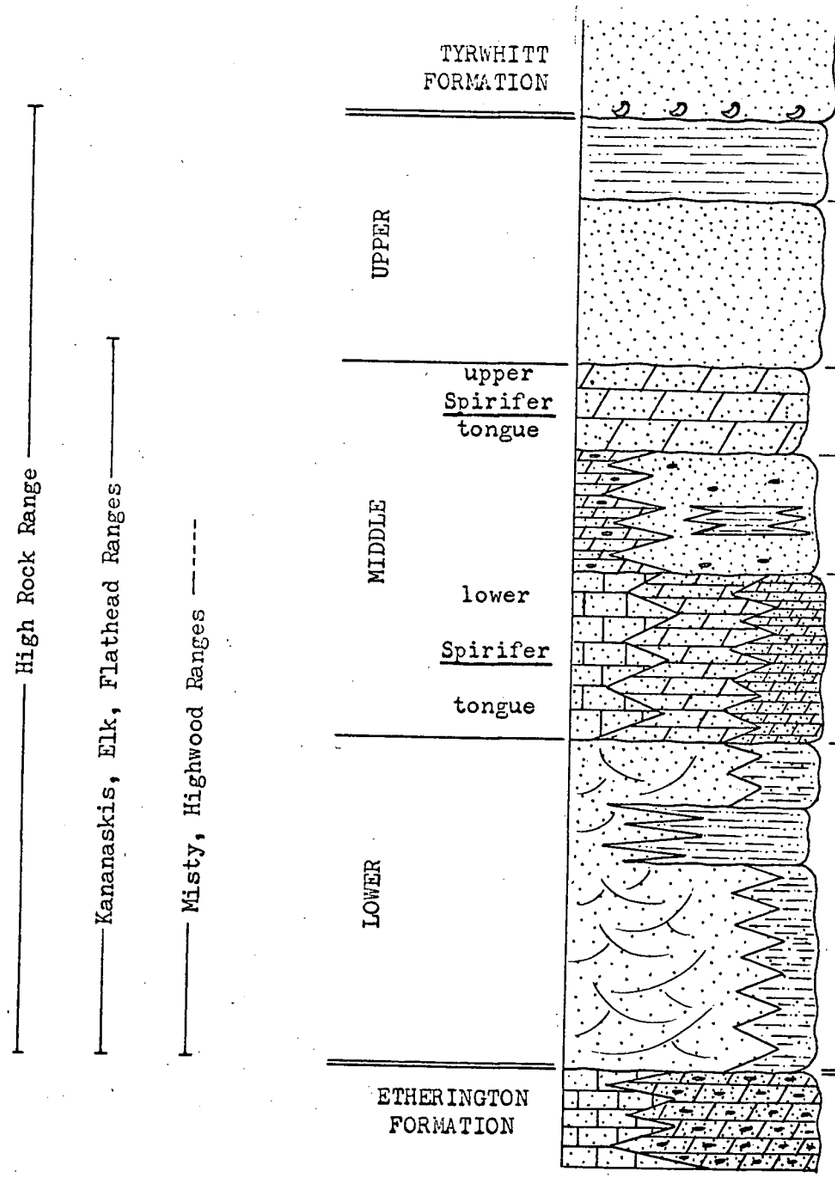


Figure 5

Sandstone, dolomitic and quartzitic; very fine and fine-grained; silicified productoid brachiopods common; brown and light grey weathering; massive; resistant

Siltstone, dolomitic, argillaceous; medium greenish-grey; even textured; locally many Orbiculoidea; medium to light brown weathering; very hard; resistant

Sandstone, dolomitic, very fine- to fine-grained; well sorted; even textured; flaggy to blocky; very light tan and grey weathering; hard; moderately resistant

Dolomite, very sandy; fine to very coarse crystalline; highly porous; granular; abundant silicified brachiopods; hard to soft; moderately resistant

Sandstone, dolomitic; light tan-grey; very fine to fine; well sorted; locally very cherty; locally some argillaceous greenish-grey or maroon siltstone; locally fossiliferous; grades to dense dolomite to southwest; brown to grey wthr.

Limestone, grey to maroon; sandy; locally argillaceous; very fine to coarse skeletal calcarenite; many silicified, locally red, brachiopods; hard; resistant

Dolomite, highly sandy; light grey to light tan; microcrystalline to coarsely-crystalline; many silicified brachiopods; locally very porous; hard; resistant

Sandstone, dolomitic to quartzitic; light grey to light tan; very fine to fine-grained; locally cross-bedded; contains some beds of dark greenish-grey, argillaceous, brown weathering siltstone; grades eastward into siltstone; massive, blocky or platy-flaggy; medium to light brown weathering; hard; resistant; lower contact sharp and distinct; maintains a relatively constant thickness throughout the area

Dolomite, grey; very dense, microcrystalline; contains abundant very fine to fine quartz sand, evenly disseminated and as very distinct, brown weathering differentially etched laminae; abundant chert nodules; light grey weathering; very hard; massive; highly resistant

Limestone, dark grey; skeletal calcarenite; fine- to coarse-grained; sandy; locally contains silicified brachiopods; massive; hard; resistant; medium to light grey weathering

and its recognition there is somewhat tentative. The lower contact of the formation is sharp, conformable, and distinct, except where sandstone beds in the uppermost Etherington dolomites (Ewin Creek Member), as in Misty Range (33), necessitate the establishment of an arbitrary boundary. The upper contact is probably either a diastem or small unconformity.

The age of the Todhunter Formation is here interpreted as Pennsylvanian, and since it is bounded by Late Mississippian and Middle Pennsylvanian, it is probably Morrowan.

The Todhunter Formation is here designated the base of the Rocky Mountain succession, following the original definition, because it is more closely related to it than to the underlying Etherington Formation. Although the stratification and resistance to erosion is such that its topographic expression is similar to that of the upper Etherington Ewin Creek Member (Plate IX), it bears a closer relationship lithologically to the Rocky Mountain since it is from the base of the Todhunter that beds of sandstone are essentially continuous.

It has been suggested by McGugan and Rapson (1962) that the lower part of the Rocky Mountain succession is a facies equivalent of part of the Etherington Formation in the easterly areas (Daisy Creek Member of this thesis), and indeed the presence of green and maroon shales in each would at first seem to support this proposal. However, Figures 2 and 3 demonstrate the impossibility of such a correlation. In addition, fossils in the Todhunter Formation are of Pennsylvanian age and those in the Etherington Formation are of Late Mississippian age.

Lithologic Description

The major lithologic constituents of the Todhunter are sandstone and dolomite. Siltstone is subordinate in most sections, and shale is rare,

though disseminated clay or argillaceous partings occur in some places. The sandstones are virtually identical to those in the overlying Tyrwhitt Formation and underlying Etherington Formation. Similarly the dolomite and limestone is identical to that forming most of the Etherington and lentils in the Tyrwhitt. In addition, green and maroon siltstone and shale are not without their counterparts in some sections of the Tyrwhitt and in the eastern Daisy Creek Member of the Etherington. Thus each rock type present in the Todhunter occurs in the adjacent formations, and the difference among these three formations is in the proportions of rock types in each, the Etherington being predominantly dolomite and limestone, the Tyrwhitt predominantly sandstone, and the Todhunter a mixture of both dolomite and sandstone. The Todhunter is therefore, in essence, a transitional unit between the Etherington and Tyrwhitt Formations.

Sandstone

The sandstones comprising the Todhunter are clean, well sorted, very fine- to fine-grained, and are composed of subangular to angular grains of quartz, with some chert and only a few percent of feldspar. Dolomite is the main cementing mineral, but quartz cement predominates at a few localities, and mixtures of the two are common. The sandstones are light tan, light grey, and light tan-grey in colour. Weathering colours are generally some shade of brown. Medium and coarse sand grains of quartz and chert occur but are uncommon except at Ewin Creek (18) where three separate zones, each 1 foot thick in the lower and upper divisions contain many scattered medium to coarse grains(Plate XVB). These zones are the lowest levels in the Carboniferous succession studied at which coarse sand grains occur in amy significant amount.

Stratification of the sandstones ranges mostly from 1 to 10 feet, and is thinner in some sections than that of the overlying strata (Plate IX). Cross-stratification is abundant in the lower division in Elk Range (26,21) and at Ewin Creek (18).

Virtually all of the sandstones are hard to very hard and resistant, and although some are cliff-forming, most are neither prominent nor recessive. At Mount Ptolemy (10,157) and Andygood Creek (8) the lower division is a recessive, poorly exposed, ledge- and slope-forming sequence of sandstone and siltstone. At Mount Hosmer (24) and Mount Broadwood (11) the lower division is not exposed, and it could consist in part of limestone and dolomite.

Siltstone

Siltstone is a characteristic component of the Todhunter. It is present in all three divisions, but the thickest beds are in the lower and upper parts.

Siltstone is present in the lower division at Mount Ptolemy (157), Storm Mountain (32) and in Palliser Range (44). These siltstones are light tan to dark greenish-grey, even textured, sandy, micaceous, partly argillaceous, massive to platy and flaggy, and are light yellowish-brown to medium brown weathering. Some contain thin, shaly, rubbly weathering zones in contrast to siltstones in the underlying Etherington which are tight and cemented with dolomite, and characteristically lack clay.

Siltstone in the middle division occurs at Mount Loomis (21) and Ewin Creek (18) where it is dark grey and dark reddish-maroon to pale green respectively. At Mount Loomis the siltstone contains a 6 inch, light greenish-grey, soft, platy to shaly zone.

Siltstone in the upper part is confined to a distinctive marker bed at

the very top in High Rock Range (13,18). At Ewin Creek this bed is 20 feet thick, dolomitic, very slightly argillaceous, medium greenish-grey, sandy, and very even textured. It contains numerous Orbiculoidea shells, some of which are fragmented. At Alexander Creek this same bed is only 9 feet thick and contains thin, soft, recessive weathering, rubbly and flaky, greenish argillaceous zones.

Shale

Shale is not common in the Todhunter, but that which is present is very distinctive because of its green or maroon colour. The largest number of argillaceous zones occur at Ewin Creek (18). There, seven zones which are green or maroon and from 1 inch to several feet thick give the unit a variegated appearance. These zones consist of very thin shaly partings, and thicker beds of argillaceous siltstone and dolomite. Maroon clay is also present in the dolomite and limestone of the Spirifer tongues at Ewin Creek and in Elk Range. Clay is also associated with nearly all of the siltstones, in which it may be evenly disseminated, or distributed as thin partings 1 or 2 inchs thick.

The Spirifer Tongues of the Middle Todhunter

The major part of the middle division of the Todhunter consists of two tongues, each containing several beds, that are composed of microcrystalline through coarsely crystalline sandy dolomite. These tongues are typically highly fossiliferous, with spiriferid brachiopods being the main type present. On the basis of composition, texture, fossils, and stratigraphic position, the lower of these two tongues can be traced northward from High Rock Range into undolomitized, fossiliferous, skeletal limestone in Elk and Kananaskis Ranges, and to the southwest at Cummings Creek (5). The upper tongue consists everywhere of dolomite. The total distance over

which these two tongues persist is about 100 miles, from Mount Broadwood (11) to Kananaskis Range (40), and both tongues may be represented in Bow Valley by two thin dolomite beds. It is suggested that farther west the Spirifer tongues may coalesce with the Etherington Formation through a wedging out of the clastic sediment of the lower division of the Todhunter.

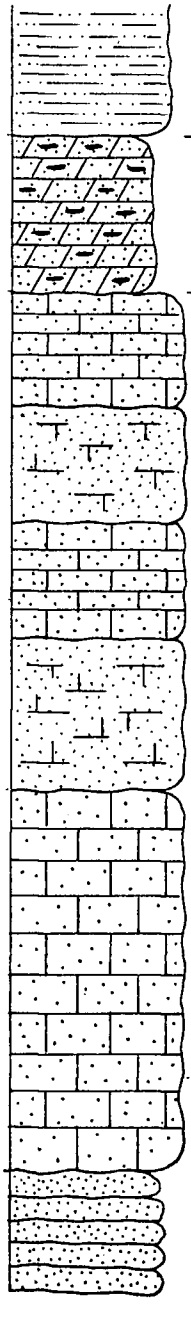
The significance of the Spirifer tongues is three-fold: 1) they are among the only distinctive, fossiliferous beds in the entire group of strata studied that appear to be time-planes or approximate time planes(based upon physical criteria); 2) the well preserved silicified brachiopods are important indicators of geologic age; and 3) indications that the crystalline dolomites were originally skeletal calcarenites, and appear to be zoned outwards from the remnant area of limestone, provides some information about the dolomitization process.

For purposes of discussion these two tongues are called the lower and upper Spirifer tongues. Only the lower tongue has remained in part undolomitized and this primary limestone will first be described in summary form.

Limestone of the Lower Spirifer Tongue: At Mount Loomis (21) the lower Spirifer tongue (Figure 6) comprises 23 feet of limestone and sandstone, overlain by 4 feet of dolomite. The lower 10 feet, which is fairly uniform, medium to very coarse-grained skeletal (echinoderm) limestone, contains fairly numerous silicified, red, spiriferid brachiopods, and rests with sharp contact on quartzitic sandstone. The upper 13 feet consists of two sandstone-limestone alternations with gradational boundaries, each limestone and sandstone bed being of about equal thickness. The sandstones are fine-grained, very highly calcareous, and contain scattered medium to coarse echinoderm fragments. The limestones are dark grey to maroon, very poorly sorted, argillaceous, somewhat sandy,

DETAILED SECTION OF THE LOWER SPIRIFER TONGUE

Mount Loomis



LOWER SPIRIFER TONGUE

Siltstone, sandy, slightly argillaceous; dark grey; massive; light brown weathering; very hard.

4' Dolomite, light tan-light grey; medium to coarse crystalline; abundant very fine sand and light grey irregular chert nodules; many sand to granule-size silicified brachiopod fragments; light tan weathering

13' Limestone, dark grey to dark maroon; argillaceous; very poorly sorted, very fine-coarse, skeletal calcarenite; abundant very fine sand; very numerous red, silicif. brachiopods, most fragmented; top 1 foot medium to very coarse calcarenite with stringers of maroon clay and many bryozoa; dark maroon weathering; very hard; resistant; ?Spirifer curvilateralis GSC loc. 48323

Sandstone, light grey; very highly calcareous; fine-grained; some medium to coarse crinoid columnal fragments; fiarly well sorted; thick bedded; pale green-light grey weathering; very hard; resistant

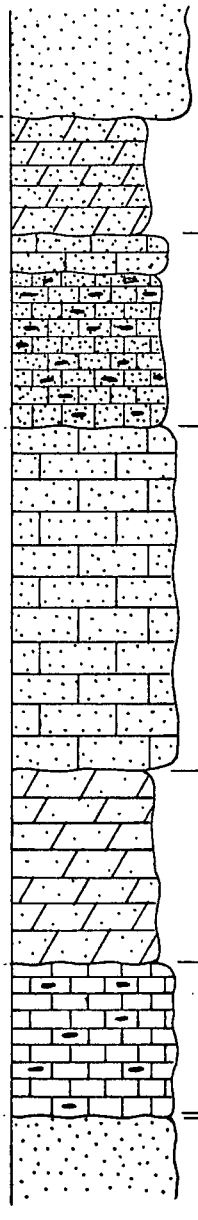
10' Limestone, light grey; medium to very coarse-grained; skeletal calcarenite; parts contain abundant granule-size echinoderm fragments; abundant very fine sand; fairly numerous silicified, red brachiopods; lower contact sharp; massive; light grey weathering; hard; resistant

Sandstone, quartzitic; medium-light grey; very fine-grained; well sorted; very platy to flaggy; light tan-light grey weathering; hard; cliff-slope forming.

Figure 6

DETAILED SECTION OF THE LOWER SPIRIFER TONGUE

Mount Storelk



LOWER SPIRIFER TONGUE

Sandstone, dolomitic, quartzitic; very fine-fine; well sorted; even textured; sharp contact; light tan weathering; hard; resistant; cliff-forming

3' Dolomite, light tan-grey; fine and medium crystalline; abundant very fine-fine sand; top surface cherty with brachiopods; massive; light brown weathering

1' Limestone, light grey; coarse-very coarse calcarenite

4' Limestone, light brown; extremely fine-microtextured; much fine to coarse skeletal sand; extremely abundant very fine-fine sand; many silicified brachiopods; medium grey-tan weathering; hard; moderately resistant; Derbya sp. Composita, ?Spirifer curvilateralis, GSC loc. 53470

9' Limestone, grey-maroon; fine-very coarse skeletal calcarenite much micrograined matrix; sand very fine-fine, few medium; zones of maroon, argillaceous, highly sandy limestone; exceedingly numerous red, silicified brachiopods, many fragmented; very massive; medium grey to maroon weathering; hard; resistant; Derbya sp., Spirifer occiduus, Spirifer cf. matheri, Spirifer cf. curvilateralis, Amplexi-Zaphrentis sp. GSC loc. 53461, 53463, 53473

5' Dolomite, light tan; very fine-medium crystalline; texture variable; little very fine sand; gradational upwards and downwards; massive; light tan weathering; hard; resistant

4' Limestone, medium grey; very fine to microtextured; much fine-very coarse skeletal echinoderm fragments; lower contact very sharp; small round chert nodules; very massive; medium grey weathering; hard; resistant; cliff-forming

Sandstone, dolomitic; medium grey; very fine-fine; fairly well sorted; some fine cross-stratification; medium brown weathering; hard; resistant

Figure 7

and are characterized by very numerous red, silicified spiriferid brachiopods, most of which are fragmented, many to sand and granule sizes. The upper contact is gradational into the overlying dolomite.

The lower Spirifer tongue is somewhat different 6 miles to the north at Mount Storelk (26) (Figure 7). A 5 foot bed of dolomite in the lower part seems to represent the dolomitized upper half of the lower bed at Mount Loomis. The two sandstone beds within the tongue at Mount Loomis are missing at Mount Storelk, and the two maroon limestone beds appear to have coalesced northward to form a single, maroon, argillaceous limestone bed (Plate XIV A). One of the more notable features of the argillaceous limestone is the irregular zones of maroon, argillaceous and extremely sandy, poorly sorted limestone it contains, together with the exceedingly numerous red, silicified brachiopods. These maroon limestones are very conspicuous from a long distance. A 4 foot bed of cherty, sandy, microtextured limestone in the upper part is possibly correlative with the cherty dolomite at the top of the tongue at Mount Loomis.

This same Spirifer tongue in Kananaskis Range, 14 miles to the northwest, is represented by only 7 feet of limestone overlain by 3 feet of dolomite. The limestone here contains less sand-size skeletal grains than elsewhere, only a little very fine quartz sand, no maroon clay, but fairly numerous rounded nodules and uneven layers of chert. The upper 1 foot of the bed is completely replaced by medium crystalline, structureless dolomite. As in other sections, there are numerous silicified spiriferid brachiopods (but none are red), and they are accompanied by many silicified productoid brachiopods. This bed weathers light grey and is conspicuous from a long distance because of the contrast in weathering colour with the adjacent brown weathering sandstones. The overlying medium to very coarsely crystalline, very sandy, structureless dolomite is partly fossiliferous, and the

base contains some disseminated fine to coarse, black, detrital phosphorite sand grains that are well rounded, and associated with many finely fragmented Orbiculoidea shells. This is one of the lowest levels at which detrital phosphorite grains occur in the Carboniferous strata studied.

Dolomitized Equivalent of the Lower Spirifer Tongue: The lower Spirifer tongue consists of dolomite almost everywhere south and east of Kananaskis and Elk Ranges. Two microfacies (Figures 2,3) within the dolomitized part are recognized on the basis of texture and crystal size. The dolomite within a zone laterally adjacent to the primary limestone is porous, medium to coarsely crystalline (Plate XV A), whereas farther away it is dense and microcrystalline. This apparent zonation may reflect original microfacies within the primary limestone, the coarser textured dolomites being the altered equivalents of calcarenites, and the finer textured dolomites being the altered equivalents of calcilutites. On the other hand it may be related to chemical properties (such as concentration of magnesium) of the solutions involved in the alteration of the limestone. The sections at Ewin Creek (18), Storm Mountain (32), and Mount Hosmer (24) lie within the inner, coarser microfacies, and all other sections lie within the outer, microcrystalline microfacies.

At Ewin Creek (18) the tongue consists of light grey to light tan, granular, medium through very coarsely crystalline dolomite (Plate XV A) that is very porous, with abundant sparry, granular calcite lining the pores. Red to maroon clay is present between the dolomite crystals in some zones, and there is abundant fine to medium and a little coarse, well rounded quartz sand disseminated throughout. Silicified, red, partly fragmented Spirifer and very thin shelled, small Composita (most abundant) brachiopods and echinoderm fragments are abundant, and there are a few thin layers of maroon chert. This is the only section of dolomite that contains red

silicified fossils and maroon clay, and because of these constituents, together with the stratigraphic position, this unit is equated with the sandy, maroon to grey, skeletal limestone beds in Elk Mountains (Figure 8).

The microcrystalline dolomite microfacies consists of medium through very light grey dolomite that is very finely crystalline to microcrystalline. Some zones are sugary, and some beds are rendered extremely porous by many small solution vugs. Very fine and fine quartz sand and silt range from very abundant (constituting up to nearly half the rock) to very rare in some beds. Chert is abundant locally and occurs as rounded to lenticular nodules and layers, and in rare instances preserves a skeletal calcarenite texture (at Mount Broadwood 11, and Alexander Creek 13). Silicified fossils are generally absent, but there are some thin zones containing many silicified brachiopods and echinoderm columnals. The beds are generally massive, very light grey, light tan-grey and nearly white weathering.

In comparing the two microfacies it is to be noted that they differ in crystal size, abundance of fossils, and occurrence of chert.

The Upper Spirifer Tongue: The upper *Spirifer* tongue differs from the lower tongue in that it is 1) almost everywhere medium to coarsely crystalline and typically highly porous dolomite, 2) consistently fossiliferous, with silicified *Spirifer* and *Composita* brachiopods, and 3) is somewhat thinner, particularly in High Rock, Elk, and Kananaskis Ranges. It is similar to the lower tongue in that it has the same texture as the coarser microfacies.

The upper tongue is composed of several beds in most sections, and in brief they consist of light tan to light grey (locally maroon, 18) dolomite that is generally medium and coarsely crystalline, and only rarely finely crystalline. They contain silt and sand of fine to medium and locally coarse grade that ranges from nil to exceedingly abundant. A fine,

secondary vuggy and intergranular porosity is typical, and the dolomite is in part highly porous. Silicified Spirifer and Composita brachiopods and echinoderm columnals range from rare to extremely numerous, and are either disseminated or concentrated in thin layers. Chert is locally abundant, and cross-bedding in the dolomite is present at Mount Broadwood (11). The dolomite is mostly very massive, and moderately hard and resistant.

A special feature of the upper tongue is two silicified coquina-like beds in the section at Mount Broadwood. One of these occurs near the top of the tongue and consists of 3 feet of completely silicified, quartz-cemented, highly comminuted, fine skeltal material in which only bryozoan fronds are identifiable. A few inches above this is a second, thinner, 6 inch bed of silicified coquina that contains highly fragmented remains of numerous bryozoans, brachiopod? shells, fairly numerous ooliths?, rare ostracods, and some echinoderm columnals. These two coquinas are interbedded with medium crystalline, granular, highly porous dolomite.

Another silica replacement in the upper tongue at Alexander Creek (13) and Mount Ptolemy (157) suggests that at least part of this tongue was originally a skeletal, echinoderm calcarenite. Here, in the middle of the tongue, which is medium to coarsely crystalline dolomite, is a dark lenticular layer up to 1 foot thick in which an original clastic, medium- to coarse-grained skeletal limestone texture has been faithfully preserved by silicification prior to dolomitization.

The two Spirifer tongues are separated by sandstone and siltstone beds in most areas. At Mount Broadwood and Andygood Creek however, these clastic beds are represented by dolomite similar to that forming the tongues, and it appears as though the tongues have coalesced.

Todhunter Formation in the Misty Range Near Highwood Pass

Correlation of individual beds in the Todhunter from High Rock and Elk Ranges to Misty Range is difficult. Although all the lithologic elements that characterize the Todhunter are present here, they occur in proportions different from those in other sections. The upper division of the formation, together with the upper Spirifer tongue appear to be missing, and lateral changes in lithology by facies change are abrupt within Misty Range. For example, the sequence of Todhunter beds at Storm Mountain (32) bears little resemblance to the Todhunter sequence at Mount Arethusa (33) yet the two sections are only 2 miles apart. Similarly at Mount Elpoca (39) a few miles to the north, there is very little similarity of probable Todhunter equivalents with that at Mount Arethusa. Part of the reason for these inconstancies is that most of the lower Spirifer tongue grades into sandstone in Misty Range, and the upper tongue appears to be absent, perhaps because of non-deposition. Without the Spirifer tongues as markers, the Todhunter may be difficult to recognize since the sandstones and siltstones in it are identical to those forming the overlying Tyrwhitt Formation.

Todhunter Formation in the Bow Valley Region

Distinctive strata that characterize the Todhunter south of Highwood Pass quickly disappear northwards, making recognition of the formation somewhat uncertain in the Bow Valley region (Figure 8). At Mount Elpoca (39), Mount Wintour (38), Pigeon Mountain (42), Tunnel Mountain (41) , Palliser Range (44), and Bare Mountains (45) only beds equivalent to the lower clastic division can be recognized with confidence. In these sections, one or two thin sandy, microcrystalline dolomite beds are possibly correlative with one or both of the Spirifer tongues. For mapping purposes in this region it would be most practical to combine the Todhunter and Tyrwhitt

Formations into a single sandstone unit.

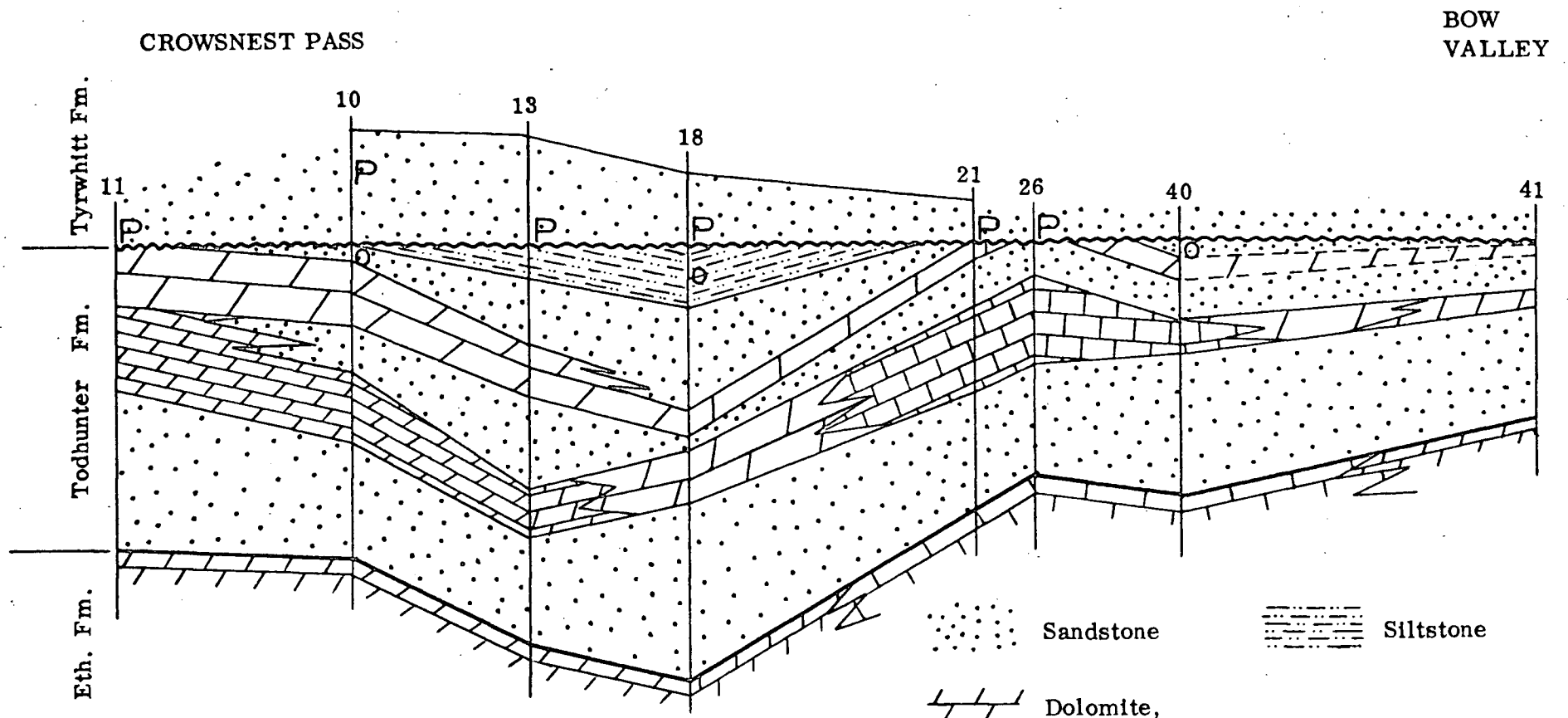
Contacts of the Todhunter

Both contacts of the Todhunter Formation can be readily located in many sections at horizons where an abrupt change to an essentially continuous sequence of beds of different lithology begins. However, the upper and lower contacts in some sections, particularly towards the east, are difficult to locate because of transition downwards into sandy dolomite, and absence of distinctive key beds in the upper part. The lower contact is conformable, the upper contact is believed to be unconformable (Figure 8).

In most sections the lower contact can be readily established where sandstone rests sharply upon cherty, sandy, dense, grey dolomite which seems to constitute a persistent division at the very top of the Ewin Creek Member of the Etherington Formation (Plate I B). In areas where the Ewin Creek dolomites are absent, the sandstones lie on grey weathering, black, skeletal limestone. The contact as located in sections shown in Figures 2 and 3 produces the greatest degree of homogeneity in all members and formations both above and below the contact. If the base of the Todhunter were placed at the base of the lowest major bed of sandstone (within the Etherington Formation) then a very complex, interfingering contact results.

It is probably significant that the lowest horizon at which detrital phosphorite sand and pebbles occur lies just above the lower Todhunter boundary, and the first influx of coarse sand grains composed of quartz and chert occurs above the boundary. It is conceivable that these lithic constituents may prove valuable for regional correlation where fossils are scarce.

The lower contact is made indistinct in some areas (sections 32, 33,



Sandstone

Siltstone

Dolomite, microcrystalline

Dolomite, fine to coarse

Limestone, fine to coarse

P .....productoid brachiopods

O .....Orbiculoidea brachiopods

Diagramatic correlation of Todhunter Formation sections within the Front Ranges showing the apparent truncation of beds by the Tyrwhitt Formation. Basal siliceous sandstone of the Tyrwhitt Formation is shown between sections 10 and 21.

Figure 8

21, 26, 38, 42, 45) where beds of very fine-grained sandstone ranging from 1 to 25 feet thick are interbedded with dense, sandy, microcrystalline or skeletal limestone in the uppermost part of the Etherington Formation (Figures 2,3). In these areas the Etherington clearly grades up into the Todhunter, and establishment of the precise contact without the aid of several criteria is difficult and arbitrary. In the present study several physical criteria have been employed in locating the contact in areas of gradation. These criteria are: 1) beds of highly sandy, grey, very dense, cherty dolomite at the top of the Etherington Formation; 2) local presence of argillaceous siltstone interbedded with the sandstone of the lower division of the Todhunter; 3)a generally uniform thickness of the lower Todhunter; and 4) the *Spirifer* tongues of the middle division that are charactistically fossiliferous, and locally associated with argillaceous, maroon zones.

Criteria for identifying the upper contact will be discussed in the section dealing with the basal contact of the Tyrwhitt Formation.

Fossils and Age

Fossils have been collected from the *Spirifer* tongues at eight different localities in the region, from south of Crowsnest Pass to Kananaskis Range. These localities are given below with lists of fossil identifications and age assignments made by E. W. Bamber of the Geological Survey of Canada.

GSC loc. 48307 West side of Mt. Ptolemy 2.2 miles N 50° W from peak, and 4 miles south of Island Lake, Crowsnest Pass.

? *Spirifer curvilateralis* Easton - incomplete spec.
Composita cf. *ozarkana* Mather

Age: This collection is underlain by *Spirifer occiduus* and is therefore Pennsylvanian (probably Morrowan) in age.

GSC loc. 48308 Same locality as above collection

Spirifer occiduus Sadlick
Composita cf. lateralis (Girty)

Age: Pennsylvanian, probably Morrowan

GSC loc. 48305 Same locality as above collection, and from the underlying bed.

Spirifer cf. cavecreekensis Hernon
Composita cf. sulcata Weller

Age: This collection could be either Morrowan or Late Chesterian in age.

GSC loc. 48329 South end of Elk Range, .4 miles south of Mt. Loomis and 1.8 miles N 40° E of mouth of Cadorna Creek.

Ovatia? sp. - poorly preserved

Age: Insufficient material for age determination

GSC loc. 48323 Same locality as above collection, from overlying bed.

? Spirifer curvilateralis Easton - incomplete spec.

Age: S. curvilateralis is found elsewhere in the region above S. occiduus, which is Pennsylvanian in age. This collection is therefore probably Pennsylvanian in age.

GSC loc. 53470 Southwest corner of Mt. Storelk, B. C., central part of Elk Range on east side of Elk River near head.

Derbya sp.
Composita sp.
? Spirifer curvilateralis Easton - incomplete spec.

Age: The presence of Derbya strongly suggests a Pennsylvanian age for this collection. The age is probably Morrowan.

GSC loc. 53421 Same locality as above collection. From overlying bed.

Spirifer occiduus Sadlick

Age: Pennsylvanian, probably Morrowan.

GSC loc. 42826 Top of prominent ridge trending northwest off the peak of Mt. Ptolemy, 2.5 miles S 42° W from Sentinel Mt. In Flathead Range, south of Crowsnest Pass.

Spirifer cf. occiduus Sadlick
Composita cf. subtilita (Hall)

Age: Pennsylvanian, probably Morrowan.

GSC loc. 53442 Southwest corner of Storm Mt. in Misty Range. From south side of cirque, due southwest from peak of Storm Mt.

Spirifer occiduus Sadlick

Age: Pennsylvanian, probably Morrowan.

GSC loc. 53441 Same locality as above, from overlying beds.

Spirifer curvilateralis Easton

Age: Collection 53442 of Pennsylvanian age underlies this collection. Therefore collection 53441 must be of Pennsylvanian age also.

The age of the middle, fossiliferous division of the Todhunter Formation is interpreted as Pennsylvanian because of the presence of Spirifer occiduus and Derbya sp. An early Pennsylvanian or Morrowan age is suggested by the presence of Atokan fossils in parts of the overlying Tobermory and Kananaskis Formations, and late Mississippian Chesterian fossils in the underlying Etherington Formation. The lower division of the Todhunter is unfossiliferous and the age may be Mississippian or Pennsylvanian.

The Mississippian-Pennsylvanian Boundary

On the basis of the above fossil identifications, the Mississippian-Pennsylvanian boundary apparently lies somewhere between the top of the Etherington Formation and the base of the middle division of the Todhunter Formation (lower Spirifer tongue) within the 35 to 55 feet of unfossiliferous beds that constitute the lower division of the Todhunter. In view of the

transitional nature of the Mississippian and Early Pennsylvanian faunas in the Big Snowy Group in Montana (Easton 1962), the apparent abruptness of the change from a Chesterian to a Morrowan fauna in the Etherington-Todhunter sequence might suggest an interruption in sedimentation took place at the end of the Mississippian in this area. However, the locally transitional nature of the formational contact, and the transitional nature of the Todhunter Formation itself, suggests that some other factors such as ecological conditions and rate of sedimentation might be the cause of the abrupt change in faunas.

TYRWHITT FORMATION

General Statement

The name Tyrwhitt Formation is here proposed for a sequence of sandstones with subordinate interbedded dolomite which differs from the Todhunter Formation mainly in a greater proportion of sandstone, and a greater thickness.

The Tyrwhitt Formation is entirely of marine origin and consists mainly of sandstone with subordinate amounts of dolomite, siltstone and minor amounts of green-grey shale. The sandstones are very fine- and fine-grained, well sorted, even textured quartz-chert arenites, that contain thin laminae of disseminated medium and coarse, highly rounded quartz and chert grains in some beds. They are very hard and compact, and tightly cemented by dolomite and quartz. Colour of the fresh rock is tan to light grey to grey-white, and weathered surfaces are most commonly medium to light brown, with the quartzitic beds weathering grey-white. Dolomite beds, which are sandy and fine- to coarsely-crystalline, and locally fossiliferous, occur as thin lentils that may represent original near-shore coquinas.

In outcrop several characteristics combine to distinguish the formation from the Todhunter and Storelk Formations. The tight cementation and low porosity of the sandstones produce a rock of considerable resistance to erosion, however they are not as resistant as the quartzitic sandstones of the overlying Storelk Formation, or the carbonates of the underlying Etherington Formation. The Tyrwhitt is characteristically a slope-forming unit, and rarely forms prominent cliffs. The good stratification contrasts with the massiveness of the overlying Storelk Formation. The weathering colours also contrast with the white weathering, black lichen-covered Storelk Formation and with the greys of the underlying carbonate rocks.

The Tyrwhitt differs from the Todhunter mainly in the smaller proportion of dolomite and absence of limestone beds, greater thickness, and generally thicker stratification. However difficulty may be experienced in separating the Tyrwhitt from the Todhunter for regional mapping purposes because similar types of sandstone, dolomite and siltstone occur in each, and they commonly have a similar topographic expression. Thus under certain circumstances these two formations may be conviently grouped together.

The Tyrwhitt Formation is a persistent stratigraphic unit and is relatively homogenous both horizontally and vertically although its thickness varies considerably throughout the area (Table IX). Its regional distribution parallels that of the Todhunter but it remains easily recognizable over the entire area. Like the Todhunter it becomes thinner towards the northwest and southwest of the central High Rock and Kananaskis Ranges. Eastward it thins to zero through erosional truncation that has probably accentuated an original, less rapid thinning due to differential sedimentation. The thickest section measured is 347 feet in southern Kananaskis Range (40).

Fossils in the Tyrwhitt are similar to those occurring in the Todhunter Formation, and the age of the Tyrwhitt is interpreted as Pennsylvanian, probably Morrowan. As in the Todhunter, the fossils occur almost invariably in beds of sandy dolomite.

The strata of the Tyrwhitt are believed to be equivalent to beds occurring from 138 to 250 feet above the base of the Rocky Mountain section at Tunnel Mountain described by Beales (1950). At Highwood Pass on Mount Arethusa (33) in the type section of the "Storm Creek Formation" (Raasch 1956;1958), equivalent beds are units 7 to 13 inclusive.

Lithologic Description

The Tyrwhitt Formation consists predominantly of sandstone, but dolomite, siltstone, and minor amounts of shale are important accessory lithologic types.

Sandstone

Composition: Only a cursory examination of thin sections and a limited amount of staining was done to determine the composition of the sand, but it is clear that 90% or more consists of quartz and chert in which the chert varies from a few percent to about 30%. Minor constituents include potassium feldspar and about 1% or less of heavy minerals which include very small, highly rounded zircon, tourmaline, rutile and some magnetite (which may in part be authigenic).

Cement: The bonding material in all of the sandstones is either dolomite or quartz, or both mixed together in various proportions. A mixture of dolomite and quartz is the characteristic cement in most beds, and they are present in two forms. The first is as a diffuse, homogenous mixture in which quartz in optical continuity with the grains forms a porous but firm framework and the dolomite occurs in the pores. The second form is a distinct, alternating sequence of laminae and thin layers of quartz and dolomite cement that range down to a thickness of 1 millimeter. Some beds on the other hand are cemented entirely by dolomite, and others entirely by quartz. The dolomitic sandstones are typically medium to light brown weathering, indicating that the cement is a ferroan dolomite or a mixture including some ankerite.

Colour: The typical fresh surface of outcrop samples is some shade of tan or light grey, but the colour may range from light grey-white through shades of tan and grey to medium brown. The colour is dependent

upon the kind and amount of cement, and the degree of weathering. Were the sandstones completely unweathered, such as might be found in drill cores, all may be very light grey to grey-white, but at the surface even small amounts of dolomite tend to weather and produce tan to brown colours. In spite of this however, many dolomitic sandstones have remained very light grey, nearly white, perhaps because of an absence of iron in the dolomite. All sands cemented with quartz are light grey-white. Colours as dark as medium grey to medium brown occur but are not common.

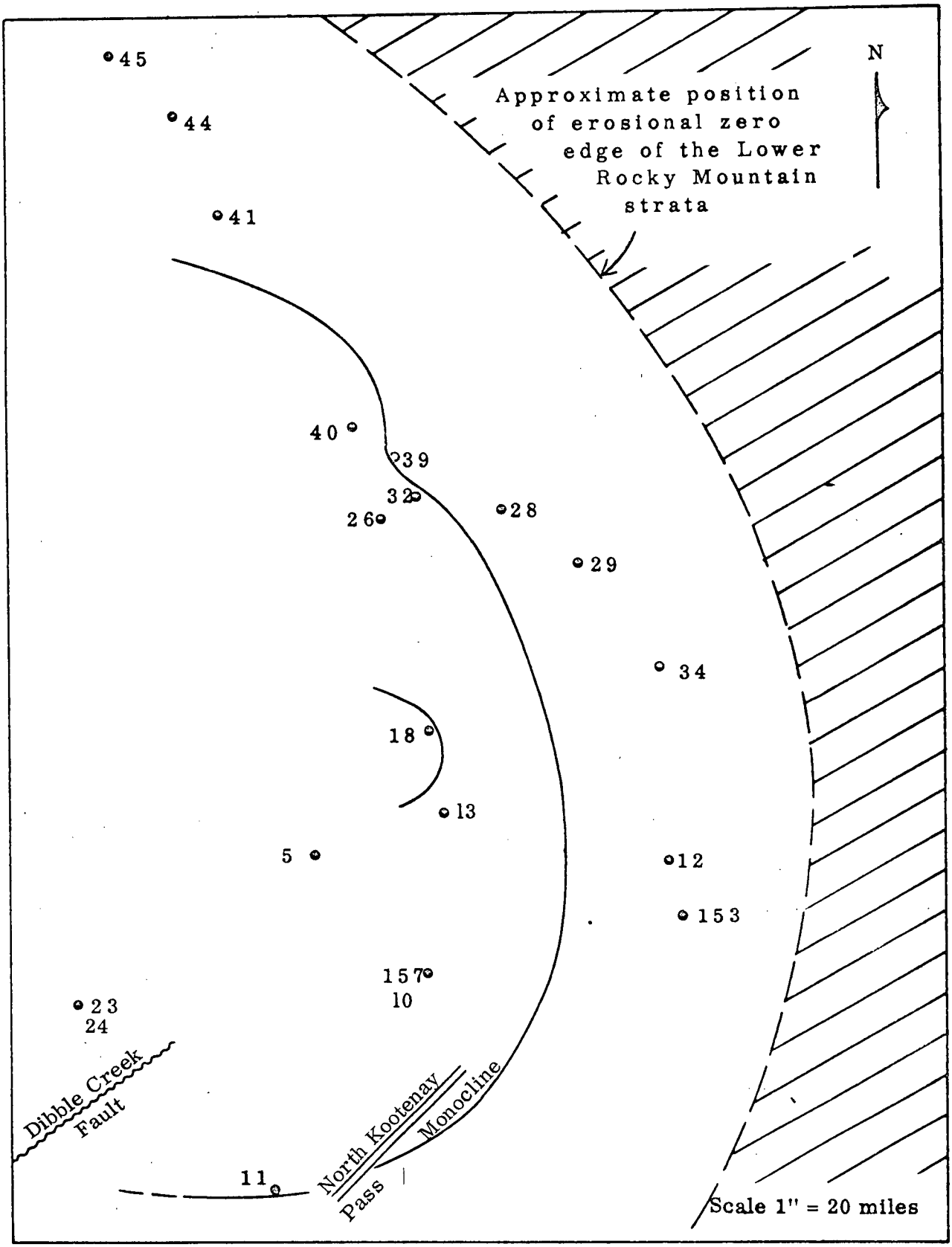
Weathering colours reflect even more readily the mineralogy and proportion of the two bonding materials. Sands cemented entirely by quartz weather very light grey-white or white, and are characteristically covered with black and grey lichen that modify the actual colour, producing a very distinctive dark greyish-black colour. Dolomite-cemented sandstones always weather some shade of brown to tan, and the greater solubility of the carbonate causes them, in contrast to the quartzitic sandstones, to be etched differentially to a lower level. This differential etching is most marked in sandstones cemented with both quartz and dolomite, particularly where the two are segregated into alternating zones. The weathering colour of sandstones cemented with both dolomite and quartz that are evenly mixed produces brownish-grey or greyish-brown colours.

Grain Size, Roundness, Sorting: The grain size of the Tyrwhitt sandstones is their most distinctive single characteristic. They are very fine- to fine-grained, and medium- and coarse-grained sandstones do not occur. Many beds are composed exclusively of very fine sand, others mainly of fine sand. In some beds medium and coarse sand grains occur as disseminated accessories within a fundamental framework of very fine to fine sand.

The very fine and fine grains are mainly angular to subrounded, but range up to rounded. The degree of roundness increases rapidly with increasing grade size. Medium and coarse sand grains are rounded to highly rounded. Chert grains seem to be less well rounded than quartz grains of the same size. The striking difference in degree of roundness between the smaller and larger grains undoubtedly reflects the property of finer sand grains to remain angular, particularly in an aqueous environment, regardless of the amount of transport, whereas the larger grains may become highly rounded during one cycle (Folk 1960). However, it seems likely that part of the roundness of the larger grains was inherited from a previous cycle of erosion and abrasion.

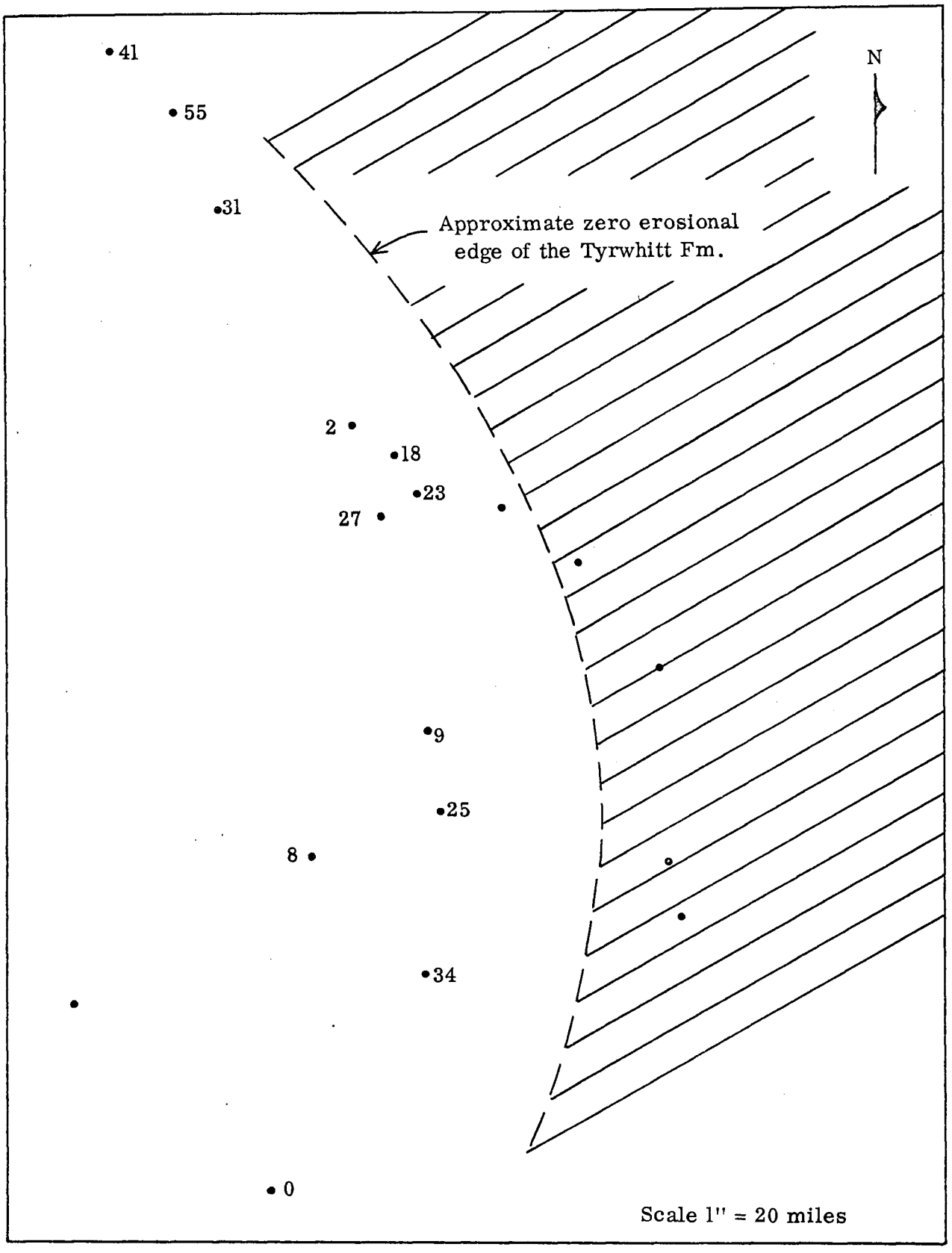
The larger grains are characteristically distributed within the beds of very fine- to fine-grained sandstone as distinct laminae, ranging down to the thickness of a single grain. Some zones contain only a few disseminated larger grains, whereas others contain equal numbers of large and small grains. The boundaries of the zones range from sharp to diffuse. In a few beds that are as much as several feet thick, very abundant medium to coarse grains are evenly disseminated.

The degree of sorting for these and all sandstones studied have been visually estimated by means of a binocular microscope fitted with a graduated ocular, rather than upon precise measurements. Sorting in the majority of sandstones reaches a high degree, and many are remarkable for the uniformity of grain size. Half the sections measured consist almost exclusively of very fine-grained, well sorted sandstone, and the other half consists of 60% to 85% very fine-grained, well sorted sandstone. An exceptional section in Palliser Range (44) contains only 46% very fine-grained, well sorted sandstone. Sections containing significant amounts



Index map showing location and numbers of sections after palinspastic reconstruction for Figures 10, 11, 15.

Figure 9



Percentage of medium or medium and coarse sand in sandstones and dolomites of the Tyrwhitt Formation. See Figure 9 for section numbers.

Figure 10

of medium and poorly sorted beds seem to lie east of sections that contain only small amounts of medium and poorly sorted sandstones or sandy dolomites (Figure 10) and were presumably nearer an eastern shore line, source area, or transporting agent that introduced the sand.

Stratification: The Tyrwhitt Formation is well stratified in contrast to the overlying Storelk Formation. Individual beds range from 1 to 50 feet in thickness, but those in the 3 to 20 foot range are most abundant. Beds tend to have a greater average thickness than those in the Todhunter Formation (Plate IX B). Most beds are massive and without internal parting planes, but some beds in each section do contain partings that produce a platy to thick stratification. Of the beds with internal parting, a medium to thick parting is the most common (see glossary for definition of stratification terms).

Cross-stratification is not an outstanding characteristic of the Tyrwhitt, although sections in some areas, such as at Mount Ptolemy (157) and Alexander Creek (13), contain an abundance of cross-bedding. Sections 5, 32, 40, and 26(Plate VII A) contain only between 20 and 46 feet of cross-stratified beds, and cross-stratification seems to be completely lacking in sections 11, 18, 39, 41, and 44. The regional distribution of cross-stratification seems to bear no obvious relationship to parameters such as sorting and grade size.

Siltstone

Siltstone is a very minor constituent of the Tyrwhitt Formation, contrary to the published descriptions of these and adjacent strata (McGugan and Rapson 1962; Nelson 1962). Siltstone is lacking in some sections, and in others occurs in a few beds ranging in thickness from 1 to 6 feet. Nearly all of these are very even textured and range from dark

grey, greenish-grey, to light grey and brown. They may be dolomitic, and most are argillaceous, or are associated with thin shale partings either within the bed or at its contacts. Many contain sparse to abundant very fine quartz sand grains. One distinctive characteristic of the siltstones is that they almost invariably contain tiny flakes of muscovite, and are commonly pyritic. The beds may be massive or may have flaggy, platy and flaky partings. They are typically very hard, although more recessive than adjacent sandstones. Nearly all weather to a conspicuous brown colour. In Elk, High Rock and Kananaskis Ranges a bed of siltstone occurs in association with lentils of sandy dolomite that are described below.

Shale

Very thin beds or partings of shale have been observed in some sections, and might be found in most if exposures were complete. The shale is predominantly dark greenish-grey, highly silty, flaky to platy and highly recessive. It is most abundant in Kananaskis Range where 10 separate zones were examined. There, individual beds of silty shale from 1 to 6 inches thick are grouped within 50 foot zones in the upper and lower parts. These thin shale beds occur both within and at the contacts of major sandstone units, and typically have very sharp, flat, lower contacts but grade rapidly upwards into the overlying sandstone.

In Misty Range, sections contain several zones of silty shale that are light to dark grey, ranging from the thickness of partings up to 6 inches. In Elk Range the siltstone beds contain or are associated with very thin greenish, flaky shaly zones.

Dolomite

Thin lentils of sandy, fine- to coarse-crystalline dolomite from 1 foot

to 17 feet thick are characteristic of every section of the Tyrwhitt Formation although they form only a very small part of its total thickness. These dolomites are very similar in texture and appearance to the Spirifer tongues in the Todhunter Formation.

Texturally the dolomite beds possess a considerable degree of variation and it is difficult to adequately describe them in general terms. In overall aspect however they are light grey, light tan, medium brown to light yellowish-tan, very fine- through coarse crystalline dolomite. Their texture is granular to tight and compact. Some are exceedingly porous because of the presence of numerous solution vugs ranging up to about 1 inch across. Some beds are soft, friable and "punky", and others are very hard. Most beds contain abundant sand of very fine to coarse grade that consists of both quartz and varicoloured chert. Some contain brown-black, detrital, highly rounded phosphorite sand grains. The sand grains are generally highly rounded, but the degree of roundness decreases with decreasing grade size. Some beds contain equal amounts of sand and dolomite, and may grade laterally into sandstone. A very few of the beds are strongly cross-stratified. Chert layers and nodules are abundant in some beds. Contacts with the adjacent sandstones range from very sharp to gradational. Weathering colours range through browns and tan to grey. Individual beds range from massive through flaggy and may be either hard and resistant or soft and recessive.

Chert has preserved an original coquina-like texture in the dolomite beds at three localities. At Alexander Creek (13) two beds 1 1/2 and 1 to 2 feet thick are silicified coquinas. They are very vuggy and porous, and contain thin zones which are less well silicified and consist of porous dolomite. At Mount Loomis (21) the top 3 to 6 inches of a dolomite bed

consists of chert that appears to preserve in part, the texture of an original clastic, skeletal limestone. Similarly, at Mount Elpoca (39) a 1 foot bed of granular, extremely porous, leached dolomite is partly silicified and contains two thick layers of chert which internally seem to have the texture of a sandy coquina. These few remnants of original coquina-like textures, together with the abundance of poorly sorted sand some of the beds contain, suggests that they may have originally been shallow water, near shore or strand-line coquinas that have been subsequently completely dolomitized, or less commonly extensively recrystallized.

Dolomite beds are most common in the Alexander Creek section (13) where 8 separate and distinct beds have a total thickness of 32 feet. The thickest individual beds in the member occur at Mount Loomis (21) where three zones composed of several beds are 13, 4, and 17 feet thick respectively. Sections in Bow Valley area contain only one thin bed of dolomite.

The shape and lateral extent of the dolomite beds is poorly known because similarities in appearance make correlation of individual beds difficult. Individual beds probably are lenticular and wedge out or pass into sandstone within relatively short distances as is diagramatically illustrated in Figure 2. However, one bed contains abundant Orbiculoidea shells at Mount Loomis (21), Mount Storelk (26) and Kananaskis Range (40), and since this is interpreted as a single bed, here named the Orbiculoidea Bed, it has a lateral extend of about 25 miles. Towards the south this same bed may also be present at Alexander Creek (13), Mount Hosmer (24), and Mount Broadwood (11) because a few to numerous Orbiculoidea shells occur in a dolomite bed in each of these sections.

Silicified articulate brachiopods in the Tyrwhitt Formation, though not

really abundant, locally occur in large numbers in some of the dolomite beds. In view of a similar association in the Todhunter Formation it seems to be a general rule in this sequence that the brachiopods lived in the carbonate lithofacies.

Contacts and Thickness Variation

Both the lower and upper contacts of the Tyrwhitt Formation are sharp and nongradational. North and south of central High Rock Range, marked thinning of the Todhunter strata suggests an unconformable lower contact (Figure 8). Data regarding the nature of the upper contact are inconclusive but it is tentatively suggests that it is conformable.

Lower Contact: The contact between the Todhunter and Tyrwhitt Formations appears in outcrop to be conformable, but regionally it seems to be unconformable, mainly because of variations in thickness and lithology of the upper part of the Todhunter. This apparently unconformable relationship may be explained by erosion, or nondeposition combined with differential subsidence and sedimentation, or by facies change. Figure 8 illustrates angular truncation which three lines of evidence suggest is due to either erosion or nondeposition: 1) the basal Tyrwhitt sandstones rest on horizons in the Todhunter as low as the middle part of the middle division; 2) the base of the Tyrwhitt consists of a widespread, relatively uniform, siliceous productoid-bearing sandstone; and 3) a conglomeratic or lag-type deposit containing fragments of Orbiculoidea shells and detrital phosphorite grains occurs at two localities where most of the upper Todhunter is missing. The hiatus represented by this unconformity cannot be large, since fossils above and below it indicate a probably Early Pennsylvanian age for both the Todhunter and Tyrwhitt Formations.

A widespread, thick, siliceous, productoid-bearing, basal sandstone occurs immediately above the Todhunter Formation between Mount Broadwood (11) and Mount Loomis (21). This suggests that in this area the contact with the Todhunter is a single bedding surface and not a facies boundary. At Mount Ptolemy (10) several beds totalling 37 feet at the base of the Tyrwhitt consist of very fine- to fine-grained, well sorted, dolomitic sandstone that contain abundant irregular masses, layers and nodules of grey-white weathering quartz-cemented sandstone and some grey chert nodules. At Alexander Creek a basal 5 foot cherty dolomite and 30 foot sandstone bed constitute the basal zone. The sandstone is very fine- to fine-grained and contains thin zones with numerous medium and some coarse quartz sand. Evenly spaced throughout are numerous grey-white weathering layers and lenses of silica-cemented sand from 1 to 4 inches thick. At Ewin Creek (18) a basal 5 foot silty sandstone is separated from an overlying 18 foot thick dolomitic and quartzitic sandstone by 6 inches of green silty shale. At Mount Loomis (21) the basal sandstone, which is 15 feet thick, is very fine-grained and contains abundant grey-white weathering chert- or quartz-cemented nodules and knobby masses. Northwards from this locality the basal sandstones lose their distinctive siliceous character and only the presence of fossils or other distinctive criteria can be employed in delineating the boundary. At all of the above locations, silicified productoid brachiopods have been observed in the siliceous sandstone. At sections 157-10 they occur 22 feet above the base, and at sections 13 and 18 they occur 5 feet above the base, whereas at section 21 they are distributed throughout the bed. At section 26 they are present on the basal surface of what may be an equivalent of the basal siliceous sandstone farther south. Productoid brachiopods have also been collected from poorly exposed beds immediately

above the Spirifer tongues at Mount Broadwood (11). In addition a "honey comb" colonial coral has been collected from the productoid beds at sections 157, 13 and 18.

At three locations, Andygood Creek, Mount Ptolemy, and Kananaskis Range there occurs in what is here defined as the uppermost beds of the Todhunter Formation, numerous fine fragments of Orbiculoidea shells and sand-, granule- and pebble-size detrital phosphorite grains (Figure 8). At sections on Andygood Creek and Mount Ptolemy, the top bed of the Todhunter consists of two feet of very fine-grained, silty, dolomitic sandstone that contains very numerous, finely fragmented, black to brown Orbiculoidea fragments, a few silicified articulate brachiopod fragments, and variable amounts of dark brown-black, subangular to well rounded detrital sand- through pebble-size fragments of sandy to silty phosphorite, phosphatic sandstone, and pelletoidal phosphorite (Plate XVI). At Kananaskis Range in the uppermost one foot of very fine- and fine-grained sandstone of the Todhunter are very numerous fine Orbiculoidea shell fragments and numerous fine to very coarse sand-size, black, highly rounded, detrital phosphorite grains. The Orbiculoidea-phosphorite bed in all three sections is placed within the Todhunter Formation because it is overlain sharply by sandstones of the Tyrwhitt and does not appear to be a basal clastic of it, and because locally (at section 8) it is gradational downwards. In addition, at section 157,10 fragments of phosphorite up to 1 inch long have been incorperated into the basal few inches of the basal siliceous Tyrwhitt sandstone bed. It is probably significant that the Orbiculoidea-phosphorite fragments have been found only at localities (157, 10, 8, 40) where the uppermost Orbiculoidea-bearing siltstone bed of the Todhunter (at 18 and 13) is missing. The distribution of the Orbiculoidea-phosphorite zone, both regionally

and stratigraphically, together with the fact that the Orbiculoidea are in a highly fragmented condition, suggests that this zone represents the condensed equivalent of at least part of the upper Todhunter. The highly fragmented Orbiculoidea shells and phosphorite grains may represent a type of lag deposit that accumulated in agitated waters while the upper Todhunter sandstones and siltstones were accumulating in less turbulent water. Thus differential rates of sedimentation may account for the thickness variation of the Todhunter, rather than subaerial erosion of uplifted beds.

In Bow Valley region no evidence of unconformity between the Todhunter and Tyrwhitt was observed, indeed, no distinct boundary delineates these formations, and any contact must be defined arbitrarily. For practical purposes the top surface of the highest thin, dense, sandy dolomite bed is probably the most distinct horizon (Figure 8). The contact in Misty and western Highwood Ranges is arbitrarily located also but in reality probably lies above the dolomite beds equivalent to the Spirifer tongues.

These data indicate that the lower contact is probably unconformable, and they may be interpreted as indicating that either erosion or nondeposition and differential subsidence created the discontinuity and thickness variation in the Todhunter. The data presently available suggests that the contact is diastemic in origin rather than erosional, but additional conclusions are not warranted at this time.

Upper Contact: The upper boundary of the Tyrwhitt Formation is everywhere sharp and non-gradational in outcrop, however similarities in texture and composition of the uppermost Tyrwhitt and lowermost Storelk sandstones in some sections cause difficulty in locating the contact. Evidence regarding the conformability of this contact is conflicting, and a definite conclusion has not been reached with the present data.

Regional evidence suggesting an unconformable boundary includes marked thinning of the Tyrwhitt and apparent convergence of the Orbiculoidea Bed with the base of the Storelk Formation. Abrupt thinning of the formation towards the southwest from Mount Ptolemy might indicate erosional truncation, particularly when this thinning is accompanied by convergence of the Orbiculoidea Bed with the base of the Storelk Formation (Figure 2). Towards the north the Tyrwhitt also thins, from 347 feet in Kananaskis Range (40) to 46 feet at Panther River (45). This regional thinning of the Tyrwhitt however, may be of minor significance regarding its value in interpreting the nature of the upper contact, when it is observed that towards the southwest and north, thinning occurs in all the Pennsylvanian formations. This suggests that some more permanent and persistent control, such as differential subsidence and sedimentation acted throughout early to middle Pennsylvanian time, and that erosional truncation did not necessarily occur prior to deposition of the Storelk Formation. On the other hand, since unconformities apparently exist at the top of the Kananaskis, Storelk, and Todhunter formations and they thin to the southwest and north, then an unconformity may exist at the top of the Tyrwhitt.

In outcrop the contact appears to be conformable in all but one section (26), where an apparently anomalous truncation of uppermost Tyrwhitt beds occurs (Plate VI B). At this locality 4 1/2 feet of beds appear to wedge out within a distance of about 50 feet against the base of the Storelk. On the south side of Storelk Canyon at least 3 feet of dolomitic, very fine-grained, light brown sandstone containing fairly numerous small oxidized pyrite nodules and numerous extremely thin, dark, oxidized, pyritiferous films and anastomosing stringers, are distinctly truncated over a distance of about 25 feet (Plate VI B). On the north side of the canyon (which unfortunately does not expose the beds well) 1 1/2 feet of very light tan,

finely crystalline, highly sandy dolomite occur but were not observed on the south side. This angular truncation may be attributed to either subaerial erosion, submarine scouring, or gentle low-angle cross-bedding. Of these the first seems to be the least likely, and it is tentatively suggested that local scouring by currents which deposited the overlying cross-bedded Storelk sandstones produced the local truncation.

From the above data there seems to be good evidence of an unconformable contact between the Tyrwhitt and Storelk Formations. However, the local and apparent regional discordance at the contact may be interpreted as the result of differential sedimentation and subsidence. Until positive evidence is found for an unconformity, the contact will be considered to be conformable.

Fossils and Age

Fossils are not abundant in the Tyrwhitt Formation, but well preserved silicified brachiopods are numerous in a few thin zones. The brachiopods, which constitute most of the fauna, are found almost exclusively in beds of sandy dolomite which suggests that their distribution was controlled primarily by environmental conditions. Useful fossil collections have been made from three main zones within the formation, at the base, in the middle and at the top.

The fossils collected from the Tyrwhitt Formation were identified by E. W. Bamber of the Geological Survey of Canada as follows:

Basal Siliceous Bed

GSC loc. 48313 West side of Mt. Ptolemy 2.2 miles N 50° Wfrom peak and 4 miles south of Island Lake, in Crowsnest Pass.

Antiquatonia cf. *hermosana* (Girty)

Pleurodictyum meekanum (Girty) of Nelson, 1962
Amplexi-Zaphrentis sp.

Age: Early Pennsylvanian

GSC loc 55591 49368 Southeast corner Mt. Broadwood, 1/2-1 mile north of mouth of Bean Creek, 7 1/2 miles due east of Elko, B.C.

Antiquatonia cf. portlockiana var. crassicostata (Dunbar and Condra)
Antiquatonia cf. hermosana (Girty)

Age: Early Pennsylvanian

GSC loc. 49249 Head of Alexander Creek, B.C., southern High Rock Range, north side of ridge on south side of creek, 6.7 miles E 7° S from south end of Grave Lake.

Pleurodictyum meekanum (Girty) of Nelson, 1962

Age: Late Mississippian (Chesterian) or Early Pennsylvanian

GSC loc. 48311 On north side of ridge, south side of Ewin Creek and Beehive Pass trail in Beehive Map-Area, 2.6 miles W 15° S from Beehive Mt.; locality at about 7,000 feet

Antiquatonia cf. hermosana (Girty)
Pleurodictyum meekanum (Girty) ? of Nelson, 1962
Reticulariina? sp.

Age: Early Pennsylvanian

GSC loc. 55594 Top of prominent ridge extending to northwest off peak of Mt. Ptolemy, between Ptolemy and Crowsnest Creeks. Bed forms prominent small peak high on ridge, fossils on very top of peak.

Antiquatonia cf. hermosana (Girty)
Antiquatonia cf. portlockiana var. crassicostata (Dunbar and Condra)

Age: Early Pennsylvanian

Fossils from Middle Part

GSC loc. 49387 Southeast corner Mt. Broadwood, 1/2-1 mile north of mouth of Bean Creek, 7 1/2 miles due east of Elko, B.C.

Spirifer occiduus Sadlick
Composita sp.

Age: Pennsylvanian, probably Morrowan

GSC loc. 48310 On north side of ridge, south side of Ewin Creek and Beehive Pass trail in Beehive Map-Area, 2.6 miles W 15° S from Beehive Mt., at approximately 7,500 feet.

Spirifer occiduus Sadlick
Spirifer cf. *matheri* Dunbar and Condra
Spirifer cf. *opimus* Hall
Composita cf. *sulcata* Weller

Age: Pennsylvanian, probably Morrowan

GSC loc. 53419 Southwest corner Mt. Storelk, B.C. in canyon. Elk Mountains, near head of Elk River.

Spirifer occiduus Sadlick

Age: Pennsylvanian, probably Morrowan

Fossils from top of Formation

GSC loc. 53439 Northwest corner Mt. Elpoca at north end of Misty Range, about 215 feet stratigraphically below the Spray River Formation.

Punctospirifer campestris White
Leiorhynchus? sp.
Composita sp.
Neospirifer praenuntius Easton

Age: Pennsylvanian, probably Morrowan

On the basis of these collections E. W. Bamber has indicated that the Tyrwhitt Formation is of Early Pennsylvanian, probably Morrowan age.

STORELK FORMATION

General Statement

The name Storelk Formation is proposed here for a unit of resistant, cross-bedded, quartz-cemented, very fine- to medium-grained, nearly pure, chert-quartz sandstone in the middle of the Pennsylvanian sandstone succession. It was probably this unit, which forms conspicuous dip-slopes in the vicinity of Bow Valley, that prompted D. B. Dowling (1907) to introduce the name Rocky Mountain Quartzite. The Storelk is a widespread, relatively uniform quartzite that forms an excellent marker unit. In many sections the formation is essentially a single bed. It is generally coarser grained than the sandstones in adjacent formations. In some sections coarse, large-scale cross-bedding is prominent, and some cross-stratification is probably present in each section. Its upper contact is marked by a heretofore unrecognized regional unconformity marked by a chert-phosphorite-sandstone pebble conglomerate.

The Storelk Formation corresponds to units 3, 4, and 5 in the uppermost part of Raasch's (1956,1958) "Storm Creek Formation" on Mount Arethusa at Highwood Pass. At Tunnel Mountain it corresponds to Beales' (1950) 102.5 foot quartzitic sandstone unit.

Lithologic Description

In gross aspect the Storelk Formation is virtually a single, massive bed (with variable parting), composed predominantly of quartz-cemented, white or grey-white, quartz-chert sandstone which possesses a high degree of internal variation of grain size, texture and sorting.

Colour: The colour of fresh surfaces is white or very light grey-white.

Near the base, where dolomite cement occurs in some sections, a tan-grey colour is typical. In Crowsnest Pass area chalky, altered chert

grains in some zones have absorbed iron oxides that give the rock a tan or pink colour.

The dominant weathering colour is very light grey-white or white, however a very distinctive type of black and grey lichen almost completely covers the weathered surfaces in most areas. Small patches of white show between the individual lichens to produce an overall dark grey colour that is very distinctive when viewed from a distance. The distinctive dark grey western dip-slopes in Misty Range and Fairholme Range adjacent to Bow Valley are formed by the Storelk Formation. Abundant orange to pink staining occurs locally and contrasts vividly with the weathering colour of adjacent formations. Orange staining is abundant at Ewin Creek (18), Alexander Creek (13) and Mount Ptolemy (157,10), whereas at Cummings Creek and Mount Broadwood (11) the rock weathers white and pink and is not covered by lichens.

Cement: Quartz is the principal cementing material and this is probably one of the most distinctive single characteristics of the formation. The quartz occurs as overgrowths on the quartz grains and almost completely obscures their original shape and roundness, producing an extremely hard, impermeable rock composed almost entirely of silica (Plates XVII,XVIII). Dolomite becomes increasingly abundant toward the base to the point where it is the dominant cement in the lower one third of some sections. Dolomite cement commonly occurs as traces in other parts of the formation, and may even be the only cement in a few zones several feet thick. At Mount Hosmer (24) much of the cement is calcite and the formation here is atypical.

Composition: The sandstones of this formation, like those of adjacent formations, are composed of over 90% quartz and chert, and may be termed pure quartz sandstone or orthoquartzite. Much of the sandstone

is probably composed of 98% silica. Examination of thin sections and limited staining for feldspar indicates that many specimens contain only 1% or 2% feldspar. It is probable that none contain over 5% feldspar. Chert is abundant in most specimens, but it ranges from only a trace up to about 30% or more. Many of the chert grains are altered, apparently as a result of leaching, to dull, white (often stained pink or tan), porcellaneous grains. All gradations from fresh chert through grains with porcellaneous texture to porous, soft, chalky, clay-like grains have been observed. This type of alteration of chert seems to be characteristic of sandstones in the area that are cemented with quartz, although not every quartz-cemented sandstone contains altered chert. The leaching of chert grains may have provided a partial source of silica for the quartz cement.

Accessory heavy minerals form less than 2% of the rock, but are very characteristic elements. They range in abundance from rare in some zones to rather numerous in others. Zircon, tourmaline and magnetite have been identified. Rutile may also be present (as in sandstones of the adjacent formations) but it has not been identified in the few slides studied. The magnetite may be largely authigenic since both rounded and euhedral grains are present. The zircon and tourmaline grains are rounded to very highly rounded and predominantly of fine sand grade. Magnetite ranges from very fine to medium sand grade.

Grain Size and Sorting: The sandstones are very fine- to medium-grained (Plates XVII, XVIII) in contrast to the very fine- to fine-grained sandstones of the Tyrwhitt, Todhunter, and Tobermory formations. However, the Storelk sandstones may locally consist of only very fine and fine sand grades and thus differ little from the other formations in this respect. Although the Storelk is essentially homogeneous

in gross aspect, it exhibits characteristic internal variation in grain size and sorting. Virtually every section consists of zones ranging from laminae only a few grains thick up to zones many feet thick that differ in grain size and sorting. Many of these zones (which have obscure boundaries) contain variable amounts of coarse sand. This coarse sand occurs only as disseminated grains and does not form coarse-grained sandstone.

There is a gradual decrease in grain size and complementary increase in degree of sorting toward the base of the formation. The lowermost part is generally very fine- to fine-grained and well sorted in contrast to the upper part which commonly is poorly sorted.

Variations in grain size also occur laterally, however the variation is irregular and does not appear to bear a definite relationship to the other parameters studied.

The Storelk sandstones tend to be more poorly sorted than those which characterize the adjacent formations, but like grain size, this property is variable from zone to zone and from one locality to another. The finer grained, lower part is generally well sorted. Higher in the formation zones of well sorted and medium sorted sands alternate, and are accompanied by thinner zones of poor sorting where coarse and medium grains are abundant. In overall aspect the formation is medium sorted.

Roundness: Sand grains in the Storelk are more highly rounded than those in adjacent formations. The increased degree of roundness extends into the finer grades, which in adjacent formations are subangular to subrounded. Fine sand in the Storelk is rounded, and larger grains are rounded to well rounded. Secondary quartz overgrowths and intense interpenetration of grains obscures the original shape and roundness of most of the grains.

Stratification: The nature of the stratification is one of the most diagnostic features of the formation for purposes of field identification. In many sections it appears to essentially form a single, massive bed. However, in Misty Range it is thickly and distinctly stratified and there is considerable difficulty in distinguishing the Storelk from the upper part of the Tyrwhitt which becomes very massive and quartzitic (Plate XIII).

Large-scale cross-stratification (Plate VII B) is present through much of the formation where it is extremely massive, but it is not everywhere conspicuous because of a common lack of parting planes along the cross-sets. On the other hand, abundant sets of inclined parting planes in otherwise very massive and homogenous rock suggests an abundance of cross-stratification. Cross-bedding is most common in Elk Mountains and High Rock Ranges and least common in Misty Range.

Contacts

Lower Contact: The lower contact is very distinct in some sections but difficult to distinguish in others because in some areas the lowermost part of the Storelk closely resembles the Tyrwhitt sandstones in colour, grain size, mineral cement and topographic expression. Nevertheless the actual surface of contact is sharp and nongradational. The contact is clearly defined at Mount Broadwood (11), Mount Elpoca (39), Kananaskis Range (40) and Mount Storelk (26) because a thin bed of sandy dolomite forms the topmost bed of the Tyrwhitt Formation. At Storm Mountain (32) the topmost bed of the Tyrwhitt is a dolomitic sandstone that in part contains extremely numerous medium and coarse quartz and chert grains, that corresponds to Raasch's (1956,1958) bed No. 6, "Storm Creek Formation".

The lower contact may be conformable or unconformable, but at present it is tentatively considered to be conformable.

Upper Contact: The upper contact is interpreted as a previously unrecognized regional unconformity. It is everywhere sharp and easily recognized on the basis of the contrast in topographic expression, weathering colour, stratification, mineral cement, and grain size between the Storelk and Tobermory Formations. A basal conglomerate in the Tobermory Formation is developed locally. Local evidence of erosion on the upper surface has been observed only at Mount Broadwood (11). There, the upper surface is very irregular, and marked with numerous pits from 1/8 to 1 inch deep, and a few larger depressions that extend down to a depth of 8 inches. Much hematite staining occurs in the upper one foot and in places extends down to a depth of several feet. Elsewhere, the upper surface is smooth and flat or gently undulating. This type of contact is very well exposed at Tunnel Mountain beside Bow River (Plate X).

Topographic Expression

The highly siliceous and massive character of the Storelk in most areas makes it more resistant to erosion than either the Tyrwhitt or Tobermory Formations, hence it commonly forms conspicuous cliffs or ridges that are bounded by ledges or slopes above and below. This combines with the weathering colour to make the Storelk an easily recognized and useful index unit.

Fossils and Age

No fossils were found in the Storelk and conclusive proof of its age is lacking. Until additional data are forthcoming it will be considered to be Early Pennsylvanian (Morrowan).

TOBERMORY FORMATION

General Statement

The name Tobermory Formation is proposed for a distinctive succession of marine dolomitic and quartzitic, very fine- to fine-grained, predominantly light grey, well sorted through poorly sorted, quartz-chert sandstones that contain a few thin interbeds of microcrystalline dolomite, silicified pelecypod coquinas, and chert pebble zones. The sandstones closely resemble those in the Tyrwhitt Formation and individual specimens from each are virtually indistinguishable, but in overall aspect the Tobermory lacks the general uniformity and persistence of textural properties that characterize the Tyrwhitt. The distinctiveness of the Tobermory is due largely to its position between the cross-bedded, quartzose Storelk Formation and the overlying dolomite of the Kananaskis Formation.

The Tobermory thickens gradually from 9 feet in Palliser Range (44) to 333 feet at Mount Ptolemy (157,10), and in the line of section shown in Figure 2 is wedge-shaped in form. The marked thinning towards the north, and also towards the southwest is consistent with that occurring in the underlying sandstone formations. The thickest section (157), also contains the greatest amount of cross-bedding and the largest proportion of medium to coarse sand grains.

The Tobermory shows a close relationship to the overlying Kananaskis Formation because it contains beds of dense, microcrystalline dolomite, pelecypod coquinas, chert pebble conglomeratic zones and fossils that also occur in the Kananaskis. Also, the transitional nature of the upper contact implies a close relationship, in contrast to the unconformable lower contact which is marked locally by a chert-phosphorite pebble

conglomerate and rarely by a sandstone granule-pebble conglomerate.

The strata here designated Tobermory Formation probably correspond to beds occurring between 352 and 376 feet above the base of Beales' (1950) section of the Rocky Mountain (Plate X).

Lithologic Description

The Tobermory consists mainly of sandstone but contains minor amounts of dolomite. Details of the texture and composition vary considerably from one location to another, and accordingly statements concerning these characteristics must be generalized.

Sandstone

Composition: The sandstones appear to be composed almost entirely of quartz and chert, with very minor amounts of feldspar. Chert occurs in greater amounts than in the Tyrwhitt Formation. Accessory heavy minerals include zircon, tourmaline and rutile up to about 1%. An exceptional section on Mount Hosmer (24) contains a large quantity of detrital phosphorite grains.

Cement: Quartz and dolomite are the dominant cementing minerals in the sandstones, and calcite cement occurs locally in a few beds. The relative amounts of quartz and dolomite cement vary from one locality to another. Also some beds are cemented entirely by dolomite, others entirely by quartz, and many by mixtures of these two minerals. One important feature of the sandstones is the tendency for the two types of mineral cement to occur in alternating zones that range from very thin laminae up to individual beds many feet thick.

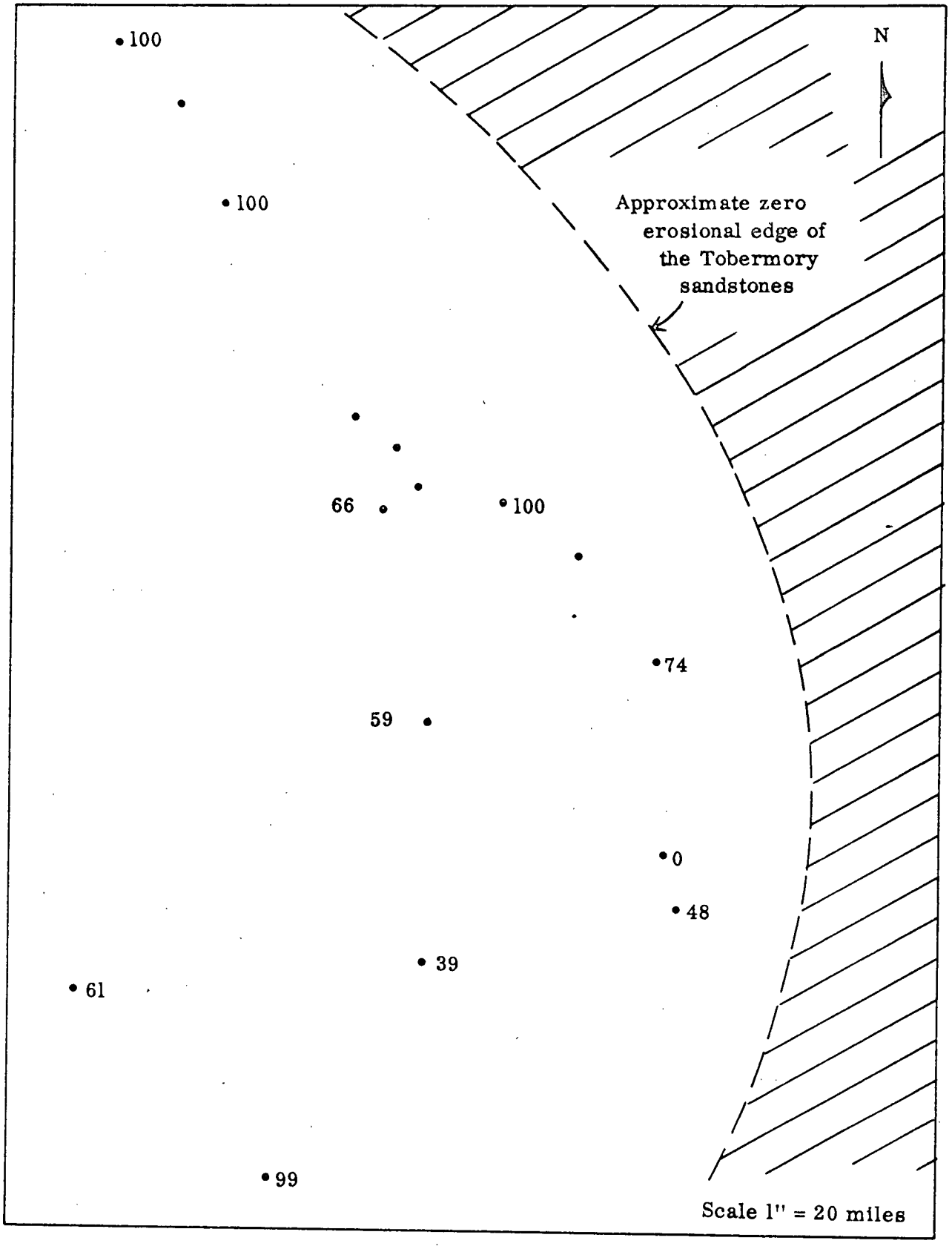
The section at Mount Broadwood (11) is very highly dolomitic throughout and some beds are composed of half dolomite and half sand. At section 18 the upper part of the formation is very dolomitic.

Colour: The sandstones are on fresh surfaces always some shade of grey. Most are light grey, but some range to medium grey. This is in contrast to the typical tan to brown colours of many of the Tyrwhitt sandstones.

The sandstones weather medium to light brown and grey. In some sections the predominant colour is shades of brown, in others greys predominate. As in the underlying sandstones, dolomitic beds weather shades of brown, and quartzitic beds weather grey. Some beds are cemented by a mixture of quartz and dolomite and consequently the weathering colour is brownish-grey.

Grain Size, Sorting, Roundness: The sandstones, like those of the Todhunter and Tyrwhitt are very fine- to fine-grained. Medium and coarse sand grains occur as accessory grains in many beds, either as distinct laminae or disseminated evenly through the bed. Only rarely do medium- to very coarse-grained sandstones occur, and the thickest one observed, at Mount Ptolemy (157), was 6 inches thick. In this same section several very fine-grained sandstone beds contain layers of medium- and coarse-grained sandstone from 1 to 2 inches thick. Many of the larger grains consist of varicoloured chert.

A regional pattern of degree of sorting is partly related to the variations in thickness. At Tunnel Mountain where the formation is 26 feet thick it is entirely very fine- to fine-grained, and somewhat shaly. Towards the south the thickness gradually increases to 333 feet at Mount Ptolemy. This increase in thickness is accompanied by a progressive increase in the content of medium and coarse sand, and at Mount Ptolemy two-thirds of the beds contain some medium and/or coarse sand (Figure 11). To the west at Mount Broadwood, as at Tunnel Mountain, the sandstones are entirely very fine- to fine-grained, and the formation is correspondingly thin. At Mount



Percentage of well sorted sandstone
in the Tobermory Formation.

Figure 11

Hosmer however, most of the Tobermory is medium to poorly sorted because of the presence of abundant phosphorite grains that range from sand grades through to 1 inch pebbles.

Variations in degree of roundness of the grains follows the same pattern as that in the Tyrwhitt, that is, increased degree of roundness with increased grain size. The finer grains are angular to subrounded, and the medium and coarse grains are rounded to highly rounded. The larger chert grains are slightly less well rounded than quartz grains of the same size.

Stratification: Bedding in the Tobermory Formation is variable, and similar to that of the Tyrwhitt, so that each contrasts with the exceedingly massive Storelk which separates them. In the Tobermory individual beds range from 1 to as much as 45 feet thick, and may or may not contain partings.

Cross-stratification is generally not a characteristic structure in the formation, being altogether absent at Mount Broadwood and Tunnel Mountain. Mount Ptolemy is the exception however, for here about two-thirds of the sandstones contain small-scale cross-stratification or even more abundant cross-lamination. This section containing the greatest amount of cross-stratification, also contains the greatest amount of medium and coarse sand, and furthermore is the thickest section measured. These data imply proximity to source area or transporting agent.

Dolomite

Dolomite accounts for only a small part of the total thickness of most sections. Beds range in thickness from 1 to 14 feet, the thickest beds being at the top. Texturally most are microcrystalline and resemble dolomite composing the Kananaskis Formation, but differ from those in the

Tyrwhitt Formation. Most contain very fine to fine quartz sand, and some contain much medium to coarse quartz and chert sand. A few are conglomeratic, and several contain many chert nodules. At the base of the formation in four sections a 3 to 10 foot sandy, locally conglomeratic dolomite bed rests with sharp contact directly upon the Storelk Formation.

Basal Dolomite and Conglomerate: At Tunnel Mountain (40) the basal bed is 5 feet thick, brown weathering, very finely crystalline, and contains abundant disseminated, very fine to medium, well rounded quartz sand and a few coarse rounded grains. Some parts are sandstone and light grey weathering, quartz-cemented masses constitute about one-third of the bed.

At Mount Storelk the basal dolomite bed is 7 feet thick, very finely crystalline, granular, and contains very abundant fine to medium quartz sand and some coarse rounded quartz sand. A fine granule-pebble conglomerate up to 6 inches thick, composed of fragments of very fine- to fine-grained, well sorted quartz sandstone occurs locally at the base. Some of these fragments are angular, many are subangular, and a few are well rounded. They range in size from medium sand to granules and fine pebbles up to five-eighths of an inch long. The fragments are set in a very fine crystalline matrix of dolomite with very abundant disseminated fine to coarse quartz sand.

At Mount Broadwood the basal dolomite bed, 10 feet in thickness, is light grey, very finely crystalline and highly porous and vuggy due to the solution of undolomitized fossil fragments. Very abundant fine and medium, well rounded quartz sand grains, and some coarse quartz grains are disseminated throughout. Locally the lowermost 2 feet consist of very fine-crystalline, very sandy and conglomeratic dolomite (Plate XIX A). The

sand consists mainly of very poorly sorted quartz grains and varies in amount from very little to very abundant. The larger grains are highly rounded. Altered, subrounded to highly rounded, fine to coarse, porcellaneous white chert grains are fairly numerous. Numerous highly rounded pebbles and granules of chert and phosphorite up to about three-quarters of an inch long are scattered throughout the sandy dolomite. In general the chert is white, very silty, very highly rounded and porcellaneous, but a few of the smaller fragments are subangular to subrounded. The phosphorite pebbles contain abundant angular to highly rounded quartz grains from silt to medium sand grade. The pebbles are dark brownish-black, very highly rounded, and very smooth and polished. A very few rounded pebbles of very fine- to fine-grained to poorly sorted sandstone are present. The sandstone of these pebbles seems identical to that in the underlying Rocky Mountain sandstones. Three small phosphatic vertebrate tooth or bone fragments were found in the conglomerate.

At Mount Elpoca 3 feet of very sandy, medium brown weathering, very fine-crystalline dolomite immediately overlying the Storelk sandstones appears to be the only representative of the formation. It is overlain by a 2 to 4 inch thick conglomerate, into which it grades rapidly, which is similar to that at the base of the Tobermory at Mount Broadwood. The conglomerate consists of: abundant subangular to highly rounded pebbles of white, even textured chert, spicular in part; abundant angular to highly rounded pebbles of very dense, black, silty and sandy phosphorite; several phosphatic bone fragments, that, in part, occur within the phosphorite pebbles; rare, small pebbles of well sorted, very fine- and fine-grained, white sandstone; rare brown weathering dolomitic sandstone fragments of pebble size (2 inches maximum) similar to the uppermost sandy part of the

underlying dolomite bed; and rare Orbiculoidea shell fragments. The fragments of chert, phosphorite and sandstone range from granule to pebble grade, but most are small and medium pebbles. They are angular to highly rounded. The matrix is black, very fine textured, sandy phosphorite or phosphatic clay. Either fragments or matrix may form the bulk of the rock locally.

Phosphorite pebbles also occur in the basal bed of sandstone at Cummings Creek (5) (Plate XIX B). There, a very fine- to coarse-grained, poorly sorted, quartzitic sandstone with abundant highly rounded coarse sand, granules and small pebbles of black phosphorite form a 2 foot bed at the base of the Tobermory Formation. Some of the grains contain abundant quartz sand and silt. A few fragments of dolomitic, very fine-grained sandstone of small pebble grade, and a few granules of very fine granular dolomite are also present. Pebbles are most abundant in the upper half of the bed, and a few very thin zones of finely fragmented Orbiculoidea shells occur in the uppermost part. A second zone with abundant phosphorite pebbles and granules occurs 8 to 9 feet above the base of the formation.

Pebble Zones Within the Formation

In addition to the phosphorite and chert pebbles in the basal conglomerate, two zones of similar pebbles within the formation occur at Mount Broadwood and Mount Ptolemy.

At Mount Broadwood two pebble zones 3 to 4 inches thick occur in the upper seven feet of the formation. The higher of these is medium to poorly sorted sandstone composed of fine to medium quartz grains in which there is a thin zone of very coarse sand, granules and very few subangular pebbles of chert. The sand and granules are well rounded. The lower zone contains clastic grains concentrated in a relatively thin zone of fine to coarsely

crystalline, light grey, vuggy, porous dolomite (Plate XX). The grains consist of coarse and very coarse, highly rounded quartz, and chert that ranges from coarse sand to 1/2 inch pebbles. The pebbles are subrounded to subangular, and roundness of the grains decreases with increasing size. Several different types of chert are present. This lower zone is underlain by a lenticular, silicified pelecypod coquina that also contains a few scattered chert pebbles and some coarse, well rounded sand grains and fewer granules.

At Mount Ptolemy a 3 foot bed of dense dolomite with abundant silt and very fine to coarse sand occurs 107 feet below the top. The coarser grains consist of well rounded quartz and chert. Granules and pebbles of chert up to 1/2 inch are widely disseminated, but some occur in small clusters. The chert is subangular to well rounded, and white, light yellow, orange, reddish-orange, purplish-grey and dark brown. Many different varieties can be distinguished. Dark brown chert contains abundant very fine quartz sand. Some light coloured chert contains fine to medium quartz sand, and a few contain spicule-like structures. One chert fragment contained abundant bryozoa. Rounded chert nodules from 1/2 to 3 inches in diameter, with concentric colour rings of pink, light purple and grey occur in association with the clastic chert grains. A second zone of chert and phosphorite pebbles occur in the upper part of a 2 foot bed of very fine-grained sandstone at the top of the formation. The pebbles of chert and phosphorite are numerous and range from sand grade to 1 inch in diameter. They are subrounded to highly rounded, and less commonly subangular. Several varieties of chert may be distinguished. The phosphorite grains are dark brownish-black, and the chert shades of grey.

Pelecypod Coquinas

Thin white pelecypod coquina beds occur in the Tobermory at Mount Broadwood, Mount Ptolemy, and at Summit Lake (in Crowsnest Pass). At Mount Broadwood there are two coquina zones in the upper 50 feet of the formation. The upper zone is 1 foot thick, lenticular, white, and completely silicified. It contains a few scattered chert pebbles, some granules, and some well rounded coarse sand grains. The lower zone is 3 feet thick, and is almost completely replaced by light grey, fine to very fine crystalline dolomite with much intergranular and fine vuggy porosity. Several thin layers of silicified coquina occur in the upper foot. Fine to coarse sand is fairly abundant in the coquina.

At Mount Ptolemy a 1 foot zone 165 feet above the base of the formation contains several thin layers of silicified coquina 1/4 inch to 3 inches thick. Ten feet above this are several more 1/4 to 1/2 inch thick layers of coquina in the sandstone. At Summit Lake, a short distance to the north, a 3 foot partially silicified coquina is exposed in a cliff exposure on the north side of the highway. From this bed a collection of fossils was made.

Contacts and Thickness Variations

The lower contact of the Tobermory Formation is interpreted as being unconformable and the upper contact conformable, and gradational to sharp.

The lower contact is everywhere sharp and distinct. Three lines of evidence combine to suggest that the contact is unconformable: 1) the presence of detrital chert, phosphorite, sandstone and dolomite fragments at the base in some sections, 2) local erosion of the top surface of the Storelk Formation, and 3) the regional stratigraphic and structural relationships between the Tobermory and older Carboniferous formations (Figures 3,12).

The upper contact of the Tobermory Formation and its stratigraphic relationships with the Kananaskis Formation are far less clear than are those of the lower contact, however the upper contact is considered to be conformable on the basis of the following observations: 1) no definite evidence of erosion, 2) close genetic relationship between the Tobermory and Kananaskis, each containing thin coquina and chert conglomerate zones, together with Kananaskis-type sandy dolomites in the Tobermory and Tobermory-type sandstones in the Kananaskis, and 3) the highly dolomitic character of the Tobermory at Mount Broadwood and of the upper part of the formation at Ewin Creek where the contact (as at Mount Storelk) was somewhat arbitrarily selected.

McGugan and Rapson (1962) stated that the contact is unconformable at several localities where it is marked by conglomerates or coquinas. Chert pebble conglomeratic zones and coquinas occur within both the Tobermory and Kananaskis formations however, and consequently cannot by themselves be considered evidence for an unconformity.

The Tobermory Formation thins conspicuously towards the north and towards the southwest (Figure 2; Table IX), as do each of the other lower Rocky Mountain formations in this area. While erosional truncation at the top could be the cause of this thinning, it is suggested that it is the result of a combination of differential sedimentation, onlap, and perhaps in part of facies change and intertonguing with the overlying dolomites of the Kananaskis Formation.

Fossils and Age

Fossils are rare in the Tobermory Formation. Only two collections were made, one of which consisted of silicified brachiopods from a highly fossiliferous 3 foot bed of highly dolomitic sandstone, 95 feet below the

top of the formation at Mount Ptolemy. This bed occurs in a thick unit of tan to pinkish weathering, very fine-grained sandstone that contains numerous maroon laminae and stringers of medium and coarse chert and quartz grains which are etched to conspicuous relief and define much cross-stratification. Immediately beneath this bed, silicified foraminifera were collected from several thin layers of quartz-cemented, medium- and coarse-grained sandstone 1 to 2 inches thick. The fauna from the upper fossiliferous bed was examined by E. W. Bamber of the Geological Survey of Canada who reported as follows:

GSC loc. 42816 48885 West side of ridge, at west end of conspicuous notch in prominent ridge extending northwest off the peak of Mt. Ptolemy, between Ptolemy and Crowsnest Creeks, 2 1/2 miles due south of Island Lake in Crowsnest Pass.

Neospirifer cf. *triplicatus* (Hall)
Rhynchopora cf. *magnicosta* Mather
cf. *Pulchratia meeki* (Dunbar and Condra)
Dielasma sp.
Hustedia sp.
Orbiculoidea sp.
Reticulariina sp.
Squamularia? sp.
Cancrinella sp.

Age: This collection is Pennsylvanian in age, and the presence of a form similar to *Rhynchopora magnicosta* indicates a Middle Pennsylvanian (Atokan) age.

GSC loc. 48312 Cliff exposure, north side of Highway No. 3, B. C., 1/4 mile north of Summit Lake in Crowsnest Pass at large bend in road. Collection from 3 foot bed of white coquina, large blocks of which are visible in the talus.

Plagioglypta sp.
Schizodus sp.
Aviculopecten? sp.

Bellerophontid gastropod

Age: The elements of this fauna are long ranging, but *Plagioglypta* and bellerophontid gastropods are common in the Kananaskis Formation elsewhere in the area. The collection is probably Middle Pennsylvanian (Atokan) in age.

On the basis of these two collections, the Tobermory Formation is believed to be of early Middle Pennsylvanian (Atokan) age. This age tends to confirm the close relationship between it and the Kananaskis Formation that has been inferred from physical relationships.

KANANASKIS FORMATION

General Statement

The Kananaskis Formation is a distinctive rock unit that consists of "silty dolomites with chert breccias at some localities, and fusulinid chert near the base" (McGugan and Rapson 1961). The type section is on Mount Chester in Kananaskis Range where the formation is 180 feet thick. Fusulinids and other fossils have established the age of the unit as early Middle Pennsylvanian (Atokan).

The Kananaskis Formation remains lithologically uniform throughout the area studied, but its thickness varies considerably. In general the thickness variation parallels that exhibited by the underlying Pennsylvanian formations, that is thinning to the north and southwest, from a maximum in High Rock, Elk, and Kananaskis Ranges. It is apparently absent west of Elk Valley and west of Banff (McGugan and Rapson 1961), and it is absent at Mount Hosmer (24).

The Kananaskis Formation is a widespread, persistent, uniform, and very distinctive rock unit that is composed almost entirely of silty and sandy, very dense, microcrystalline, grey dolomite that weathers very light grey or light tan. Silt and fine to coarse quartz and chert sand is in general very abundant (PlateXXIII). Some beds are gradational into sandstone. Chert nodules are characteristic, as are thin but highly distinctive intra-formational chert breccias (McGugan and Rapson 1961; Rapson 1962). At some localities, notably at Tunnel Mountain, massive beds of grey to white chert are common. Towards the east the Kananaskis Formation appears to be represented by only a few feet of white chert or novaculite which rests unconformably on a very thin Tobermory Formation or on the Storelk or Tyrwhitt Formations. Further west the Kananaskis dolomites rests conformably on the Tobermory sandstones.

Lithologic Description

The Kananaskis Formation consists predominantly of dolomite and contains subordinate amounts of chert. The dolomite ranges from medium to light grey to very light grey. It is almost everywhere very dense, microcrystalline and uniform in hand specimen. In thin section however, some beds reveal the presence of dolomitized, clastic, calcareous grains which suggest that the original rock was a skeletal calcarenite (Plate XXII). Silt and sand are present in amounts varying from only a trace in some beds to very abundant in others (Plate XXIII), and are abundant in most beds. Some beds appear to be gradational into sandstone. The sand is predominantly in the finer sand grades, but ranges from very fine through coarse, and grain sizes vary from one locality to another. Some beds in some sections contain a great abundance of very fine to very coarse quartz and chert sand. Chert always comprises the largest grains, and quartz reaches coarse sand grade only. Chert fragments, both rounded and angular, and of pebble size occur in a few zones. Degree of roundness of the sand grains increases with grade size to very well rounded in the coarser sand grades.

Chert is characteristic of the Kananaskis. It occurs as rounded to lenticular nodules, irregular masses, and lenticular, uneven layers up to 12 inches thick, and locally several feet thick in the Bow Valley area. At Mount Storelk and Ewin Creek virtually every bed contains some chert, and five separate beds at Mount Storelk are capped by a 6 to 12 inch layer of grey chert. An intraformational chert breccia up to 2 feet thick was observed in most sections.

The dolomite is well stratified and individual, very massive beds range from about 2 to 25 feet thick. The dolomite is very hard, generally

highly resistant, and weathers either light grey or very light grey, except in Elk Range and along the east side of Kananaskis Valley where it is light tan to medium brown.

Sandstone forms only a small part of the total Kananaskis Formation, but a few thin beds of sandstone similar to that comprising the underlying Pennsylvanian formations are commonly present. Near the middle of the formation at Ewin Creek a 4 foot bed of very fine- and fine-grained sandstone contains very numerous medium and many coarse, well rounded quartz and chert sand grains, together with fairly numerous granules and fine chert pebbles up to 1 inch long. Similar chert pebbles occur in the Tobermory Formation.

Contacts

The lower contact, as discussed previously, is probably conformable. The upper contact in contrast is unconformable, and the Permian Ishbel strata directly overly the early Middle Pennsylvanian Kananaskis dolomites. This contact was observed at only one locality (Mount Broadwood) where a poorly exposed 1 foot bed of sandstone rests on the Kananaskis. The sandstone is poorly sorted, medium- and coarse-grained, phosphatic, and the lower half contains many subrounded to rounded phosphorite pebbles and some white chert pebbles. McGugan and Rapson (1961, 1962, 1963a) have also reported thin conglomerates at the base of the Ishbel, and locally marked relief on the underlying Paleozoic rocks.

Regional Distribution

The thickest sections of the Kananaskis Formation occur in High Rock, Elk, and Kananaskis Ranges, and the unit thins in all directions from this region (Figure 2; Table IX). The thinning appears to be due in part to

pre-Permian erosion in some areas, and to spectacular stratigraphic condensation in others.

East of Kananaskis Valley, in Misty Range, at Lake Minnewanka and northward along strike from Palliser Range, McGugan and Rapson (1961, 1962, 1963a) report that the Kananaskis Formation is represented by a few feet of white novaculitic chert or silicified carbonate that commonly contains Plagioglypta and Bellerophon. The relationship of this chert to the Kananaskis dolomite, and to chert and sandstones occurring in western Highwood and Livingstone Range is discussed under the section dealing with the Rocky Mountain strata in these ranges.

Fossils and Age

Few fossils have been obtained from the Kananaskis Formation during the present study. One collection was made from a bed of dolomite 80 feet below the top of the formation at Ewin Creek. E. W. Bamber of the Geological Survey of Canada reported as follows on this collection:

GSC loc. 48309 Top of ridge near peak, south side of Ewin Creek and Beehive Pass trail, 2.6 miles W 25° S from Beehive Mt. and 2.8 miles S 8° W from Mt. Lyall, at 8,700 feet elevation.

Cancrinella sp.
Hustedia sp.
Squamularia? sp.

Age: This collection is definitely younger than Mississippian, and the Hustedia and Cancrinella are similar to those from the Tobermory Formation. This collection is probably Middle Pennsylvanian (Atokan).

McGugan and Rapson (1961, 1962) have reported the presence of fusulinids from the Kananaskis Formation which clearly indicate an early Middle Pennsylvanian (Atokan) age.

ROCKY MOUNTAIN STRATA IN THE LIVINGSTONE AND HIGHWOOD RANGES

General Statement

The lower Rocky Mountain Supergroup (Pennsylvanian) thins eastward to an erosional zero edge within the Foothills (Figure 1,3). In Livingstone and eastern Highwood Ranges these strata are bounded by unconformities, are almost totally unfossiliferous, and are isolated by lack of continuous exposure from complete sequences of Rocky Mountain strata. Therefore their age and stratigraphic position relative to the Rocky Mountain sequence further west are imperfectly known. On the basis of lithology and stratigraphic position they appear to be correlative with the Tobermory and Kananaskis Formations of early Middle Pennsylvanian age.

The lower Rocky Mountain strata in easternmost exposures consist almost entirely of quartz-cemented and calcite-cemented, very fine- and fine-grained, quartz-chert sandstone that contain variable amounts of medium and coarse grains (Plate XXI). Chert characteristically occurs in a narrow zone within the sequence (Figure 3; Plate V), and in southern Livingstone Range one and locally two thin beds of white limestone are present (Plates II, III). In thickness these strata range from 25 feet in westernmost Highwood Range to a maximum of 98 feet at The Gap in Livingstone Range (Table IX).

Lithologic Description

Sandstone

The sandstones contain more than 90% to 95% quartz including variable amounts of chert (Plate XXI). Much of the chert is white, soft and chalky. Feldspar also occurs but amounts to less than 5% of the rock. Distinctive small, rounded, black to dark brown phosphorite sand grains occur in minor

amounts in some beds, and locally give the sandstone a "salt and pepper" appearance. The sandstones are predominantly medium or light grey on fresh surfaces, but some are dark grey due to bitumen staining.

The sands are cemented by quartz, calcite and some dolomite. Some beds are entirely quartzitic (Plate XXI A), others calcitic, and others are cemented with both quartz and calcite (Plate XXI B). A very characteristic feature of much of the sandstone in Livingstone Range is that called lustre-mottling, produced by calcite cement occurring as poikilitic crystals up to 1/2 inch in diameter surrounded by quartz-cemented sand (Plate XXI B). On fresh surfaces these crystals reflect light off cleavage surfaces, and on weathered surfaces very conspicuous pits up to nearly 1 inch diameter mark the position where individual calcite crystals have been leached out. Section 12 is very calcareous throughout.

Very fine to fine sand forms the framework of all the sandstones, and variable numbers of medium to coarse grains are commonly disseminated through the rock. Most of the sand grains appear to posses a slightly greater degree of rounding than those of similar size in the Todhunter, Tyrwhitt, and Tobermory Formations to the west. The degree of sorting is variable, but about two-thirds of each section is well sorted. The sole exception is at Daisy Creek where most of the sandstones are poorly sorted (Figure 11).

The sandstones are all normally stratified, and cross-stratification seems to be rarely present. The thickness of individual beds ranges from 1 foot to 25 feet. Most beds are massive layers, but some have thin to platy and flaggy parting. The sandstones weather brown to medium and light grey, and brownish-grey. Most are very hard and resistant and tend to form cliffs.

Limestone

A few very unusual beds of limestone are interbedded with the sandstone succession in southern Livingstone Range. They consist of white, fine to very coarsely crystalline calcite. Most of the beds are striped and banded with very thin, discontinuous, en echelon lenses up to several inches long and from 1/16 to 1/4 inch thick that are composed of light to dark brown and grey, finely crystalline calcite with disseminated light brown to tan, very fine to fine dolomite euhedra (Plate III B). Contacts of the limestone beds with adjacent sandstones are sharp and distinct (Plates II, III A).

At Green Creek (153) two of these beds, each 1 foot thick, occur in the lower part of the succession. Two beds and several lenses occur at Daisy Creek (12) (Plates II, III A). There, near the middle of the sequence a bed of sandstone contains a lenticular layer of limestone up to 1 foot thick at the base. Within this sandstone are several long, gently curved, thin, lenticular layers of limestone from 6 to 15 feet long, and 2 to 3 inches thick, that are arranged en echelon (Plate III A). Laterally the sandstone bed is truncated by the overlying sandstone bed. The middle part of this overlying bed consists of an undulating layer of pure white, strongly colour banded (Plate III B) limestone up to 3 feet thick with very sharp contacts (Plate II).

The origin of these limestone beds is unknown, but they may have developed through the recrystallization of coquina layers, or less likely as a primary precipitate or replaced evaporites.

Chert

The individual sections of sandstones in western Highwood and Livingstone Ranges each contain a zone of chert from 8 to 25 feet thick that may represent a signle, widespread layer. The chert zone in each section has

been correlated and arbitrarily selected as a datum in Livingstone Range (Figure 3).

At Lantern Creek (28) an unusual cherty sandstone unit 25 feet thick unconformably overlies with a basal 1 foot chert-phosphorite pebble conglomerate strata correlated with the Tyrwhitt Formation (Figure 3). Above the conglomerate is 5 feet of white, highly spicular, dull chert, stained yellowish-brown. This chert is overlain by a 1 foot zone that contains numerous scattered, highly rounded, white, sandy chert pebbles up to 1/2 inch in diameter. The remaining 19 feet of the succession is very fine-grained, quartz-chert sandstone that is irregularly cemented by quartz and white porcellaneous chert which varies from diffuse wisps to dense patches and large masses of white porcellaneous chert that contain thin streaks and laminae of sand. Some zones are pure, sand-free, dull, white, spicular chert.

At Mount Livingstone (34) a similar sequence was observed although no chert conglomerate is present at the base of the chert which lies within the sandstones. The lower 5 feet of the siliceous zone consists of a 5 foot bed of sandstone in which layers and irregular masses of white to grey chert constitute half the rock. The upper 3 feet of this bed contain numerous angular chert fragments that range from granule size up to 3 inches. This bed may correlate with the 5 foot chert bed bounded by chert pebbles at section 28. The overlying 11 feet of beds consists largely of white, dull, porcellaneous chert that contains varying amounts of disseminated very fine sand. Much of the chert is mottled from tiny patches of quartz-cemented sand. Much of the chert is mottled from tiny patches of quartz-cemented sand. This grades upwards into 5 feet of very fine- to fine-grained sandstone that is irregularly cemented with white, dull, porcellaneous chert and similar

to the underlying bed. This 16 foot zone of cherty sandstone may correlate with the similar 19 foot zone at section 28 (Figure 3).

To the south, on the west flank of Livingstone Range at The Gap (16), the cherty zone is 25 feet thick (Plate V), and at Green Creek (153) the cherty zone is only 8 feet thick. There, the upper 2 feet consist of alternating laminae of white, sandy chert and very fine-grained sandstone. The lower 4 feet consist mainly of white chert in layers 1/2 to 6 inches thick, intercalated with thinner stringers of sand. The basal 1 foot is a bed of white chert. The chert in this zone contains many spicules as well as scattered sand grains.

At Daisy Creek (12) the cherty zone is missing, apparently because of pre-Jurassic (or possibly pre-Permian) erosion. However, a 4 foot bed of black, nodular, bedded chert forms the basal unit of the overlying formation (Figure 3; Plate VI A), and above this are sandstones which are highly siliceous and cherty. This chert however, is thought not to be correlative with the cherty zone in other sections.

Contacts

Both contacts of the Livingstone-Highwood Range sandstone sequence are unconformable. The sequence is variously overlain by Triassic and Jurassic beds, and locally perhaps by Permian beds. The lower contact is marked by local angular truncation of older beds and by a chert pebble conglomerate at some localities.

At Lantern Creek a 1 foot bed of conglomerate separates the sands from the underlying Tyrwhitt sandstones. It consists of granules and fine pebbles up to several inches in length, that consist mainly of light grey-white, even textured, partly sandy chert, and some black, slightly sandy, fine phosphorite pebbles. All the pebbles are well rounded to highly

rounded. The abundant matrix consists of dark, phosphatic, fine-grained sandstone.

At Daisy Creek the basal bed of the sandstone sequence is a 4 foot zone of conglomeratic sandstone that is texturally very complex. It consists of granules and pebbles up to several inches long of angular to well rounded, dark to light grey, even textured chert with a high proportion of poorly sorted sand matrix. Many of the chert pebbles are silty or sandy. A few are spicular, and a few represent completely silicified skeletal limestone. Very few limestone and fine dolomite pebbles also are present. This conglomerate rests directly upon very fine, sugary, silty and sandy dolomite of the Etherington Formation.

At The Gap a basal conglomerate forms the lower 1 foot of a poorly sorted sandstone. The fragments are mainly less than 1/4 inch long, and the largest pebble observed was 1 inch. They consist of grey-white and dark grey chert. The pebbles are angular to subrounded.

At Savanna Creek (6) the basal bed is a breccia, 1 foot thick, composed of highly angular chert and dolomite fragments (Plate IV A), which range from sand size up to 5 inches and are set in a matrix of dolomitic, fine-grained sandstone. This breccia rests with sharp contact on sandy, cherty dolomite of the Etherington Formation. It is sharply overlain by sandstones of the lower Rocky Mountain type (Plate IV B).

Additional evidence of the unconformable nature of the lower contact is provided by the angular truncation of Etherington strata in outcrop south of The Gap in Livingstone Range (Douglas 1950). Angular truncation of uppermost Etherington strata is also indicated in southern Livingstone Range (Figure 3) where one of two breccias occurs at variable distances below the Rocky Mountain sandstones.

The upper contact is in most sections readily located at a horizon above which are beds of siltstone, or silty and argillaceous sandstone, or sandstones of different texture and colour from those very fine- and fine-grained, grey quartz sandstones below. Evidence of erosion at the contact has nowhere been observed, however the overlying strata are of Triassic age in some localities and Jurassic in others, and the contact is therefore unconformable. Locally very thin remnants of Permian strata may be present but they can be identified only with additional very detailed study.

Age and Correlation

Fossils appear to be rare in the sandstones of the lower Rocky Mountain in Livingstone and Highwood Ranges, and only two collections were made. E. W. Bamber of the Geological Survey of Canada reported as follows on these collections:

GSC loc. 49357
55601 Headwaters of Daisy Creek, west side of Livingstone Range in deep gully 1/4 mile NE of Cal. Std. well site. From 1 foot bed immediately beneath four foot bed of black, nodular bedded chert which immediately overlies the Rocky Mountain sandstones.

Schizodus sp.

Age: late Paleozoic

GSC loc. 48300 Savanna Creek, about 3 miles above mouth, east edge of Beehive Map Area, 1/2 mile west of east boundary; 1/4 mile north of road, near crest of Plateau Mountain Anticline, on east flank.

Euphemites sp.
Schizodus sp.

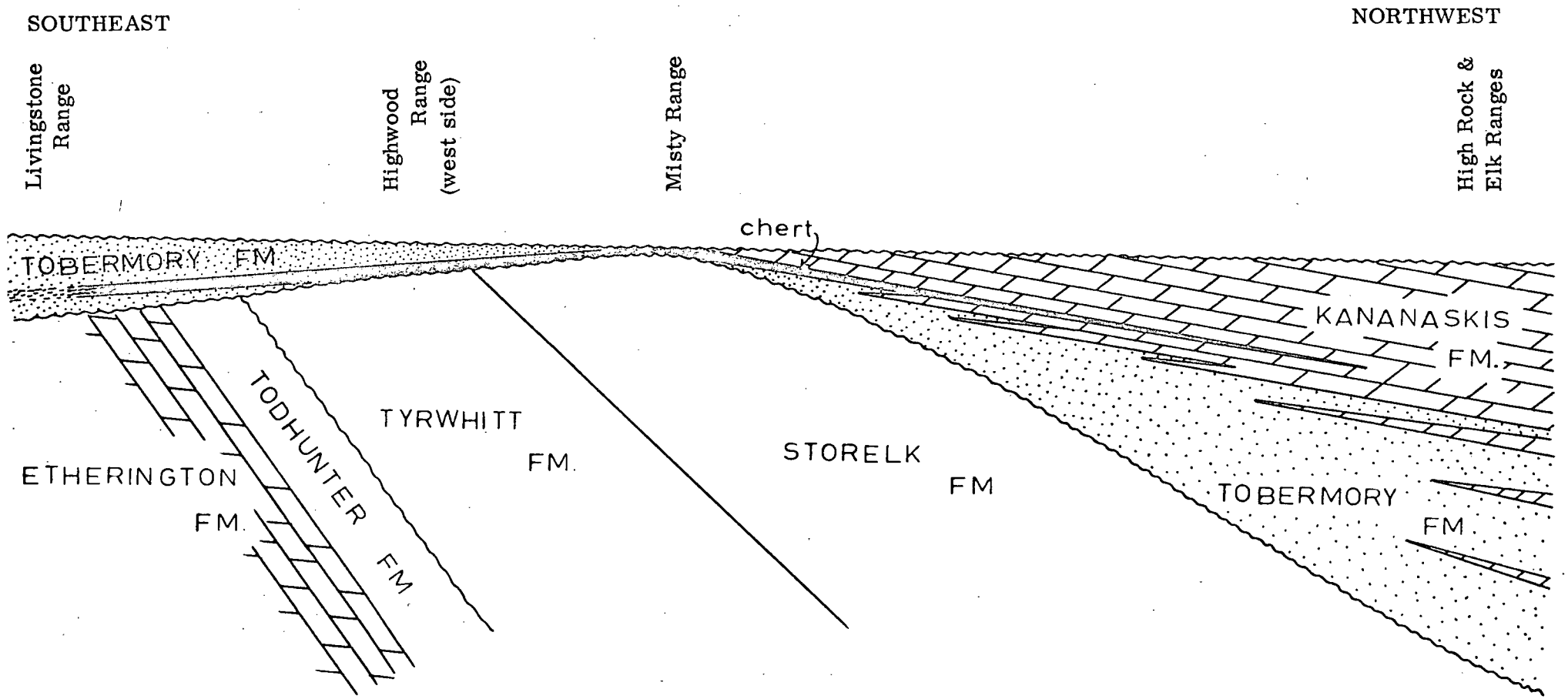
Age: *Euphemites* and *Schizodus* have a long range in the upper Paleozoic, but *Euphemites* is most common in the Pennsylvanian (Kananaskis Fm.) of the southern Canadian Rocky Mountains

The above fossils unfortunately do not provide concrete evidence for assigning a precise age to the Rocky Mountain sandstones, in part because the stratigraphic relationships of the beds from which these fossils came are uncertain, and in part because of their long stratigraphic range. They do however suggest that Middle Pennsylvanian strata may be present, but until fossils with a restricted stratigraphic range are found within the sandstones, criteria for establishing the age of these rocks must be based upon lithology and stratigraphic position.

The strongly unconformable relationship of the sandstones to the underlying late Mississippian (Chesterian) Etherington Formation suggests a post-Mississippian age. The lithology of the sandstones is very similar to the sandstones comprising the lower Rocky Mountain (Pennsylvanian) and unlike those forming the Permian Ishbel Group, suggesting therefore a Pennsylvanian age.

The abundance of quartz cement, grain size, sorting, and roundness of the sandstones in some sections suggests possible equivalence with the Storelk Formation. However, the abundance of carbonate cement in some sections and widespread dissemination of phosphorite sand grains, combined with a basal unconformity and local basal chert-phosphorite pebble conglomerate, suggests, together with the grain size, sorting and roundness parameters, lithologic equivalency with the Tobermory Formation. On the other hand, additional data seem to indicate that the sandstones are temporal equivalents of part or perhaps all of the Kananaskis Formation.

The sandstones in the Livingstone Range and eastern Highwood Range are geographically isolated from the Kananaskis Formation farther west, but are related to the Kananaskis by a bed of white novaculite or chert characterized by diverse stratigraphic relationships (Figure 3, 12). At Mount Elpoca (39)



Diagramatic vertical section illustrating the interpreted structural and stratigraphic relationships between the Middle Pennsylvanian Tobermory and Kananaskis Formations, and the Late Mississippian-Early Pennsylvanian strata in the Rocky Mountain Front Range and Foothills Sub-provinces. Not to scale.

Figure 12

at the north end of Misty Range, 6 feet of white spicular chert or novaculite containing abundant fine and medium quartz sand and fine to medium phosphorite sand in the upper foot, is underlain by a thin chert-phosphorite pebble conglomerate. This conglomerate rests on and locally grades into 3 feet of sandy dolomite, which in turn rests sharply on the Storelk Formation. Eastward at Lantern Creek (28) at the west side of Highwood Range this same bed of white, spicular chert rests unconformably with chert-phosphorite pebble conglomerate on the Tyrwhitt Formation (Figure 3, 12). Farther to the southeast a cherty zone within the Rocky Mountains sandstones which rest unconformably on the Etherington Formation, is probably correlative with the chert bed. In the opposite direction, to the northwest of Misty Range, a 7 foot bed of grey-mottled, white chert or novaculite is associated with sandy, cherty dolomite near Grizzly Creek in upper Kananaskis Valley. In this same general area two or three thinner beds of grey chert (one of which contains molds of a large pelecypod) were observed interbedded with Kananaskis dolomite. Along strike to the north (6 miles) near Rocky Creek bridge, McGugan and Rapson (1961, p. 79) reported a similar fossiliferous novaculite bed which they stated was apparently the equivalent of a similar bed at Lake Minnewanka that they referred to as the Plagioglypta novaculite. This novaculite is associated with dolomitic sandstones and cherty, sandy dolomites of the Kananaskis Formation at Lake Minnewanka. McGugan and Rapson (1961) concluded that the Plagioglypta novaculite was the condensed equivalent of the Kananaskis Formation which to the west attains a thickness of 180 feet. In view of the highly cherty nature of the Kananaskis, which contains several beds from 1 to 6 feet thick at Tunnel Mountain, and many 6 to 12 inch layers at Mount Storelk, its correlation with the Plagioglypta novaculite seems reasonable. Furthermore, fossils collected by McGugan and

Rapson (1961) from the Plagioglypta novaculite and the Kananaskis Formation indicate that both are of early Middle Pennsylvanian age.

On the basis of the above data it is concluded that the thin sequence of siliceous sandstones in Livingstone and Highwood Ranges that rest unconformably on Etherington through Tyrwhitt strata are Middle Pennsylvanian (Atokan) in age. It is further concluded that this thin sequence of less than 100 feet thickness represents the condensed equivalent of both the Tobermory and Kananaskis Formations which together total as much as 462 feet in thickness in some areas. It is suggested that the thin eastern sequence of sandstones be named Tobermory Formation, and that it be considered at least in part to be a facies equivalent of the Kananaskis Formation.

REGIONAL CORRELATION

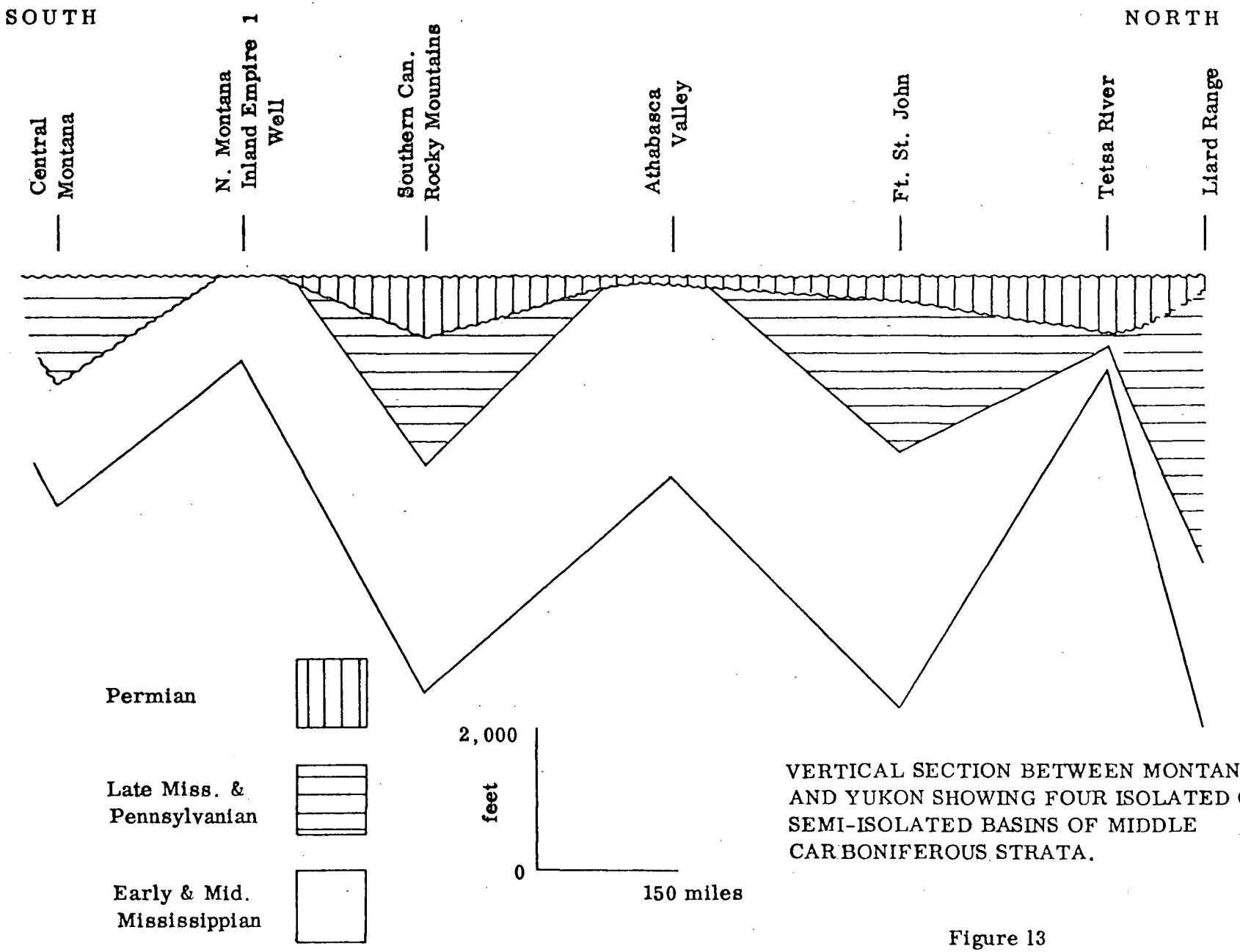
General Statement

Regional correlation of the mid-Carboniferous (Etherington, Todhunter, Tyrwhitt, Storelk, Tobermory, Kananaskis) formations is hindered because they occur as an isolated group of exposures in the southeastern Canadian Cordillera (Figure 13). They form one of four remnants of what might have originally been very widespread, laterally continuous marine strata. Several periods of erosion during the Pennsylvanian, Permian, Triassic and Jurassic have combined to remove completely the Upper Mississippian, Pennsylvanian, and, except locally, the Permian strata from the three intervening areas, and from most of the Interior Plains, producing not only erosional remnants but incomplete sections in these remnant areas. The greatest amount of erosion appears to have taken place during the Middle and Late Pennsylvanian and earliest Permian (Macauley et al, in preparation).

The stratigraphic succession and nomenclature in each of the four areas is shwon in Table VIII. Although the strata in each area are of similar ages, only gross correlations can be made at present because: 1) details of local correlation and stratigraphy have yet to be firmly established in all areas; 2) the precise age of individual formations in the two northern areas have not been established with certainty; and 3) few if any rock units persist from one area to another.

Correlation to Central Montana

In central Montana the Big Snowy Group (as revised by Gardner 1959) consists of a sequence of red, green and black shale, siltstone, sandstone, limestone, dolomite and minor amounts of evaporites. It consists of six formations which in ascending order are: Kibbey, Otter, Heath (lower part),



VERTICAL SECTION BETWEEN MONTANA AND YUKON SHOWING FOUR ISOLATED OR SEMI-ISOLATED BASINS OF MIDDLE CARBONIFEROUS STRATA.

Figure 13

TABLE VIII

Correlation Table of Late Mississippian and Pennsylvanian Formations

CENTRAL MONTANA		SOUTHERN CANADIAN ROCKY MOUNTAINS		PEACE RIVER AREA		LIARD RANGE
BIG SNOWY GROUP	Devils Pocket Fm.	LOWER ROCKY MOUNTAIN SUPERGROUP	Kananaskis Fm.	STODDART GROUP	Taylor Flat Fm.	Mattson Fm.
			Tobermory Fm.			
	Alaska Bench Fm.		Storelk Fm.			
	Cameron Creek Fm.		Tyrwhitt Fm.			
			Todhunter Fm.			
	Heath Fm.	RUNDLE GROUP	Etherington Fm.		Kiskatinaw Fm.	
	Otter Fm.					
	Kibbey Fm.				Golata Fm.	Flett Fm.

Cameron Creek, Alaska Bench (middle part), and Devils Pocket (upper part). The Big Snowy rests unconformably on Mississippian (Osage) strata of the Madison Group (Easton 1962) and is overlain unconformably by either Triassic or Jurassic strata.

The lower part of the Big Snowy Group is Chesterian in age as is the Etherington Formation, and the two are correlative except for their upper and lower contacts which are undoubtedly not of precisely the same age. The upper part of the Big Snowy Group is Atokan in age, as is the Kananaskis Formation and Tobermory Formation, thus establishing these lithostratigraphic units as essentially correlative.

The age of the middle Big Snowy is somewhat debatable because its fauna comprises an anomalous mixture of late Mississippian and Pennsylvanian forms that was interpreted by Easton (1962) as being very late Chesterian. Since the Todhunter, Tyrwhitt and Storelk Formations are dated as Early Pennsylvanian (Morrowan) there appears to be no correlation between these two divisions. However, these formations contain Neospirifer praenuntius Easton, Spirifer cf. shoshonensis, and Derbya sp. which also occur in the middle Big Snowy Group. It may later be shown that the fauna from the Todhunter and Tyrwhitt Formations are actually very late Mississippian rather than early Pennsylvanian. On the basis of similar position between formations of Chesterian and Atokan age, and in spite of the apparently dissimilar ages, the Todhunter, Tyrwhitt and Storelk Formations are tentatively correlated, at least in part, with the middle Big Snowy Group.

Correlation to the Northwest

To the northwest in the vicinity of Jasper, pre-Permian erosion apparently removed completely the Chester-Morrow-Atoka sequence that is present farther south. In the Jasper area Permian clastic sediments and

chert rest unconformably on dolomite believed to be equivalent to the Mount Head Formation (Mountjoy 1961). This absence of strata may be due in part to nondeposition. Other data suggest that some strata of Chesterian to Morrowan age may be present in this region (McGugan and Rapson 1961; 1963a).

Northward beyond Jasper, an erosional remnant in the subsurface of the Peace River region consists of a variety of marine strata of Chesterian to Pennsylvanian age referred to as the Stoddart Group (Rutgers 1958; Halbertsma 1959; Macauley et al in preparation; Irish 1963). The Stoddart Group (Table VIII) consists of three formations which in ascending order are: Golata (dominantly shale), Kiskatinaw (mainly sandstone with carbonate interbeds), and Taylor Flat (carbonate with interbedded sandstone). The Stoddart rests with apparent conformity on Mississippian (Meramecian) strata, however some authors (Halbertsma and Staplin 1960) have concluded that the contact is locally unconformable. Contacts between the formations within the Stoddart are considered to be gradational facies boundaries that appear to rise stratigraphically towards the west (Macauley et al, in preparation). The age of the Golata and lower Kiskatinaw, as indicated from plant spores and rare brachiopods, is Chesterian. Plant spores date the Taylor Flat as Pennsylvanian, probably Early Pennsylvanian since the lower contact is gradational (Halbertsma and Staplin 1960).

The Golata and Kiskatinaw Formations have been correlated with the Etherington Formation (Halbertsma and Staplin 1960; Macauley et al, in preparation), however until the age of the upper part of the Kiskatinaw and lower Taylor Flat is more firmly established, the precise relationship of the Kiskatinaw-Taylor Flat boundary to the Etherington-Todhunter boundary must remain indefinite. The Golata appears to be correlative with at least the shaly division in the lower part of the Daisy Creek Member of the

Etherington Formation, but the lower contact of the Golata and of the Etherington Formations are probably not of exactly the same age. The greater part of the Taylor Flat, if it is Early Pennsylvanian, is correlative with the Todhunter, Tyrwhitt and Storelk Formations, and perhaps with the Tobermory and Kananaskis Formations if the upper part extends into the Atokan as suggested by Halbertsma and Staplin (1960).

Farther northwest in the Liard Range area and isolated from the Stoddart Group is a thick succession of sandstones (3,700 feet or more) belonging to the Mattson Formation. The Mattson consists of three unamed sandstone members (Douglas and Norris 1959). The lower member is partly carbonaceous and contains minor shale and coaly beds that lie conformably on the early Chesterian Flett Formation. The lower member is Chesterian in age and is correlative with part of the lower shaly and sandy part of the Stoddart and upper part of the Etherington Formation. The middle and upper members have only been dated as Pennsylvanian and Permian at the top. These two members may be correlative with the Taylor Flat, and with the Todhunter through Kananaskis Formations. Limestone and dolomite interbeds in the upper member may represent tongues that originally extended northwestward from the Stoddart (Taylor Flat Formation). The Mississippian-Pennsylvanian boundary is believed to lie near the top of the lower member (Harker 1961; Hacquebard and Barss 1957).

Correlations to the West

Correlations from the present study area westward to the interior of British Columbia is made difficult by marked facies changes from miogeosynclinal to eugeosynclinal sequences, complex structures, metamorphism and igneous intrusion, large unconformities, and general paucity of readily

identifiable and useful Carboniferous fossils west of Rocky Mountain Trench. In south-central British Columbia strata referred to as the Mount Roberts Formation, Cache Creek Group and Milford Group all contain in part, fossils indicative of a Pennsylvanian age, which may make them approximately correlative with some of the lower Rocky Mountain formations. Some writers believe that these deposits may have originally covered the whole of the western Cordillera (Douglas 1963, p. 300) and that they were subsequently eroded from widespread areas. Farther west on the Pacific Coast no Mississippian rocks have been found, but Lower and Middle Pennsylvanian limestones are rather widespread, and are in part, time equivalents of the lower Rocky Mountain formations (Danner 1960; Geology and Economic Minerals of Canada 1963).

Northwestward,in east central British Columbia along the west side of Cariboo Mountains, Sutherland-Brown (1957) has studied the Guyet and Antler Formations which are Carboniferous in age, the former probably being Mississippian, and thus possibly correlative with the Etherington Formation. These formations are typical eugeosynclinal sequences and the source of the fine detritus in both formations is thought to lie to the southwest.

Regional Diachronism of the Sandstone-Carbonate Boundary

The boundary between carbonate rocks and interbedded finer clastic sediments, and the overlying quartz sandstones is diachronic and becomes older toward the north (Nelson and Rudy 1961; Nelson 1962). In the southernmost Canadian Rocky Mountains the boundary coincides essentially with the Mississippian-Pennsylvanian boundary. Farther north in Peace River and Liard regions it is early Chesterian.

GENESIS OF THE MID-CARBONIFEROUS FORMATIONS

The area under study is situated on or near the former eastern margin of the late Paleozoic Cordilleran miogeosyncline. To the east lay the broad, stable shelf of the continental interior, while to the west lay a tectonically unstable eugeosyncline which seems to have exerted little influence on sedimentation in the miogeosyncline during Carboniferous time.

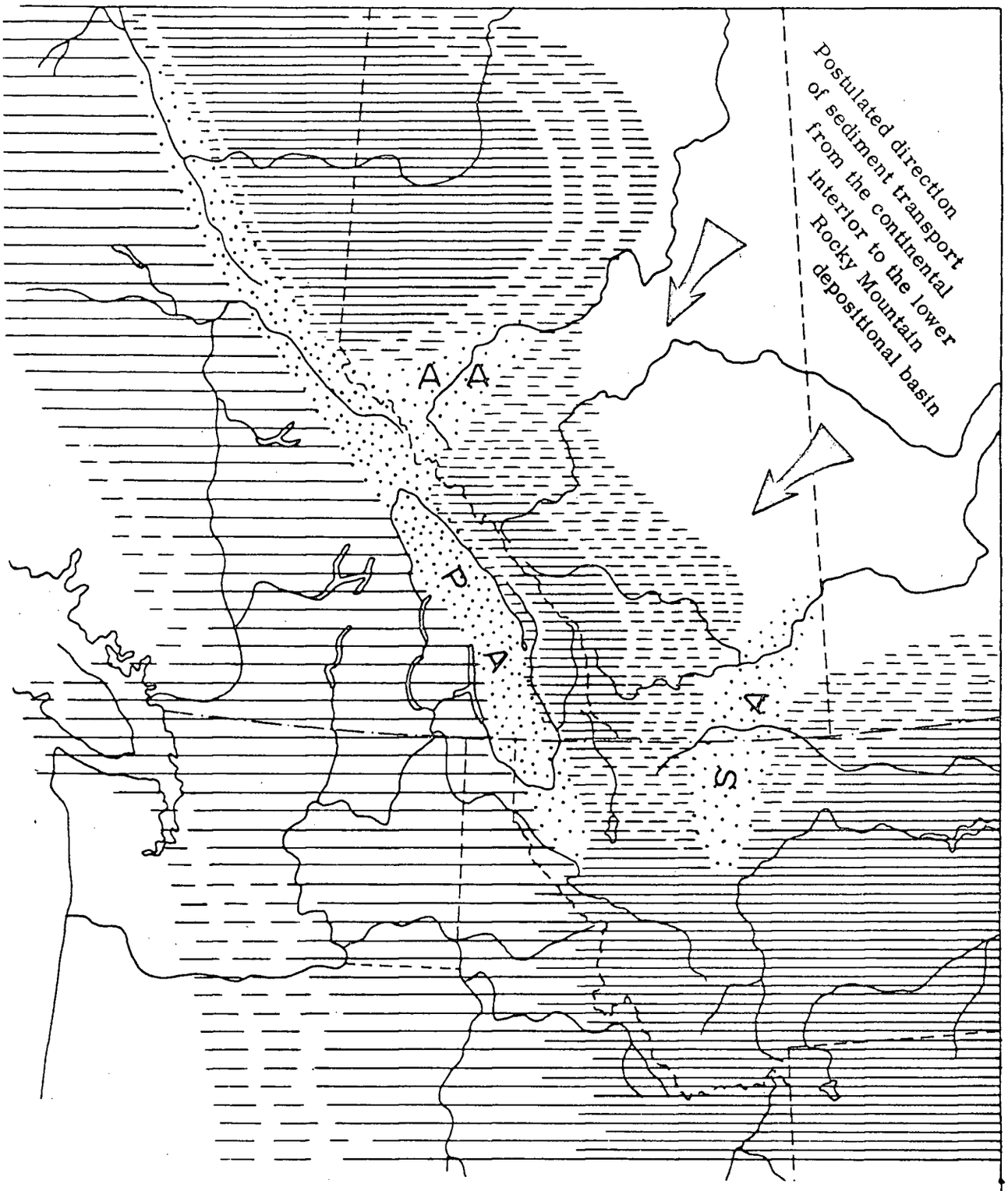
Provenance and Paleogeography

Identification of the source rock and area from which the clastic constituents of the lower Rocky Mountain (Pennsylvanian) sandstones and conglomerates were derived is difficult because of the high degree of mineralogical and textural maturity of the sands and gravels, and because post-Carboniferous erosion has left the Late Mississippian and Pennsylvanian deposits of this area as an isolated erosional remnant.

Two potential source areas exist: the central Cordillera to the west, and the Interior Plains and Canadian Shield to the east. In both regions there would have been a large potential supply of siliceous detritus, and certain parts of these regions were probably undergoing subaerial erosion during middle Carboniferous time. Within the lower Rocky Mountain strata no evidence points conclusively to either area as a source, however an eastern source area is favoured (Figure 14) for reasons discussed in the following pages.

Western Source Area

On the basis of evidence external to the sediments of the lower Rocky Mountain there at first seems ample justification for postulating a western source for the sediment. Within the central part of the Cordillera an orogeny involving uplift, igneous intrusion and intense metamorphism is



Eugeosyncline with local land areas

Postulated aerial extent of miogeosyncline, basin and shelf

Postulated low barrier ridges near sea-level

Palaeogeographic map of Early and early Middle Pennsylvanian time showing position of postulated Purcell Arch (PA) and its northwestward continuation, Sweetgrass Arch (SA), and Athabasca Arch (AA), which may have been low land or submarine ridges that delineated four depositional regions.

Figure 14

believed to have occurred in post-Cambrian and pre-Carboniferous time (Douglas 1963, pp. 297-99, 301; White 1959, pp. 66-70). Erosion of uplifted areas seems to have lasted in the interior until Carboniferous time, judging from the general absence of pre-Carboniferous strata above older Paleozoic and Precambrian igneous and metamorphic rocks in the southern interior of the Cordillera. Furthermore, during Carboniferous time, orogenic uplifts are known to have occurred in distant parts of the Cordillera. To the south in Nevada and Idaho the intense Antler Orogeny uplifted areas from early Mississippian intermittently through to Permian time (Roberts et al 1958), while far to the north in north-central British Columbia Middle Mississippian limestones truncate Lower Mississippian through Cambrian strata (Gabrielse and Wheeler 1961), indicating major uplift and erosion. In the latter region granitic rocks may have been emplaced during the Carboniferous, and farther west there is an angular unconformity beneath Permian strata (Gabrielse and Wheeler 1961). In view of these intense orogenic and erosional episodes within the Cordillera during late Paleozoic time, it seems possible that potential source rocks for the lower Rocky Mountain sediments were elevated and eroded during early and middle Pennsylvanian time.

In scattered parts of the southern Canadian Cordillerian interior however, the accumulation of eugeosynclinal rocks apparently occurred simultaneously with the deposition of the lower Rocky Mountain sediments, for sedimentary rocks referred to as the Mount Roberts Formation, Cache Creek Group and Milford Group all contain in part, fossils indicative of a Pennsylvanian age. Thus some regions were undergoing uplift, others subsidence. This is to be expected because of the very nature of the tectonic environment of the eugeosyncline. The presence of volcanic rocks, tuffs and lithic conglomerates in the above groups indicate that subaerial

conditions prevailed at least locally at times during the late Paleozoic within the southern Canadian Cordillera.

In spite of the above indications of uplift and erosion within the Cordillera during Carboniferous time, there is no evidence within the lower Rocky Mountain sediments that this region to the west contributed a major proportion of the sediment that accumulated in the miogeosyncline. The lower Rocky Mountain strata appear to lack igneous, metamorphic and volcanic rock fragments, and abundant feldspar and heavy mineral accessories, which would be expected to characterize these rocks if the adjacent eugeosynclinal rocks had served as the source of sediment. It therefore appears that sediment in any significant quantity was not transported eastward from within the Cordillera. It is postulated, as will be shown farther on, that a topographic barrier separated the eugeosyncline from the miogeosyncline and effectively isolated two adjacent depositional regions.

Eastern Source Area

The sediment comprising the lower Rocky Mountain sandstones is very mature, consisting mostly of very fine and fine quartz-chert sand, containing little feldspar and only traces of the most stable, highly rounded heavy mineral accessory grains. This is the kind of sediment that would be derived by prolonged erosion of low or peneplained areas, such as the continental interior, not from an orogenic uplift area.

The source rocks from which the sand and gravel of the lower Rocky Mountain were derived may have been in large part sedimentary. This is suggested by the high degree of roundness of the large quartz sand grains and accessory heavy mineral grains. The chert and phosphorite grains similarly indicate a sedimentary source. Unfortunately, the sand which comprises the bulk of the sandstones is very fine and fine sand grade, that

is angular to subangular, and thus provides no concrete evidence as to whether the source rock was sedimentary or igneous-metamorphic. The paucity of feldspar and abundance of chert in the sands suggests that the bulk of the grains could have been derived from the erosion of pre-existing sandstones. On the other hand, intensive chemical decomposition of crystalline rocks under humid climatic conditions in areas of low relief, such as may have prevailed over the present Canadian Shield area during Carboniferous time, could produce a residual sediment composed of only the most stable minerals. Thus part of the very fine and fine quartz sand could be first cycle.

Within the lower Rocky Mountain sandstones there is little conclusive evidence regarding the direction from which the clastic sediment came. It is therefore suggested, in the absence of concrete evidence to the contrary, that the bulk of the quartz and chert sand was introduced to the depositional area from the continental interior (Figure 14), either directly from the east and northeast, or from the north by longshore marine currents. A local source for the detrital phosphorite pebbles is suggested by their size, and a similar local source for the coarse chert sand, granules and pebbles is suggested by the angularity and size of many of these grains. This chert may have been derived, in part at least, through erosion of Mississippian strata (including the Etherington Formation) immediately to the east (Figure 12).

An eastern source for the lower Rocky Mountain sands seems, for the present at least, the more likely area in spite of the fact that the late Paleozoic geologic history of most of the Interior Plains and Canadian Shield must be based upon inference and speculation, since Upper Mississippian, Pennsylvanian and Permian strata are absent in this region. The

following lines of evidence combine to suggest however, that during middle and late Mississippian time and Pennsylvanian time, large parts of the present Interior Plains and Canadian Shield area may have been subjected to subaerial erosion: 1) The youngest Mississippian strata in the subsurface, the Charles Formation of Meramecian age, is a sequence of evaporitic sediments that cap the underlying regressive Mississippian carbonate succession (Edie 1958). The Etherington Formation of Chesterian age in the eastern Cordillera is a thin sequence of lagoonal sediments which, with the overlying lower Rocky Mountain sands, constitute a regressive sequence also. Thus, the Carboniferous rocks preserve a record of sea withdrawal, probably westwards toward the Cordilleran geosynclines and basins; 2) It was suggested by Porter in 1958 (p. 365) that Mississippian strata in Manitoba were exposed to subaerial erosion during middle Mississippian time as a consequence of sea withdrawal towards the southwest. At this time sands were apparently transported from the northeast; 3) Paleodrainage, consisting of deep (up to 400 feet), steep-sided river channels, was developed in middle Mississippian carbonate rocks in southwestern Saskatchewan prior to deposition of overlying Cretaceous sediments (Reasoner and Hunt 1958, pp. 398-99, 402). A similar drainage pattern could have been developed by southwestward flowing rivers in late Mississippian and Pennsylvanian time.

The Paleozoic rocks underlying the Interior Plains consist of limestone, dolomite, anhydrite and shale that contain only minor amounts of disseminated silt and sand. Originally some of these strata in the area of the present Shield may have passed into sandy mear-shore facies. Sandstone is rare or lacking in the Plains sequence of Paleozoic rocks, except for one widespread sandstone called the Coleville sand member of the Bakken Formation, which ranges up to as much as 60 feet thick in the southern Plains (Reasoner and

Hunt 1958, p. 395). Gross estimates of the total volume of sand in the lower Rocky Mountain prior to post-early Middle Pennsylvanian erosion, suggests that this quantity, if spread over the southern Canadian Interior Plains area, would form a layer only a few inches thick. In view of this, it is possible that disseminated sand grains from the eroded Paleozoic carbonate sediments underlying the Interior Plains, plus some of the sand eroded from the Coleville sand member, could have constituted the source of a large proportion of the lower Rocky Mountain sands. Whether the crystalline and clastic rocks of the Canadian Shield supplied any sediment is not known, but small areas could have been exposed to subaerial erosion during the Pennsylvanian. Much chert could have been eroded from the Paleozoic Plains carbonate rocks.

Paleogeography

The absence of igneous, metamorphic and volcanic rock fragments, and the paucity of feldspar and heavy minerals in the lower Rocky Mountain (Pennsylvanian) sandstones suggests that a physical barrier to the west prevented immature sediment, eroded from eugeosynclinal rocks, from reaching the miogeosyncline to the east. White in 1959 (p. 70-71) recognized the possibility of such a barrier existing in late Paleozoic time in the present position of the Purcell Range in southeastern British Columbia. The Purcell Range is now a northward-plunging geanticline (Reesor 1957, p. 150) which, with its northwestward continuation into northern Selkirk and eastern Cariboo Mountains, separates miogeosynclinal Carboniferous and Permian rocks in the southern half of the Canadian Rocky Mountains from widely scattered, essentially contemporaneous eugeosynclinal rocks in the southern Cordilleran interior. This geanticline is composed predominantly of Proterozoic with some Cambrian to Ordovician sedimentary rocks. Although it owes much of its

present structure and elevation to Laramide deformation, its position between eugeosynclinal and miogeosynclinal sediments, and the absence of younger strata above it, suggests that it might have stood as a very low topographic barrier or arch between the two depositional provinces during late Paleozoic time(Figure 14). A thin veneer of lower and middle Paleozoic carbonate sediments could have covered this barrier preventing erosion of the clastic rocks comprising the arch.

Southeastward along strike in Beaverhead Range (which straddles the Idaho-Montana border in northeastern Idaho), the Beaverhead Arch (composed of Proterozoic sediments blanketed by a thin sequence of Ordovician and Devonian sediments) is postulated by Scholten (1957, pp. 167, 169) to have been raised some time during Early to Middle Mississippian time (or shortly afterward). This arch formed an effective barrier for a short time between the eugeosyncline and miogeosyncline-shelf areas where different kinds of sediment accumulated simultaneously.

It is here postulated that the Beaverhead Arch and Purcell Arch were the southern parts of a long, narrow barrier ridge (Figure 14) that effectively separated the miogeosyncline from the eugeosyncline during parts of Carboniferous time. It is not surprising that a postulated structure of this size should lie near or adjacent to the Rocky Mountain Trench, itself a major structure probably with crustal roots.

The Purcell Arch during the Carboniferous was probably little more than a shallow sill or submarine ridge near sea-level, but at times of lowered sea-level it was possibly exposed. Thus, although there could have been a free communication of sea water between depositional areas to either side, it effectively prevented the transfer of sediment from west to east. Perhaps much of the silica found in the Carboniferous formations in the southern

Canadian Rocky Mountains was derived in solution from the eugeosyncline to the west. The total length of the Purcell Arch is unknown, but it may have served as a similar barrier between the sediments of the Stoddart Group in the Interior Plains and Carboniferous eugeosynclinal sediments in the Cordillera.

In the general vicinity of Jasper and upper Athabasca River valley, a branch or offshoot of the Purcell Arch might have extended to the northeast during late Mississippian and Pennsylvanian time (Figure 14). This Athabasca Arch, if it existed, would have been composed of Mississippian carbonate rocks, and like the Purcell Arch, would have been a low barrier near sea-level, at times just above and undergoing slight erosion, and at other times just below and receiving sediment. It is postulated that this low arch served to separate two structural and depositional basins, the Stoddart basin to the north, and the lower Rocky Mountain basin to the south (Figure 13).

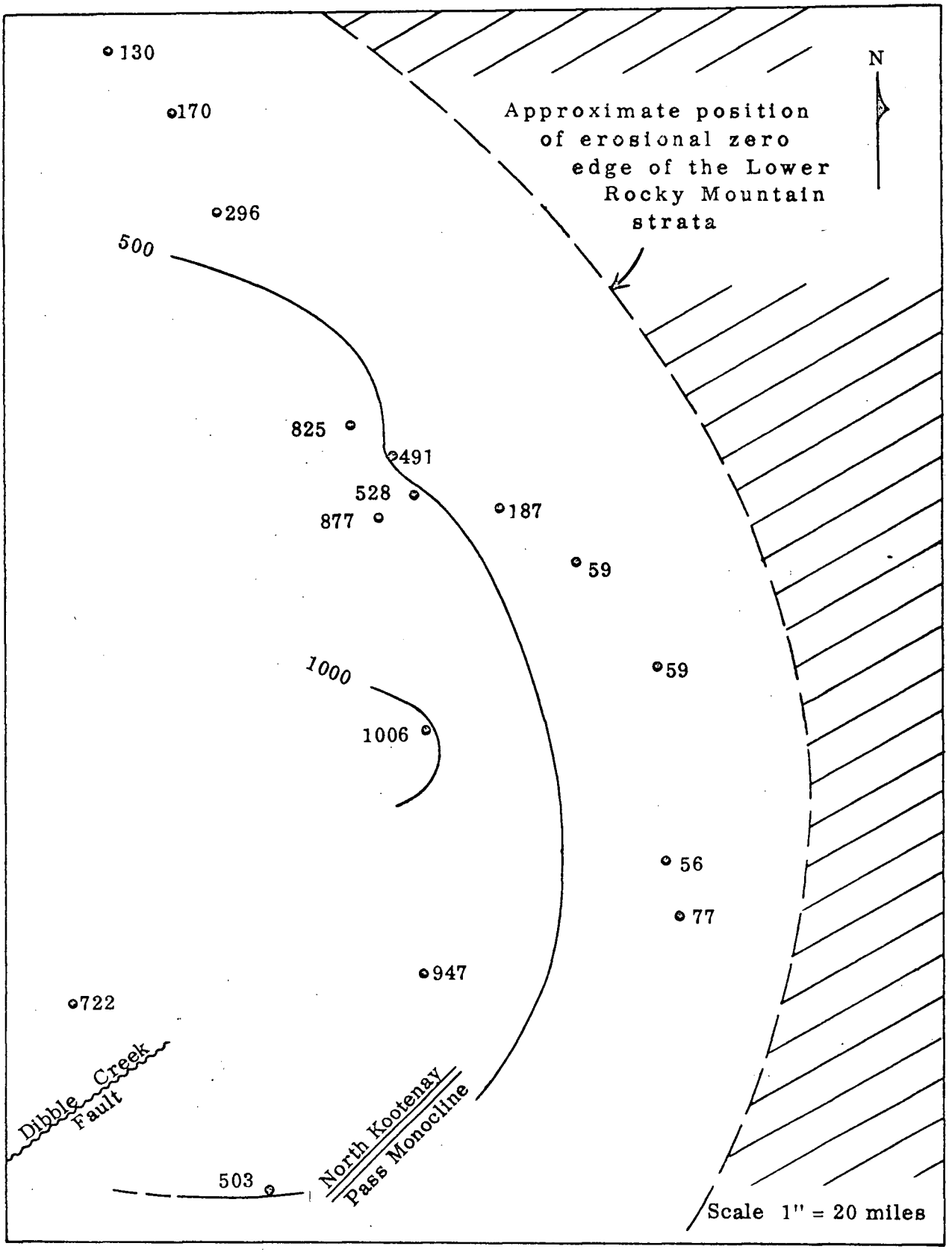
A third arch, the Sweetgrass Arch, may have served as a southern boundary for the lower Rocky Mountain Pennsylvanian basin (Figure 13, 14), separating it from late Mississippian and Pennsylvanian shelf and basin areas of central and eastern Montana. This arch is composite in form and complex in history (Tovell 1958), but like the Purcell Arch it could have formed a low, near sea-level or shallow submarine barrier. As noted by Wells (1957) the arch may have received only a little sediment during late Paleozoic time.

From Figure 14 it may be noted that the three postulated barrier archs discussed above are oriented in a northwest and northeast direction. It may be significant that these trends parallel the apparently fundamental structural fabric of western Canada (Haites 1960).

Lower Rocky Mountain Depositional Basin

The original extent of the lower Rocky Mountain strata and shape of the Pennsylvanian depositional basin cannot be accurately determined because the margin of these deposits in all directions is an erosional edge. It is postulated that the basin was elongated in a northwest direction, and was delineated by the Purcell Arch, the Athabasca Arch, the Sweetgrass Arch, and possibly by a stable platform in northwestern Montana between the southern Purcell Arch and Sweetgrass Arch (Figure 14). To the east the basin was probably bounded by a laterally migrating, impermanent coastal area that lay an unknown, but probably not a great distance east of the present erosional edge of the sediments. Within the study area, which represents the east-central part of the basin, isopachs drawn on a palinspastic base of the stratigraphic sections measured (Figure 15) reveal the general shape of this part of the basin, and the position of two fault structures which may have contributed to the downwarping of the basin during the Pennsylvanian. Perhaps these two subparallel, northeast-trending fault structures (the Dibble Creek Fault, Leech 1958, 1962; and the North Kootenay Pass Monocline, Price 1959, 1962) reflect the activity of some fundamental structural features which acted like steps along which relative downward movements towards the northwest during Carboniferous time contributed to the subsidence of the lower Rocky Mountain structural basin.

The Dibble Creek Fault has been interpreted by Leech (1958, p. 37; 1962, p. 397) as a structure near the northwest edge of a relative highland that existed south of the fault from Late Precambrian to Middle Devonian time. It is tempting to speculate that this old highland influenced deposition even as late as Pennsylvanian time. The following observations suggest the proximity of the Crowsnest Pass Pennsylvanian deposits to some sort of



Palinspastic-isopach map showing total thickness in feet of the Lower Rocky Mountain (Pennsylvanian) sandstone succession, general shape of the depositional basin, and position of two fault structures which may have contributed to the basin downwarping. See Figure 9 for section numbers.

Figure 15

marginal area to the south or southwest: 1) decrease in thickness of lower Rocky Mountain sandstones toward the southwest from about 1,000 feet in central High Rock Range to about 500 feet at Mount Broadwood (Figure 15); 2) the presence at Mount Broadwood of abundant medium and coarse sand in the Storelk Formation, and several chert-phosphorite pebble zones in the Tobermory Formation; 3) the abundance of phosphorite pebbles in the Tobermory Formation at Mount Hosmer; and 4) clear evidence of erosion on the top of the Storelk Formation at Mount Broadwood.

Although much of the above evidence is based upon interpretation and hypothesis, they combine to demonstrate that the area in which the lower Rocky Mountain sediments accumulated may have been a separate structural basin that was bounded on three sides by low topographic barriers, which, although preventing the transportation of sediment from the west, allowed a generally free communication of marine waters between the depositional areas to either side of the barriers.

Depositional History of the Lower Rocky Mountain and Upper Rundle Strata

General Statement

The terrigenous clastic sediments of the Permo-Pennsylvanian Rocky Mountain Supergroup represent the terminal deposits of an extended period of cyclic marine regressive sedimentation that began early in the Mississippian (Illing 1959a, 1959b; Drummond 1959; Middleton 1963). The early and middle Mississippian part of this major regressive sequence in Elbow Valley contains two cycles which apparently represent smaller regressive-type successions (Middleton 1963). Each cycle began with deposition of sediment in open marine environments (the water being probably more than 500 feet deep during earliest Mississippian time (Middleton 1963, p. 1826) and ended

with the deposition of sediment in a restricted-evaporitic environment. The Etherington, Todhunter, Tyrwhitt and Storelk Formations constitute a third regressive sequence in the upper part of the larger Permo-Carboniferous sequence, in which skeletal calcarenites that were deposited on an open marine shelf are overlain by dolomites of restricted-lagoonal environment which had previously been accumulating together with green and maroon shales in lagoons farther east. These grade upwards into very fine- and fine-grained, well stratified terrigenous shelf sandstones that are capped by a thick, coarsely cross-stratified, slightly coarser-grained sandstone of very shallow water origin. During this time the rate of sedimentation slightly exceeded the rate of subsidence. This third regressive trend or cycle ended with a brief period of differential warping and emergence at the end of Early Pennsylvanian time, with consequent erosional truncation of Lower Pennsylvanian and Upper Mississippian strata towards the east. Following this, during a relatively brief inundation and transgressive period of sedimentation, the Tobermory sandstones and Kananaskis dolomites were deposited west of a cuestal ridge of older Pennsylvanian sandstones, a ridge that was produced by the differential warping and erosion (Figure 12). East of this ridge a thin sequence of Middle Pennsylvanian sandstones were deposited.

During Chesterian and Pennsylvanian time the interaction among a variable rate of supply of terrigenous sediment and character of the sediment, and the variation in the rate and kind of subsidence along the eastern margin of the Cordilleran miogeosyncline, together with possible eustatic sea-level fluctuations, produced the external geometry and internal variations displayed by the Etherington Formation and lower Rocky Mountain Supergroup formations.

Etherington Formation

At the end of Meramecian time a brief period of extremely shallow water or emergent conditions prevailed in the area as suggested by the presence of local limestone or claystone conglomerate beds at the base of the Etherington Formation, the abruptness of the contact between the Etherington and Mount Head Formations, and the possible truncation of Mount Head strata towards the east (Douglas 1958, p. 59). Low ridges and shallow depressions (of depositional and possibly erosional origin) may have existed in the area during this interval. It is postulated that a long, low, narrow cuestal ridge of Mount Head (Carnarvon) limestone, subparallel to and near the eastern margin of the present Front Ranges existed at this time (Figure 3). Upon re-flooding of the coastal area, this ridge appears to have separated a very shallow, near-shore trough or lagoon to the east from a very broad shelf to the west. Gradual subsidence of the entire region, but at a greater rate west of the ridge resulted in the eventual accumulation of more than twice the thickness of carbonate sediments on the shelf than in the trough-lagoon area.

The initial deposits in the restricted trough or lagoon were green- and maroon-coloured clay, and calcareous sediments that were penecontemporaneously dolomitized. The initial deposits on the shelf were skeletal sands and muds. The trough was soon filled with sediment, thereby eliminating the barrier. It is probable however, that almost immediately, barrier bars composed of skeletal sand developed parallel to the former limestone ridge and thus continued to maintain the restricted or semi-restricted, evaporitic-lagoon environment to the east. During the remainder of Chesterian time these bars gradually migrated westward (perhaps in response to falling sea-level) but the lagoons east of them persisted. Water in the lagoons remain-

ed very shallow because of the slow rate of subsidence, and at certain times evaporites were deposited. This regional pattern of an eastern restricted-evaporitic environment passing westward into an open marine shelf environment exactly parallels that prevailing during most of the earlier part of the Mississippian period farther east (Illing 1959a; Middleton 1963). West of the barriers a normal marine shelf and bank environment persisted, upon which echinoderms, bryozoa, brachiopods and corals grew, locally in great profusion.

On the open marine shelf thick deposits of skeletal sands, oolites, and calcareous muds accumulated (identical to those comprising older Mississippian strata in this region) contemporaneously with the accumulation of shales and dolomites in the lagoons. The shelf sequence of strata exhibits much internal complexity because of the former existence of many microenvironments which were due largely to local variations in water depth, water turbulence, and proximity to shore and near-shore terrigenous clastic sediments. Several lithofacies belts appear to have paralleled the eastern margin of the shelf. These lithofacies belts were composed of oolites, pseudoolites, cleanly washed skeletal sands, fine calcareous muds, and mixtures of these. Banks, shoals, and depressions on the shelf probably produced microenvironments which were characterized by the deposition of carbonate sediments ranging from the finest mud to the coarsest sand. Small quantities of terrigenous clay were periodically mixed with some of the finer muds, and at times floods of fine and very fine terrigenous quartz sand blanketed the calcareous sediment. Numerous fluctuations in sea-level caused many minor lateral migrations of these microenvironments and microfacies. The migrations may have been cyclic in character since there is a cyclic pattern to the strata in the lagoonal succession (Douglas 1958).

Throughout Chesterian time variable amounts of terrigenous sand were introduced into the lagoon and shelf environments, but near the end of the epoch the proportion of terrigenous sand deposited was increased. These clastic sediments diluted the autochthonous carbonate sediments, and the amount deposited at times was so great that beds of sand from 1 to 25 feet thick periodically blanketed the lagoon and shelf sediments. Eventually deposition of allochthonous quartzose sediment dominated, then completely replaced the autochthonous carbonate sediment, initiating the post-Mississippian period of clastic sedimentation.

Lower Rocky Mountain Supergroup

The lower Rocky Mountain sediments were deposited in a structural basin, the size and shape of which were discussed under Paleogeography (see also Figures 13, 14, 15). During most of Early and early Middle Pennsylvanian time the basin of deposition was kept nearly filled with sediment, and the whole area probably consisted of a wide shelf, perhaps sloping gently southwestward, submerged beneath a shallow fluctuating sea, and with little relief save that produced by local barrier bars. Towards the east the shelf may have merged almost imperceptibly into a low, peneplained region of the continental interior.

Deposition of the Pennsylvanian sediments began with the accumulation of sands and silts now comprising the lower Todhunter Formation, over a nearly featureless platform composed of Etherington carbonate sediments. The very fine to fine sands locally may have formed cross-bedded barrier bars that isolated quiet, parallic lagoons to the east, in which clayey silts accumulated (Figure 3). Deposition of sand and minor amounts of silt continued, but two brief interrutions are recorded by the presence of tongues of dolomite and limestone in the middle Todhunter. These beds were formed by

the deposition of skeletal sands and muds when the supply of terrigenous sediment was temporarily reduced, and they represent a repetition of the environmental conditions that prevailed during Chesterian time. These alternations in environment, which began in late Chesterian time and persisted into early Morrowan time, serve to illustrate the transitional nature of the change from carbonate to terrigenous clastic sedimentation. Minor amounts of maroon-coloured clay in some beds attest to the very shallow waters that, at least periodically, covered the shelf. The tongues of calcareous sediment may originally have coalesced with the upper Etherington carbonate sediments farther west. The calcareous sediment of the tongues was later extensively dolomitized, except in the more westerly areas, and this replacement may have resulted from the process known as seepage reflux-ion (Adams and Rhodes 1960). The source of the magnesium may have been in brines concentrated in evaporitic pans that could have formed behind barrier bars to the east of present exposures. The calcareous sands and muds of the Spirifer tongues must have been unstable and readily susceptible to alteration because of the following properties: large surface area of fragmented skeletons and fine muds; instability of the organogenic calcite; and a relatively high content of magnesium in the echinoderm fragments. Dolomitization of only the uppermost part of the limestones of the Spirifer tongues in some areas suggests the replacing solutions seeped downwards. The apparent zonation of the tongues probably resulted from dolomitization of calcareous sediment of variable grain size which was related to the environment of deposition. Other significant factors such as degree of compaction, porosity and permeability, organic catalysts (including bacteria which exert a control over the pH and Eh), and concentration of the brine solutions may have played an important role in the dolomitization process.

After deposition of the Spirifer tongues differential sedimentation, perhaps reflecting differential subsidence, resulted in a slightly greater thickness of sediment accumulating in the central part of the basin (54 feet of upper Todhunter beds) than along the basin margins (Figure 8). During infilling of this shallow depression, sand and silt by-passed the more shallow water in the basin flank areas, and locally lag deposits consisting of finely fragmented Orbiculoidea shells and rounded granules and pebbles of detrital phosphorite accumulated in the sands of the marginal area. The basal Tyrwhitt sands in Kananaskis and Flathead Ranges were deposited directly over this conglomeratic material. In these areas the Tyrwhitt-Todhunter contact appears to be unconformable, but it is interpreted as a diastem rather than as an erosional unconformity. Elsewhere Tyrwhitt sands were deposited on similar Todhunter sands and the contact is obscure.

A new influx of very fine and fine quartzose sand blanketed the shelf and truncated the Todhunter strata (Figure 8) initiating deposition of the Tyrwhitt Formations sediments. During this time conditions were favourable for the growth and preservation of productoid brachiopods over a large part of the shelf in the southern part of the area. Deposition of terrigenous sediment was now firmly established, and several belts characterized by sediment of progressive decrease in grain size outward from shore appear to have formed. The presence of these facies belts depended upon the availibility of sediment of various grades which may not always have been present. Nearest to the shore, in the zone of highest turbulence, grains of medium and coarse sand were concentrated and mixed with the finer sand grades. Farther offshore in a belt that probably covered most of the shelf the sediment consisted predominantly of very fine and fine sand. Beyond this zone there existed at certain times a belt of unknown width characterized

by extremely weak currents over which very thin layers of green, silty clay up to 1 foot thick were periodically spread. These three depositional environments shifted laterally in response to fluctuations in sea-level, and the lithofacies associated with them now succeed one another vertically, comprising a sequence of beds up to 350 feet thick. The finer sands predominate in this sequence because the belt in which they were deposited was the widest, and grains of this grade were most abundant. Some of the shale beds, and some siltstones present in this sequence, could have been deposited in lagoons or depressions on the shelf. Sea-level fluctuations may have been eustatic in nature, or may have been partly the result of variable rates of supply of sediment or rate of subsidence. Probably these three factors operated together in a complex fashion.

Periodically, environmental conditions which favoured the growth of marine organisms prevailed over the shelf. The skeletal remains of these organisms accumulated in lenticular beds from 1 to 17 feet thick. Some of the beds may have been shell coquinas whereas others may have been skeletal (echinoderm) calcarenites. Much of this skeletal material may have accumulated near shore as a littoral or sub-littoral lithofacies. At one time over a large part of the shelf very large numbers of the inatriculate brachiopod Orbiculoidea lived either in this environment or near it, and their shells are associated with one of the carbonate beds which serves as a useful key bed. Subsequent alteration of the calcareous beds, perhaps through seepage refluxion, converted the calcite to dolomite.

After deposition of Tyrwhitt sediments the entire area appears to have changed to an environment characterized by very shallow water, high energy, and many fluctuations in current strength, due largely to a drop of sea-level, perhaps accompanied by a decrease in the rate of subsidence.

In addition, the character of the sediment introduced changed, becoming slightly coarser grained. This might have been due to a change in the character of the source area, or to the westward migration of a belt of coastal sand dunes that could have existed east of the basin during late Mississippian and earlier Pennsylvanian time. Barrier bars, submarine dunes and perhaps even aeolian dunes locally may have been common. The great variability of current and wave strength allowed fine to coarse sand to be constantly shifted about and mixed in all proportions. Because of the fluctuating nature of the currents, these sands now exhibit much internal lamination produced by alternating zones of various grade sizes and sorting. The bars and dunes probably were internally cross-stratified. The high degree of roundness of most of the Storelk sand grains was probably largely inherited from previous cycles, but undoubtedly it was increased during this last cycle.

Following deposition and lithification of the Storelk sands a brief period of differential warping, emergence and erosional truncation of the Early Pennsylvanian sandstones and Etherington carbonates occurred. The erosional truncation appears to have been concentrated east of a line trending to the northwest through Misty Range (Figure 12). The superior resistance to erosion of the Storelk sandstones may have produced a long, narrow, cuestal ridge along the strike of exposures in Misty Range. Erosion of the sandstones forming this ridge appears to have been slight. The inferior resistance to erosion of the eastern dolomite-shale facies of the Etherington allowed these strata to be eroded to a shallow depression, and east of present exposures the Etherington Formation could have been completely removed at this time. When subsidence resumed and the area was inundated, initiating a period of Middle Pennsylvanian transgressive sedimentation, the

Storelk ridge and the area to the east may have remained at or just above sea-level. West of the ridge a broad shelf similar to that existing during deposition of the Tyrwhitt Formation was re-established.

The initial deposits of the transgressing sea were locally chert, phosphorite, and some sandstone sand and gravel that was mixed with sand or calcareous skeletal material to form a conglomeratic or sandy coquina. Subsequently the coquina was dolomitized. Sand of very fine to coarse grade was introduced onto the shelf, and currents winnowed out the finer grades, shifting them shelfward, leaving the coarser grades in the more turbulent coastal zone, similar to that prevailing during earlier Pennsylvanian time. Periodic fluctuations in sea-level, perhaps combined with variations in the rate and character of the sediment supplied, with consequent lateral migration of microenvironments, resulted in the superposition of different lithofacies and the eventual formation of a sequence of sandstones with contrasting grain size, sorting and texture in different beds. Periods of shoaling or influx of coarser sand are indicated by the presence of medium to poorly sorted sandstones and by laminae of medium and coarse sand. The occurrence of several zones of pelecypod coquina further suggests periods of shallow water, near-shore conditions, as does the local abundance of fine cross-stratification.

The interbedded dolomite strata in the Tobermory that are similar to those forming the Kananaskis Formation, together with the similar ages of these two units, suggests that while Tobermory sands were accumulating, carbonate sediment of the Kananaskis was being deposited simultaneously farther west. During brief periods of diminished terrigenous sand supply, the environment existing farther west may have migrated into the more easterly parts of the shelf, resulting in the formation of thin dolomite

beds containing variable amounts of sand. The highly dolomitic character of the Tobermory in some areas further suggests that an area of carbonate sedimentation existed not far to the west.

The gradual decrease in thickness of the Tobermory Formation from 333 feet in the south to only a few feet in the north may be the result of a combination of onlap along the basal unconformity, reduction in the amount of sand deposited in the north, and intertonguing with the Kananaskis dolomites. The bulk of the Tobermory sediments was deposited in Elk-High Rock-Flathead Range area, and it is suggested that the Mount Ptolemy area was near one of the localities where particularly large amounts of sediment were introduced. The decrease in thickness by 200 feet to the southwest between Mount Ptolemy and Mount Broadwood may reflect the same relationships.

After the Tobermory sediments had accumulated to their present thickness in eastern parts of the shelf, a slight diminution in the quantity of sand introduced into the area may have then allowed the environment in which carbonate sediments had been accumulating farther west to transgress eastward and be deposited above the Tobermory sands. A simple rise of sea-level does not seem to have been the main cause of this transgression because the Kananaskis sediments appear to have been deposited in water as shallow as or even shallower than those of the Tobermory. Simultaneously with this decrease in the amount of quartz sand introduced, chert sand and fine gravel was transported to the area in greater amounts, probably from a local source lying either to the east or west.

The cuestal ridge of Storelk sandstone that was elevated prior to deposition of the Tobermory sands may have persisted throughout most of the early Middle Pennsylvanian, and the dolomites of the Kananaskis appear to have formed only west of this ridge (Figure 12). On the central part of this

ridge several feet of white chert, which possibly represent a silicified carbonate, are all that accumulated while up to 180 feet of dolomite were deposited to the west. Perhaps this bed of chert is the time equivalent of part of the Tobermory Formation also. If younger beds were deposited above the chert they were subsequently eroded. To the east of the Storelk ridge a thin sequence of sandstones was deposited during early Middle Pennsylvanian time. These sandstones appear to be correlative with at least part of the Kananaskis dolomites, but perhaps also with part of the Tobermory sandstones.

The environment in which the Kananaskis sediments accumulated is difficult to interpret, but the great abundance of quartz and chert sand and gravel, bedded and nodular secondary chert, and very dense structureless dolomite is probably the result of complex processes. The very dense texture of the dolomite, the unusual dessication-type chert breccias, and abundance of replacement chert lend rather strong support to a hypothesis of penecontemporaneous dolomitization of fine calcareous mud in a restricted lagoonal environment in which evaporitic conditions may have prevailed (McGugan and Rapson 1961; Rapson 1962). On the other hand, environmental conditions at times must have been favourable for the growth of marine organisms since fusulinids, brachiopods, pelecypods and bryozoa are found in certain beds, and thin sections reveal abundant ghost-like remnants of skeletal limestone textures in some beds. Perhaps broad mud flats, where fine textured lime muds were precipitated from highly saline, very shallow, warm waters, existed over the area. Fluctuations in sea-level may have periodically resulted in flooding of the mud flats and lagoons by normal sea water, during which time marine organisms inhabited a normal marine shelf environment. Concentration of magnesium and silica may have occurred through evaporation on the mud flats. Penecontemporaneous replacement of

the sediment by dolomite and silica (or by seepage refluxion) would be the natural outcome of these processes in this environment. Penecontemporaneous dessication and fragmentation of chert may have provided the source of the chert fragments in the dolomite (McGugan and Rapson 1961; Rapson 1962). Possibly some of the chert sand and gravel was derived through erosion of older Mississippian cherty carbonate sediments to the east. The absence of Kananaskis dolomite in more westerly areas (McGugan and Rapson 1962, p. 359), including Mount Hosmer area, suggests the possibility that a land area existed in the area presently occupied by the Main Ranges or Western Ranges of the Rocky Mountains, and perhaps the Purcell Arch was exposed to erosion at this time. Chert is abundant in the carbonate rocks of older Paleozoic formations in Stanford Range (Henderson 1954), and this general area may have contributed sediment to the eastern trough. The sand in the microcrystalline dolomite, either as even disseminations or as thin laminae, may have been blown onto the mud flats by wind. It seems unlikely that strong marine currents introduced all of the terrigenous clastic sediment because these same currents would have winnowed out the fine mud, unless the primary lime sediment was a clastic and had a texture similar to that of the terrigenous clastic grains.

Post-Depositional History

After deposition of the Middle Pennsylvanian (Atokan) Kananaskis sediments, a very large part of the Cordillera and adjacent Plains region appears to have been uplifted and subjected to intensive subaerial erosion since younger Middle and Upper Pennsylvanian strata are absent over a large area, and Permian strata rest with locally marked unconformity on older strata (McGugan and Rapson 1961, 1963a; Macauley et al, in preparation). Differential warping at this time may have accentuated the basinal nature

of the depositional areas of the Big Snowy, lower Rocky Mountain, Stoddart, and Mattson sediments, and allowed them to be preserved while thin sequences of sediment between these areas were completely or almost completely removed (Figure 13). Towards the east this pre-Permian unconformity merges with Permian, Triassic, Jurassic and Cretaceous unconformities which all combine to superimpose Cretaceous deposits on Lower Paleozoic strata in the eastern part of the Interior Plains. Towards the west these and younger periods of erosion have removed all of the Upper Paleozoic and younger strata from the Main and Western Ranges of the Rocky Mountains, so that the middle Carboniferous formations in the Front Ranges and Foothills are erosional remnants.

ECONOMIC GEOLOGY

Silica Sand

The strata of the lower Rocky Mountain Supergroup are not utilized at present, but the highly siliceous composition of the sandstones makes them a large potential source of silica.

Silica is presently used in the manufacture and processing of a wide variety of products of which the more important are: glass and fiberglass, ferrosilicon alloys, metallurgical flux, roofing material, cement and concrete products, silica brick, carborundum, molds for steel castings, furnace linings, fused silica for chemical laboratories, sand paper, abrasives, powdered silica for pottery and paint, fillers, water glass, and filters. Only a few industries using silica are now located in Alberta, but the presence of large and accessible sources of relatively pure silica could easily attract many of them if the economic conditions were suitable.

Many of the sandstones comprising the lower Rocky Mountain fall within the range of specifications required for pure silica sands. Probably all of the sand consists of over 95% silica (the minimum allowable) and much undoubtedly consists of 98% to 99% silica. The maximum allowable amounts of iron oxide (1%, and 0.02% for glass), alumina (4%) and titanium are probably not exceeded in the majority of beds. Unfortunately a high percentage of calcium and magnesium occurs in many of the sandstones in the form of dolomite cement, and the maximum allowable is only 0.5%. However, virtually all of the dolomite could be extracted with the use of hydrochloric acid, although this might be a costly procedure.

The grain size of silica sand for glass must be uniform and fall between coarse and fine sand grades, and half should lie within the medium sand

grade. For silicon carbide, coarse sand is best. It would appear that some of the sandstones in the Storelk Formation are the only ones which meet these size requirements. However, these sands are tightly bonded by quartz, and individual grains cannot be liberated. Crushing of these sedimentary quartzites could produce grains of any desired size. The remainder of the Pennsylvanian sandstones are predominantly very fine- to fine-grained, and although they fall below the general size required for most glass sand, their uniformity of size grade and purity after extraction of the carbonate cement should make them of value for certain silica products.

The total thickness of the sandstones in accessible areas ranges up to as much as 900 feet, and represents one of the largest presently exploitable source of relatively pure silica in the province.

Petroleum and Natural Gas

The lower Rocky Mountain strata extend westward for many miles beneath the Lewis Thrust, where their greatest potential is probably as a cap rock above the carbonate sediments of the Etherington Formation. Interparticle porosity and permeability is lacking in these sandstones because of the tight cementation, except locally in some of the sands cemented by calcite that is commonly leached out in outcrop. Many of the beds at Mount Hosmer are calcareous, and some are nearly unconsolidated sand because the calcite cement has been dissolved. Fracture porosity and permeability could be significant where these brittle strata are folded or faulted.

The beds comprising the Spirifer tongues near the base of the sandstone succession, and the dolomite lentils in the Tyrwhitt Formation, where altered to calcareous, granular, highly porous dolomite, or dense vuggy dolomite, may be suitable reservoir rocks but they are relatively thin.

Beneath the Livingstone Thrust and in the Eastern Foothills a thin sequence of sandstones (which outcrop in Livingstone and Highwood Ranges) named the Tobermory Formation, truncate crystalline dolomites of the eastern dolomite-shale facies of the Etherington Formation and small structural traps might be present beneath this unconformity.

On the whole the lower Rocky Mountain strata probably represent a poor prospect as reservoir rock for petroleum and natural gas.

Building Stone

The grey-white colour of many of the sandstones, and their resistance to erosion, might make them useful for building exteriors. However, fracturing in most beds may preclude their use as building stone if large blocks are required. Small blocks of brick-size could be readily produced.

SUMMARY AND CONCLUSIONS

1. This study involved the stratigraphic analysis of the late Mississippian (Etherington) and Pennsylvanian (lower Rocky Mountain Supergroup) formations in the southern Canadian Rocky Mountain Front Ranges and Foothills Sub-provinces between Panther River and Crowsnest Pass area. The information contained in this thesis deals mainly with the Pennsylvanian rocks.

2. It is recommended that the name Rocky Mountain be retained and raised to the rank of Supergroup. It is further recommended that the name Tunnel Mountain Formation either be abandoned or raised to the rank of Group and to consist of sandstone only. It is suggested that the Todhunter Member be raised to the rank of formation and constitute the basal division of the Rocky Mountain Supergroup.

3. Three new formations above the Todhunter are recognized in the lower Rocky Mountain, and in ascending order they are Tyrwhitt, Storelk and Tobermory. The type section of these formations is on Mount Storelk in Elk Mountains. The Todhunter, Tyrwhitt, and Storelk formations are Early Pennsylvanian (Morrowan) in age, and the Tobermory is Middle Pennsylvanian (Atokan) in age.

4. The Pennsylvanian strata in the lower Rocky Mountain consist predominantly of very fine- to fine-grained, well sorted, quartz-chert sandstones in which medium and coarse sand grains occur mainly as accessory grains, forming poorly sorted sandstones, and in some parts forming beds of medium-grained sandstone. Feldspar amounts to only a few percent, and traces of heavy mineral accessory grains include highly rounded zircon, tourmaline, rutile, and magnetite. Additional accessory grains are detrital, brown-black phosphorite and varicoloured chert of sand to fine pebble grade, and rarely of coarse pebble grade. Thin sandy dolomite interbeds are characteristic

and these typically contain the only fossils, which are predominantly silicified brachiopods. This clastic sequence is capped by a dense, sandy, cherty dolomite formation, the Kananaskis.

5. The Todhunter Formation rests conformably and locally with gradational contact on the Etherington Formation of Late Mississippian (Chesterian) age. The Tobermory unconformably lies on progressively older strata towards the east, where it may originally have truncated the Etherington Formation. The Tobermory is conformably overlain with locally gradational contact by the Kananaskis Formation of Middle Pennsylvanian (Atokan) age. Towards the west the Tobermory may grade into carbonate rocks of the Kananaskis Formation.

6. The late Mississippian and Pennsylvanian strata were probably deposited on a wide marginal shelf and in-near shore lagoons in a structural basin or embayment on the eastern side of the Cordilleran miogeosyncline. During most of this time the depositional site was probably a nearly flat, very wide shelf, submerged beneath shallow, fluctuating seas, the eastern shoreline of which probably lay not too far east of present exposures. During Chesterian time intensive dolomitization of calcareous sediments occurred along the eastern margin of the basin.

7. It is postulated the basin was bounded on three sides by low barriers called the Sweetgrass Arch, the Purcell Arch and the Athabasca Arch. These barriers have northwest and northeast trends which parallel the fundamental structural fabric of western Canada, and their intersection produced an elongate basin with a northwesterly trending axis.

8. The Etherington, Todhunter, Tyrwhitt and Storelk Formations are interpreted as a succession of marine strata deposited during a major regressive period of sedimentation. The Tobermory and Kananaskis Formations are

interpreted as marine deposits that accumulated in a transgressing sea.

9. At the end of Early Pennsylvanian time gentle warping, emergence and erosional truncation of Lower Pennsylvanian and Upper Mississippian strata towards the east produced a low ridge of Storelk sandstone along the strike of Misty Range. West of this ridge up to 460 feet of Tobermory and Kananaskis sediments accumulated while a thin sequence of sandstones less than 100 feet thick accumulated east of the ridge.

10. Etherington and lower Rocky Mountain (Pennsylvanian) strata accumulated to a maximum thickness of about 1,800 feet in the central part of the basin centred in the Flathead-High Rock-Elk-Kananaskis Range area while as little as 350 feet accumulated along the margin to the east. These strata now represent an erosional remnant because of post-depositional erosion.

11. The lower Rocky Mountain strata are believed to be approximately correlative with the middle and upper Big Snowy Group in central Montana, with part of the Stoddart Group in Peace River area, and with most of the middle and upper members of the Mattson Formation in the Liard Range area.

12. The quartz sand comprising the lower Rocky Mountain sandstones may have been derived through erosion of Paleozoic carbonate rocks (and possibly of exposed Shield rocks) in the Interior Plains. Chert sand and pebbles were probably derived from a local source, lying either to the east or west. Detrital phosphorite sand and pebbles were probably derived from a western source.

13. The highly siliceous quartz-chert sandstones of the lower Rocky Mountain constitute a large potential source of relatively pure silica that is readily accessible and reasonably close to an industrial centre (Calgary), which has a large supply of petroleum and natural gas, hydroelectric power, water and lime.

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APPENDIX

GLOSSARY

Stratigraphic Terminology and Classification:

The American Code of Stratigraphic Nomenclature is taken as the authority for all stratigraphic nomenclature and classification.

Sandstone Classification:

A wide range of composition in the Carboniferous sandstones does not occur, consequently the sandstone terminology is simple. Sandstones composed of 90% or more quartz and chert are termed quartz sandstone or pure quartz sandstone, despite the fact that up to one-third of the siliceous fraction may be chert. With greater thin section control, lithic (chert) sandstones and quartz sandstones may be recognized. The term orthoquartzite or quartzite has not been used although many of the sandstones are cemented with quartz and fit the definition of a sedimentary quartzite.

Grain Size:

The Wentworth Grade Scale is here used in describing the grain or crystal size of all rocks whether they consist of terrigenous clastic grains, clastic skeletal grains, or crystals chemically formed by precipitation or replacement. This useage provides a maximum of uniformity in terminology.

	WENTWORTH GRADE SIZES Clastic Grains	THIS THESIS Crystal Size
	pebble	-
4 mm.	granule	-
2 mm.	very coarse sand	very coarse crystalline
1 mm.	coarse sand	coarse crystalline
.5 mm.	medium sand	medium crystalline
.25 mm.	fine sand	fine crystalline
.125 mm.	very fine sand	very fine crystalline
.062 mm.	silt	microcrystalline
.004 mm.	clay	

Colour:

A standard rock colour chart has not been used in describing the colours of the rocks studied. Rather, six basic colours or shades have been used, white, grey, black, tan, brown, pink, which when modified with the terms light, medium, and dark, and combined with hyphens in various ways, the complete spectrum of colours observed has been described.

Stratification:

The essentials of the classification and terminology suggested by McKee and Weir (1953) has been followed in this study.

Texture:

Two fundamental textures of sedimentary rocks are clastic and crystalline. Clastic textured rocks consist of grains derived from the disintegration or disaggregation of some pre-existing solid material. A crystalline texture is produced when a mineral is secreted, precipitated, recrystallized or replaced.

Roundness:

The following degrees of roundness recognized by Pettijohn (1957) are here employed:

angular - subangular - subrounded - rounded - well rounded

Sorting:

The degree of sorting of the clastic rocks has been estimated visually with a binocular microscope fitted with a graduated ocular, and has been classified as well sorted, medium sorted, or poorly sorted.

SECTION 11

Location: This section is located on the east side of Mount Broadwood 14½ miles S. 20° E. of Fernie, B. C., between Elk River and Lodgepole Creek. The section outcrops 2 miles E. 20° N. from the peak of Mount Broadwood, and 0.6 miles due north from the junction of Bean Creek with Lodgepole Creek. The Rocky Mountain and Etherington strata are part of an overturned slice that dips steeply to the west. The section lies immediately north and above a good road which leads south from Morrissey Station. In spite of the apparently poor exposure a fairly complete section can be measured in the several small stream gullies. The white band that is conspicuous from the road is the Storelk Formation.

Bed		Thickness	Height Above Base

Overlying beds belong to the Kananaskis Formation which consists of grey, very fine to microcrystalline, highly sandy, massive, light grey to very light grey weathering dolomite. The lower contact is sharp and apparently conformable. Total thickness is 90 feet.

ROCKY MOUNTAIN SUPERGROUP

Tobermory Formation

23 Sandstone, dolomitic, quartzitic; cherty; light grey; very fine-grained; well sorted; dolomite cement is fine, discrete crystals; quartz cement as overgrowths; much chert as thin, long, continuous layers up to 2 inches thick and lenticular nodules that preserve laminae and are not well rounded; weathered surfaces finely etched to discontinuous paper-thin streaks of quartz cement, some reach ½ inch wide; three feet from top is a 3 inch thick zone of medium to poorly sorted sand consisting of fine to medium quartz with a thinner zone of very coarse sand, granules and very fine pebbles of several types of chert, chert pebbles subangular but remainder of fragments well rounded; seven feet from top is a 3-4 inch thick zone of chert sand, granules and pebbles up to ½ inch in size which are quite numerous and concentrated in a thin zone which consists of fine- through coarsely-crystalline, light grey dolomite with fine vuggy solution porosity, quartz occurs only in sand grades, chert in all grades, rounding of fragments tends to decrease with increasing size to subangular in pebbles, several types of chert present; below this lower zone is a lenticular 1-2 foot thick layer of completely silicified pelecypod coquina, white, and containing a few scattered chert

	pebbles and some well rounded coarse chert sand and granules; upper contact sharp, conformable; massive; dark brownish-grey weathering, chert grey-white; hard; resistant; a distinctive unit	22	503
24	Sandstone, dolomitic, quartzitic; very light grey; very fine-grained with some fine grains; well sorted; dolomite cement with quartz overgrowths; fourteen feet from top is a thin zone of light grey, very finely crystalline dolomite with scattered coarse, well rounded quartz and chert sand, and much finely comminuted fossil material replaced by granular quartz; basal 3 feet is light grey, fine to very finely crystalline, slightly sugary dolomite the lowermost 2 feet being rather porous with very fine cavities and much intergranular porosity, upper foot contains several thin layers of silicified coquina; lower 2 feet also contains fairly numerous fine to coarse well rounded quartz sand and coarse sand to granule size chert that is less well rounded together with some silicified coquina fragments; massive; light grey weathering but dark from lichen; very hard; resistant	25	481
25	Dolomite, medium grey; very finely crystalline, sucrosic; even textured; moderate amount of intergranular porosity; at bawe is a 4 inch layer of white chert; scattered chert fragments; light brown weathering; mostly poorly exposed	5	456
26	Sandstone, dolomitic; highly silty; very light grey; very fine-grained; a few thick white silica-cemented nodules; massive; dark brown and greyish weathering; hard; resistant	3	451
27	Dolomite, sandy; medium-light grey; fine-medium crystalline; even textured; disseminated but not abundant medium to coarse well rounded quartz, and less well rounded chert sand; faint etched laminae define cross-stratification; six inches from top is a thin zone, sandy and silty in part, with coarse well rounded quartz and some chert grains, and scattered bluish to white weathering, black, sandy detrital phosphorite grains of coarse sand to granule size, and a few ¼ inch chert pebbles; massive; medium brownish-grey weathering; hard; resistant	3	448
28	Siltstone, highly dolomitic; cherty; light grey; partly sandy; uneven texture; numerous small to tiny patches of light weathering silty dolomite; in all but uppermost 5 feet are numerous tiny to large, very irregularly shaped, non-rounded, white chert masses that have replaced the dolomite and are filled with silt; massive; brown and grey weathering; hard; resistant; lower part not well exposed	17	445
29	Covered	3	428

30 Sandstone, highly dolomitic; light grey; very fine-grained; even textured; well sorted; massive; medium brown and brownish-grey weathering; hard; resistant 12 425

31 Covered 7 413

32 Dolomite, sandy; light grey; very finely crystalline; highly porous and vuggy in most parts due to solution of undolomitized fossil fragments; some small molds of the brachiopod Orbiculoidea, and a few small deeply leached shell fragments; highly sandy, most is fine and medium, well rounded quartz, some coarse, evenly disseminated throughout; basal 2 feet consist of very fine-grained, well sorted, light grey, quartzitic sandstone with very thin laminae of recessed dolomitic sand; 2 feet from base is a thin zone of scattered black, highly silty and sandy chert pebbles up to 3/8 inch, well rounded, and a few pebbles of similar size composed of chert-cemented or quartzitic, fine-grained sandstone, also rounded; massive; light grey and brownish weathering; hard; resistant; A short distance laterally the upper surface of the Storelk Formation is highly irregular, knobby and pitted, and filling depressions up to 1 foot is very finely crystalline, light brown dolomite that is extremely sandy and conglomeratic; the maximum size of contained pebbles is 3/4 inch; sand grains range from very abundant very fine quartz through medium to very coarse, the latter being highly rounded; pebbles range from some subangular to mostly highly rounded; the very fine sand grains are angular and unevenly distributed, some zones being sandy dolomite, others highly dolomitic sandstone; porcellaneous to chalky white, well rounded chert grains occur in the medium to very coarse sand grades, as do phorphorite grains which range up to granules and pebbles which are black to dark brown, very sandy, highly rounded and polished; one granule of very coarsely crystalline dolomite was observed.

Total Thickness of Tobermory Formation 107

Storelk Formation

33 Sandstone, mostly quartzitic, becoming dolomitic downwards near base; grey-white to tan; very fine to coarse; upper surface pitted, channeled, very e irregular; two feet below top are a few dark purplish, quartz-cemented nodules from 1-2 inches thick, rounded, full of white, porcellaneous medium to coarse chert grains; uppermost few feet seem to be deeply weathering and not tightly cemented, and upper 10 feet are iron-stained and outcrop possesses a weathered rind; upper 10 feet mostly poorly sorted, fine- to medium-grained with numerous highly rounded coarse quartz and some chert grains; upper half of the formation consists of fine- to medium-grained sandstone with fairly numerous coarse sand grains, and

the lower half consists of very fine and fine sand with few or no medium or coarse sand grains.

Upper 10 feet poorly sorted, very fine to medium with many coarse grains; at 20 and 30 feet from top very fine to fine, well sorted; 30 to 37 feet fine, medium, coarse sand, poorly sorted; 37-42 feet covered; 42 to 48 feet fine-grained; 48-49 feet averages medium-grained, some coarse sand, medium sorting; 51, 56, 65 feet fine- and very fine-grained, well sorted to moderately well to medium sorted. from 70 to 107 feet fine and medium grains predominate, with fairly numerous coarse grains either scattered or in very thin zones, sorting in individual specimens medium to poor.

Lower half tends to become finer grained towards the base and near the base somewhat dolomitic; at 110 feet from top very fine-grained, well sorted, dolomitic sandstone in a thin zone; at 125 feet similar to upper half, fine-grained with some medium and a few coarse grains, medium sorting; at 130 feet is a thin zone of very fine, slightly dolomitic, well sorted sandstone; at 138 to 145 feet fine-grained, and at 138 feet are medium grains and medium sorting; at 155, 160 and 163-66 feet is very fine to fine sand, well sorted, with some medium grains in upper three feet; at 173, 180 and 189 feet is very fine-grained, well sorted sandstone; specimen from 173 feet dolomitic; lowermost 60 feet is very fine- to fine-grained, well sorted, and the lowermost 25 feet is somewhat dolomitic;

	The Storelk is very massive; light grey and pinkish weathering throughout; very hard; slope-forming	200	396
	Total Thickness of Storelk Formation	200	

Tyrwhitt Formation

34	Dolomite, highly silty; light brown-tan; even textured; parts are siltstone with several percent of fine muscovite grains; a few very tiny shell fragments of Orbiculoidea ; top 3-6 inches is a layer of white chert; some small deeply weathering pyrite nodules; massive; medium brown weathering to rusty; poorly exposed; upper contact not clearly defined	1	196
35	Covered	1	195
36	Dolomite, very light brown; fine to medium crystalline; even textured; a few disseminated silicified crinoid columnals; a few silicified brachiopod fragments and some chert masses; massive; medium greyish weathering; slightly pink; moderately hard	3	194

37	Sandstone, dolomitic, quartzitic; light tan-grey; very fine-grained, almost a siltstone; very even textured; well sorted; numerous etched ribs of quartzitic sand; finely cross-laminated; very conspicuous irregular platy parting; rusty brown weathering; etched ribs weather light grey; hard	6	191
38	Sandstone, dolomitic, quartzitic; very light grey; very fine-grained; well sorted; fairly thick, rusty-reddish weathered rind; massive; light pinkish and light grey weathering; hard; resistant	4	185
39	Dolomite, exceedingly sandy and silty; light grey; very finely crystalline; silt and very fine sand unevenly distributed, occurring in brown weathering, partly quartz cemented, very irregular, fucoidal-like, burrowing structures which are etched to high relief; remainder of sand fairly evenly disseminated, constituting about half the rock; thickly bedded; medium brown to slightly pink weathering; hard; resistant	4	181
40	Covered	2	177
41	Dolomite, very sandy; light grey; lower half very finely crystalline, even, with very abundant fairly evenly disseminated silt and very fine sand; upper half fine crystalline, rather evenly disseminated very fine sand and an extreme number of fragmented, silicified brachiopods: GSC loc. 49387, 48916, Spirifer occiduus, Composita sp.; massive; light pink to light tan weathering; hard; resistant	2	175
42	Sandstone, dolomitic, quartzitic; light grey-tan; very fine-grained; well sorted; alternating smooth-weathering, mainly quartzitic zones with thicker, rough, fucoid-like zones which are dolomitic; thickly bedded; mostly brown weathering; quartzitic zones pinkish and light grey; hard; resistant	12	173
43	Covered	3	161
44	Sandstone, quartzitic; slightly dolomitic; light grey, deeply stained to pink; very fine; well sorted; small amount of dolomite cement; very thickly bedded; light grey and pink weathering; hard; resistant	11	158
45	Covered	5	147
46	Sandstone, quartzitic, slightly dolomitic; very light grey to deep pink stained; very fine-grained; well sorted; massive with 1-3 inch parting; light grey and pink weathering; hard; resistant	8	142

47	Covered	6	134
49	Sandstone, quartzitic, partly dolomitic; light grey, stained pink in part; very fine-grained; well sorted; thick bedded; light grey, rusty red to reddish-brown weathering; poorly exposed	6	128
50	Covered; from the base of this zone many productoid brachiopods were collected from highly dolomitic sandstone GSC loc. 55591, 49368 Antiquatonia cf. portlockiana var. crassicostata, Antiquatonia cf. hermosana.	28	122
	Total Thickness of Tyrwhitt Formation	102	

Todhunter Formation

Middle Part

51	Dolomite, light grey; medium crystalline; even textured; a few thin zones are highly porous, finely vuggy; weathered surface granular; in middle is a thick layer of silicified coquina, containing highly fragmented remains of many bryozoa, shells, fairly numerous ooliths?, rare ostracods, and some large columnals, all cemented with quartz; massive; medium to light brown weathering; fairly hard; resistant	2	94
52	Coquina, completely silicified; cemented with quartz; only bryozoan fronds are identifiable; most is finely comminuted; light grey; massive; hard; resistant	3	92
53	Dolomite, light tan; medium crystalline; even textured; very high percentage of intercrystalline porosity and some very fine vuggy porosity; very fine cross-lamination in parts up to very coarse sets several feet long; upper few feet contain very fine silicified fossil debris; massive; medium grey to very light tan weathering; very massive; moderately hard; resistant	13	89
54	Dolomite, light grey; dense; even textured; similar to underlying dense dolomite; poorly exposed; light grey weathering	7	76
55	Dolomite, highly sandy; very light grey; very finely crystalline to dense; very abundant very fine to fine sand evenly disseminated throughout; rare coarse quartz grains; massive; light tan weathering; very hard; resistant	3	69
56	Dolomite, non-sandy; light grey; dense; very even textured; a few small lenticular, rounded chert nodules, a few inches up to 7 inches long, most rusty-reddish weathering, internally preserve an original clastic, skeletal, echinoderm limestone texture; one foot from top is a thin zone of scattered, silicified spirifer		

	brachiopod fragments and echinoderm columnals together with many unidentifiable skeletal fragments; massive; very light grey weathering; very hard; resistant	8	66
57	Dolomite, very light grey; finely crystalline; somewhat sugary; scattered silicified crinoid columnals; massive; very light grey, slightly pinkish weathering; hard; resistant	8	58
	Lower Part		
58	Covered; probably sandstone and siltstone	50	50
	Total Thickness of Todhunter Formation	94	

The underlying Ewin Creek Member of the Etherington Formation consists of dense, sandy, cherty, very light grey weathering dolomite and fine to medium crystalline, tight to porous sucroisic dolomite.

SECTION 12

Location: This section is located at the head of Daisy Creek on the west side of Livingstone Range, about 7 1/4 miles south of The Gap, near the southern boundary of the Gap Map-Area. The section outcrops 1 mile N. 12° E. of the well site which is located on Daisy Creek near the northern edge of the Blairmore Map-Area.

Bed		Thickness	Height Above Base
	Overlying beds consist of calcitic, dolomitic, and quartzitic sandstone, with some grey chert. These strata outcrop in a narrow gully that cuts a conspicuous notch in a very large, talus and grass-covered dip-slope.		
74	Chert, black, even textured; composed of lenticular nodules up to about 1 foot long; unevenly bedded; nodular throughout; between the nodules are some small masses of dark brownish-black, very fine, phosphatic limestone with an equal volume of medium to coarse, light tan, subhedral to euhedral dolomite crystals; fairly numerous masses of very coarsely crystalline, white calcite; hard; brittle; resistant	4	
73	Sandstone, cherty; dark grey; fine- and medium-grained, some coarse grains; largely chert cemented; great quantity of light tan, coarse, subhedral to euhedral dolomite crystals scattered throughout; slightly phosphatic; extremely numerous scattered silicified fossils replaced by coarse granular quartz; some fossils partly hollow and filled with calcite, GSC loc. 49357, 55601 <u>Schizodus</u> sp. massive; medium brownish-grey weathering; hard	1	
	ROCKY MOUNTAIN SUPERGROUP		
	Tobermory Formation		
72	Sandstone, highly calcitic; light grey, slightly tan; fine- to medium-grained; medium sorting; a few coarse, highly rounded quartz grains; calcite is fine- to medium-crystalline, much tends to a fine lustre mottling; many tan to white, soft, chalky, fine to very fine chert grains; fine and medium grains well rounded; between 5 and 10 feet from the base are many clots and masses of very coarsely crystalline, white calcite from less than 1 inch long up to thin layers about 1 inch thick, that contain varying amounts of sand; a few calcite masses above 10 feet; very massive; blocky fracture; light brown weathering; extremely hard; highly resistant; forms a conspicuous vertical cliff	21	56

71	Limestone, white; very conspicuously banded throughout; consists of white, very coarsely crystalline, even textured calcite with alternating light to dark brown to dark grey, finely crystalline calcite bands that contain scattered light brown, fine dolomite euhedra; the white layers are 1-5 mm. wide, the darker layers less than 1 mm. up to 5 mm. wide, most are 2-3 mm.; the darker layers are discontinuous, en echelon. lenticular, up to several inches long; bands parallel the stratification; both contacts of bed very sharp; undulates and thickness varies considerably from about 1 to 3 feet; at the base is a fairly continuous zone of sandstone thickening locally to 3 feet; locally at the top is a similar sandstone up to 1 foot thick; these sandstones are calcitic, medium grey and tan, mostly fine-grained with some rounded medium and a few coarse quartz grains, but mostly fairly well sorted; in addition these sandstones contain fairly numerous discontinuous masses of irregular shape from tiny blebs to large masses of coarsely crystalline, sandy calcite; upper and lower contacts irregular and undulatory; massive; sandstones weater light brown, the limestone light grey to white; hard; resistant	4-5	35
70	Sandstone, dolomitic, calcitic; light yellowish-tan; mostly fine-grained, some medium grains, few coarse; poorly sorted; many very light tan, soft, very fine chalky dolomite cemented areas together with finely crystalline calcite; contains several long, lenticular layers from 6 to about 15 feet long, and up to 2-3 inches thick of white, coarse to very coarsely crystalline calcite, most are gently convex upwards, and are en echelon; at the base is a lenticular layer of white calcite up to 1 foot thick; this unit is almost completely truncated within a distance of 70 feet by unit #71 which lies directly upon the basal limestone layer; massive; unweathered cliff-exposure; irregular fracture; hard; resistant; somewhat recessive within cliff sequence	3	30
69	Sandstone, dolomitic, calcitic; light tan; very fine to coarse grains, but larger grains are few to fairly numerous; poorly sorted; coarser grains are quartz and chert; grains well rounded; scattered fine to coarse crystals of clear calcite, abundant in some zones, occurring as small clusters; very irregular bedding-plane fracture from ½ to several inches thick; light brown weathering; hard; resistant, slope-forming relative to overlying bed	9	27

68 Sandstone, dolomitic; light grey; very fine- to medium-grained; fairly numerous coarse grains; poorly sorted; some chert grains; even textured; numerous small pyrite nodules up to 1/4 inch; massive; medium brown-grey weathering; very hard; resistant 2 18

67 Sandstone, calcitic; quartzitic; light grey, salt and pepper; mostly fine- and medium-grained; fairly numerous coarse, highly rounded quartz grains; poorly sorted; calcite is finely crystalline; upper foot light tan, somewhat softer, and poorly sorted, cemented with soft, extremely fine sugary dolomite; very distinct irregular fracture oblique to stratification, from 1 to several inches thick; massive; top has irregular platy fracture; medium grey weathering; hard; resistant; top recessive; gradational downwards 4 16

66 Sandstone, calcitic; light brown through light grey; very fine- through coarse-grained, but mostly fine and medium; poorly sorted, but some zones are moderately well sorted; almost all grains are well rounded; lustre mottling is very common; some parts, particularly the lower part contain a very light yellowish-brown, extremely fine, sugary, soft cement; there are a few granules and fine pebbles scattered throughout, and the lower 4 feet consist of a chert pebble conglomerate and conglomeratic sandstone in which pebbles range to fine grades, but rare fragments are 4 inches long; basal contact unconformable on dolomite; upper 3 feet of sandstone contain scattered small pyrite nodules less than 1/4 inch; upper 1-2 feet contain many small, white silica cauliflower-like masses 1/16 to 1 inch; irregular fracture 1 inch to 1 foot; medium grey weathering; hard; resistant.

Fragments in basal conglomerate range from granule size to about 1 inch average maximum, but a few are several inches long; sorting is poor, and there is a high proportion of poorly sorted fine to coarse sand matrix; fragments are predominantly subangular to rounded, but range from angular to well rounded; fragments are almost entirely chert, the surface texture of the rounded chert is finely pitted and far from smooth in detail; colours range from dark through very light grey; they are texturall cryptocrystalline, even textured, and many contain a little to aboundant very fine sand or silt; a few are organic and partly spicular, and a few represent completely silicified, skeletal, echinodermal calcarenite, one of which is 4 inches long; also very rare finely crystalline, even textured, medium grey, fine, rounded limestone pebbles, and a few fine, light tan, well rounded dolomite pebbles; chert grains range down into sand grades; quartz sand ranges up only to very coarse sand;

Within the conglomeratic zone are masses of extremely

coarsely crystalline white calcite that range from clusters of a few enhedral to subhedral grains of fine sand size up to 1/4 inch, through to small masses several inches long with no particular shape, to discontinuous layers and patches reaching 1 foot or more in length and up to several inches thick, some are pure calcite and some contain varying amounts of sand, granules and pebbles; there are all gradations from finely crystalline, highly sandy limestone to exceedingly coarsely crystalline, non-sandy calcite; boundaries of these calcite masses are gradational to very sharp.

The basal contact is variable and in outcrop the actual contact is very difficult to pick accurately;where perfectly exposed the contact is very tightly welded; hand specimens from the contact reveal that at most places poorly sorted sandstone rests directly on light tan, extremely fine sugary, soft, very silty to finely sandy dolomite, the surface of contact being welded and made conspicuous by hair-line, undulating, smooth seams coated with iron oxides; the basal 1 inch is in some places irregularly flaky to platy, rather soft sandy that contains scattered granules and fine pebbles, some of this sand could be a residual concentrate out of the underlying sandy dolomite;locally in outcrop are what appear to be large limestone pebbles at the base which may be remnant masses of what could have been a bed of limestone, medium grey, very finely crystalline, even textured, with abundant very fine quartz sand evenly disseminated, medium grey weathering, top surface is highly irregular, uneven, with some tiny fissures filled with sand. 12 12

Total Thickness of Tobermory Formation 56

Contact unconformable

RUNDLE GROUP

Etherington Formation

65 Dolomite, extremely sandy; medium grey; extremely finely crystalline, slightly sugary; uneven textured; sand grains from very fine to fine are irregularly distributed throughout; bed ranges from a slightly sandy dolomite to dolomitic sandstone; some parts are half sand; some fairly even textured sandstone present; much is dolomite with very conspicuous medium brown weathering rounded patches and elongated cylindrical masses up to 3/4 inch long and up to 1/4 inch in diameter composed of very fine-grained quartzitic and dolomitic sandstone that are etched to conspicuous relief, probably from burrowing organisms; at one point there is a 1 foot layer 1 foot from the base about 25 feet long, lenticular, composed of

very coarsely crystalline white calcite and at the top is a second similar, shorter, lenticular layer; the uppermost 1-3 inches is light brown to very light tan, very finely crystalline, sugary dolomite containing very fine sand; top 1 inch rather soft and chalky, finely vuggy in part, leached; top is irregularly platy and fairly soft; massive, thick parting; light grey weathering; hard; outcrops above a vertical, massive cliff of sandstone 6

64 Sandstone, dolomitic, calcitic; light grey; lowermost part medium grey, calcitic, lustre mottled, very fine- and fine-grained with a few medium grains, medium sorted, medium grey weathering, massive; remainder quartzitic and dolomitic; very fine-grained, some fine grains; fairly well sorted; even textured; extremely massive; light brown weathering; highly resistant; vertical cliff, e very conspicuous 10

Underlain by about 20 feet of partly covered, medium to dark grey weathering, partly ledge-forming limestone breccia and bedded limestone.

SECTION 18

Location: This section is located on the west side of High Rock Range in British Columbia about 2 1/2 miles south of Mount Lyall, and 2 miles southwest of Beehive Mountain. The section outcrops on a northeast trending spur on the north side of the large east-trending ridge extending off High Rock Range between the north and south forks of Ewin Creek, a tributary to the Fording River. The section may be reached via a good pack trail leading over Beehive Pass from the Fording River Forestry Road.

Bed		Thickness	Height Above Base
	Overlying beds belong to the Kananaskis Formation which consist of light grey, highly sandy and cherty, microcrystalline dolomite that weathers very light grey and forms conspicuous, vertical cliffs that rise to a prominent peak overlooking a large cirque on the northeast side. These dolomites form a long dip-slope dipping to the west, at the base of which is the Triassic Spray River-Kananaskis contact. Near the top of the dip-slope the following fossils were collected: GSC loc. 48309 Cancrinella sp., Hustedia sp., Squamularia? sp. The Tobermory-Kananaskis contact is arbitrarily placed at the base of the lowest exposure of continuous dolomite of the cliff-sequence. Contact conformable.		
	ROCKY MOUNTAIN SUPERGROUP		
	Tobermory Formation		
94	Sandstone, highly dolomitic; light grey; very high proportion of microcrystalline dolomite cement; even textured; very fine- to fine-grained with some medium grains; medium sorting; silty; partly friable; flaky weathering; upper 2 feet irregularly flaggy and more resistant; hard; light grey weathering; recessive to somewhat cliff-forming; upper contact sharp	8	1001
93	Sandstone, highly dolomitic; light grey; very fine-grained; silty; dolomite is microcrystalline and constitutes about half the rock; little different from Kananaskis dolomites; even textured; top is fine-grained, well sorted quartzitic sandstone; grades upwards; many small open silica vugs; massive; light grey to light brownish-grey weathering; hard; resistant; cliff-forming in relation to overlying beds	5	993

92	Sandstone, highly dolomitic; light grey; base is extremely fine-grained with very abundant dolomite cement; overlain by a few inches of microcrystalline dolomite containing numerous poorly sorted sand grains from very fine to coarse; upper half is very fine-grained, highly dolomitic, becoming quartzitic at the top with a few coarse and medium well rounded quartz grains; lower few inches contain irregular thin layers of chert; much irregular fracturing and thin parting; grades upwards; light brownish-grey weathering; hard; resistant; cliff-forming	11	988
91	Sandstone, extremely dolomitic; light grey; half sand, half dolomite; sand is mostly very fine and fine with a little medium and some silt; rather poorly sorted; dolomite is extremely fine to microcrystalline; few thin stringers of coarse sand; mostly medium brown weathering; recessive; poorly exposed	10	977
90	Sandstone, dolomitic and quartzitic; light grey, slightly tan; very fine-grained; well sorted; numerous very thin zones up to a few grains thick that contain abundant coarse to very coarse, well rounded chert sand and fewer quartz grains of medium to coarse grade; very tight, sharp, welded lower contact; locally at top is a thin chert layer with small white, silica cauliflower-like masses; massive; brownish-grey weathering and medium brown; hard; resistant	1-1½	967
89	Dolomite, highly sandy; light grey; lower 2 feet microcrystalline consisting of about half fine and very fine sand with a few medium grains; overlain by 2 to 3 inches of chert, in turn overlain by 6 inches of dark brown, argillaceous siltstone, micaceous, very platy, recessive; 2½ feet from top is a second similar siltstone 2 inches thick; upper 5 feet is light grey, microcrystalline dolomite with abundant silt and very fine sand grains evenly disseminated, and many brown films and sinuous anastomosing layers of silty clay up to 2 mm. wide, and fairly numerous white silica cauliflower-like masses up to 1 inch, with some small scattered chert nodules; massive; light tan-grey weathering; hard; resistant; this is the basal unit of the cliff-forming sequence	7	966
88	Covered	18	959
87	Sandstone, dolomitic, quartzitic; light grey; very fine-grained; well sorted; dolomite cement extremely fine to microcrystalline; thick to massive; light grey weathering; hard; resistant	5	941
86	Sandstone, calcitic; light grey; very fine- and fine-grained; few medium and rare coarse highly rounded quartz grains; moderately well sorted; highly friable, cement leached, very porous, soft; medium to light grey weathering; very recessive; no contacts exposed	2	936

85	Sandstone, dolomitic, quartzitic; light grey; very fine-grained, some rounded fine and a few medium grains, some occurring in thin stringers; well sorted; high proportion of dolomite cement; thickly bedded; light grey weathering; hard; resistant	6	934
84	Sandstone, calcitic; light grey, slightly tan; very fine- to medium-grained; medium to poor sorting; fine and medium grains well rounded; sparse coarse grains; friable, much cement leached out, soft; massive; medium grey weathering; mostly poorly exposed; very recessive; slope-forming	11	928
83	Covered	5	917
82	Sandstone, calcitic; light grey-tan; very fine-grained; well sorted; highly porous, friable, leached in part; a few rounded medium grains; lower 2 feet mostly covered, highly sandy, recrystallized limestone, slightly leached, fine granular, originally a coquina, extremely vuggy and porous from solution of fine skeletal fragments, soft, few coarse sand grains; massive; medium grey weathering; slope-forming	7	912
81	Dolomite, cherty, sandy-silty; very light grey-white; micro-crystalline; abundant silt and extremely fine sand evenly disseminated; many porcellaneous chert layers from thin laminae up to 3-4 inches thick; there are four of the thicker layers; most chert layers are finely laminated and these laminae define fine cross-lamination; 1 foot parting; light grey weathering; recessive	5	905
80	Sandstone, dolomitic; very light grey; some zones well sorted very fine-grained; others poorly sorted or medium sorted with very fine to fine and medium and few coarse grains; grains well rounded; many thin ribs and laminae etched to relief, many defining cross-lamination; very massive; light brown-grey weathering; very hard; resistant	14	900
79	Sandstone, dolomitic, light grey; very fine-grained; well sorted; lower 7 feet contain many very thin laminae and stringers up to several grains thick of medium to coarse well rounded quartz and minor chert grains; at top is a 1-12 inch layer of white chert containing many silt and very fine sand grains, stringers of sandstone, and some thin films of light green clay, particularly on the top surface; massive; medium-light grey; hard	20	886
78	Sandstone, calcitic; medium brownish-grey; fine through coarse grains; poorly sorted; grains highly rounded; very abundant fine granular sparry calcite cement; highly porous and very finely vuggy; friable; granular in appearance; only 2 feet exposed; mostly covered	8	866

77	Sandstone, dolomitic and quartzitic; light grey; very fine-grained; even textured; well sorted; fine- and medium-grained at top and bottom; very massive; light grey weathering; hard; resistant; slope-forming; from 12-19 feet mostly poorly exposed to covered, with a parting of less than 1 inch; a few small covered intervals throughout	45	858
76	Dolomite, silty; dark grey; microcrystalline; even textured; a few percent of evenly disseminated silt and extremely fine sand; numerous black chert layers and lenticular nodules up to ½ inch thick; at base is a 1-2 inch layer of black chert containing a great abundance of siliceous spines or spicules; few very thin flaky, argillaceous, sandy siltstone partings, dark grey-black; basal chert rests with sharp contact on sandstone; massive, ½ to 6 inch parting; dark brown weathering; thins laterally to 3 feet	4	813
75	Sandstone, dolomitic, quartzitic; light tan-grey; very fine-grained; well sorted; massive; light grey weathering; very hard; resistant	1	809
74	Sandstone, highly dolomitic; light grey-tan; very fine-grained; many fine grains, several percent of medium to coarse highly rounded quartz and coarse chert disseminated; much microcrystalline dolomite cement; upper contact sharp; gradational downwards; massive; light brown weathering; hard; resistant	1	808
73	Sandstone, dolomitic, quartzitic; light grey; very fine-grained; well sorted; at top are slightly coarser, well rounded fine and a few medium grains; slight variations in texture within unit; consists of alternating zones of units 71 and 72; thick to thin parting; slightly brownish-grey weathering; alternating resistant ribs and small covered intervals; hard; resistant; slope-forming	44	807
72	Sandstone, dolomitic, quartzitic; light grey; very fine-fine; well sorted; very thin 1/4 to 1/2 inch parting; light grey weathering; upper contact sharp; grades downwards; recessive	12	763
71	Sandstone, dolomitic, quartzitic; light grey; very fine- to medium grains; medium to poor sorting; some zones are better sorted than others; from 10 to 20 feet above base very numerous medium to coarse sand grains; very massive; light grey weathering, but black and grey lichens modify colour; moderately hard; large curved fractures; resistant; slope-forming	26	751
70	Sandstone, dolomitic, quartzitic; light grey; very fine- and fine-grained, some medium and few very thin stringers of medium to coarse sand grains; medium sorting; much as a		

a distinct fine ribbing etched to relief, which together with a conspicuous 1-2 inch parting defines very strong cross-bedding; grades upwards; massive; light brown-grey weathering; moderately hard; slope-forming; laterally poorly exposed 18 725

The Tobermory Formation here forms a slope that is conspicuous between the highly cliff-forming Kananaskis Formation above and the cliff-forming Storelk Formation below

Total Thickness of the Tobermory Formation 296

Storelk Formation

69 Sandstone, quartzitic; light brown, tan, and grey-white; fine- to medium-grained; mostly medium to well sorted; coarse grains are present but are not numerous; fine to coarse grains highly rounded; quartz predominates; some chert grains; chert grains altered in part to white, soft, chalky grains that commonly absorf small amounts of limonite that gives them and the rock a tan to light brown colour; lower 30 feet very fine, well sorted; above fine and medium grains increase to 47 feet where there is medium-grained, well sorted sandstone with a few fine and very few coarse grains; above medium grains decrease; at 57 feet fine and medium sand with medium sorting; at 84 feet very fine- and fine-grained, well sorted; above mostly very fine- and fine-grained with some medium grains in some zones, well sorted; from 156 to 157 feet is a medium to coarse grained zone; above to top is fine to very fine sand with some zones containing many medium grains; entire unit is very coarsely cross-bedded, with parting surfaces parallel to the cross-sets; normal stratification seems to be lacking; accurate measurement of thickness is difficult; exceedingly massive; grey-white weathering but orange and red-orange staining modified colour; mostly covered with black, and some light grey, green, orange and bright green lichen; weathering colour very distinctive; very resistant; hard; cliff-forming; distinctive unit 178 707

68 Sandstone, quartzitic; partly leached; light brown; mostly very fine-grained; well sorted; grades up and down; irregular platy and flaggy parting; medium brown weathering; recessive; occurs at change in slope 4 529

67 Sandstone, quartzitic, dolomitic; light tan; very fine- and fine-grained; well sorted; very fine grains predominate; some zones contain many fine grains; within lower 8 feet are many fine to coarse, highly rounded sand grains disseminated in poorly sorted thin layers or concentrated in thin laminae and stringers; also in lower 8 feet are alternating quartzitic and dolomitic zones up to several inches wide; extremely massive; light brown and light grey

	weathering; hard; brittle; cliff- and slope-forming; this unit may or may not belong in the Storelk Formation	95	525
	Total Thickness of Storelk Formation	277	

Tyrwhitt Formation

66	Sandstone, dolomitic, quartzitic; light tan-grey; very fine-grained; well sorted; highly dolomitic; dolomite occurs as fine to medium crystals; much very fine, irregular microcrystalline quartz cementation and some chert lenses; some poorly preserved silicified brachiopod fragments and a few Orbiculoidea sp. shells; massive; light grey to tan weathering; hard	3	430
65	Covered	15	427
64	Sandstone, dolomitic; light tan; very fine-grained; well sorted; a few well rounded medium grains; thin ribs and laminae etched to relief; very massive; medium to light brown weathering, slightly grey; hard; moderately resistant	7	412
63	Sandstone, dolomitic, quartzitic; light grey; very fine-grained; well sorted; very massive; light brown weathering; covered with black, grey-white and bright green lichen; moderately hard; moderately resistant; mostly slope-forming	43	405
62	Dolomite, extremely sandy; light tan; fine to extremely finely crystalline; largely granular; extremely abundant very fine sand; some zones contain numerous fine to coarse, well rounded quartz and chert sand grains; much appears to have been originally a sandy coquina, now partly dolomitized and the original unreplaced skeletal grains have been dissolved out leaving very numerous fine vugs and cavities filled or lined with fine sparry calcite; highly porous, soft, "rotten"; coarsely ribbed; parts are massive; light grey weathering; poorly exposed; highly recessive	14	362
61	Sandstone, dolomitic; light tan to tan-grey; very fine-grained; very well sorted; lower 3 feet massive, deep brown weathering with fine knobby surface; from 3 to 6 feet very platy; remainder has very conspicuous flaggy to blocky parting; light brown weathering; hard; moderately resistant	18	348
60	Siltstone, argillaceous; slightly micaceous; pale green to medium greenish-grey; even textured; contacts sharp; fine flaky to platy weathering; hard; highly recessive	1	330
59	Dolomite, extremely sandy-silty; medium to light grey to light brown; microcrystalline to extremely fine crystalline; lower half uniform, upper half gradually becomes argillaceous upwards; lower half massive to blocky, upper		

half becomes platy upwards and grades up into siltstone; lower half contains very numerous silicified brachiopods GSC loc. 48310 Spirifer occiduus, S. cf. matheri, S. cf. opimus, Composita cf. sulcata; at the base are well rounded fine to coarse sand grains; brown weathering; hard 2 329

58 Dolomite, sandy; light tan; very fine to extremely fine, granular; soft; largely a finely fragmented pelecypod coquina, in part dolomitized, in part silicified; poorly sorted very fine to coarse sand throughout; mostly dolomitized and many unreplaced shell fragments have been leached out, leaving numerous cavities and fine vugs, most lined with very fine sparry calcite; extremely porous; upper 6 inches contains several layers up to 1 inch thick of silicified coquina which laterally merge into one layer several inches thick; scattered fine Orbiculoidea shell fragments; light grey weathering; soft; poorly exposed; grades upwards rapidly; similar to #62 3 327

57 Sandstone, dolomitic, quartzitic; tan; very fine-grained; well sorted; a few zones contain some fine sand, and 12 feet from base are few coarse grains; lower 100 feet cemented with dolomite and weathers medium brown; from 106 to 167 feet grey-white weathering and cemented with quartz and dolomite; at 32 feet from base is a few inch thick zone containing an extreme number of finely fragmented silicified brachiopod shells and very numerous Orbiculoidea shells, all current oriented; massive to platy and blocky; lower part medium to light brown weathering; upper part grey-white to light grey; hard; resistant; cliff- to slope-forming; some small covered intervals 167 324

56 Sandstone, dolomitic, quartzitic; light grey to tan-grey; very fine-grained; well sorted; a few scattered coarse grains in parts; partly dolomite cemented, but there are many indistinct zones and masses of grey-white, lichen-covered quartz-cemented sand; lower 5 feet very fine-grained, highly silty, highly dolomitic, very similar to unit 55, containing a few silicified productoid-like brachiopod fragments that are poorly preserved and a very few small silicified echinoderm columnals and bryozoa; 5 feet from base is a 6 inch zone of highly recessive, medium to light green, silty shale and shaly siltstone, immediately above which within the basal foot of overlying sandstone are many silicified productoid brachiopods, rare coral, and a few bryozoa GSC loc. 48311 Antiquatonia cf. hermosana, Pleurodictyum meekanum, Reticulariina? sp.; massive; mostly light grey weathering, some parts brown; very hard; highly resistant; lower contact poorly exposed 18 157

Total Thickness of Tyrwhitt Formation 291

Contact unconformable? Not exposed here

Todhunter Formation

Upper Part

55	Siltstone, dolomitic, argillaceous?; sandy; medium greenish-grey; very even textured; lower 2 feet dolomitic, medium- and fine-grained, medium sorted sandstone grading upwards; numerous Orbiculoidea shells scattered throughout; very massive; distinctive light brown weathering; very hard; resistant; cliff-forming	20	139
54	Dolomite, highly sandy; calcitic; finely crystalline; sugary; much fine granular sparry calcite; extremely abundant fine to medium and some coarse quartz and chert sand; some scattered well rounded sand-size grains of Orbiculoidea; at top is a white chert layer a few inches thick that preserves an original clastic, skeletal calcarenite texture; massive; medium grey to tan-grey weathering; soft to moderately hard	3	119
53	Sandstone, dolomitic; tan; very fine-grained; well sorted; lower 5 feet deeply leached, soft, recessive; flaggy to blocky parting; very light tan weathering; hard; moderately resistant	15	116
52	Sandstone, dolomitic; light tan-grey; very fine- and fine-grained; well sorted; at base are scattered coarse and very coarse quartz and black phosphorite sand grains with numerous silicified brachiopod fragments set in a fine to medium quartz sandstone; at 3 to 4 feet from base is fine to very coarse quartz and phosphorite sand grains in a highly dolomitic zone; massive, flaggy parting; medium grey weathering; very hard; resistant	6	101
51	Sandstone, quartzitic; white; fine-grained; well sorted; some altered white chert grains; massive; white weathering; very hard; finely fractured; recessive	1	95
50	Sandstone, dolomitic; tan-grey; fine-grained with a few medium to coarse sand grains; moderately well sorted; at base are many medium and coarse sand grains and fairly numerous sand-size Orbiculoidea shell fragments; locally at 6 inches from base is a 1 inch green, fissile shale; massive; brownish-grey weathering; hard	9	94

Middle Part

49	Dolomite, highly sandy; tan; fine to medium crystalline; soft to hard; extremely numerous silicified brachiopods of the genera Spirifer and Composita; most fossils appear to be fragmented; near the middle some parts are maroon; sand is fine and medium, with a little coarse, well rounded sand; upper contact sharp and welded; massive; light tan weathering; moderately resistant	6	85

48	Siltstone, sandy; slightly argillaceous; dark reddish-maroon; laterally pale green; flaggy to platy; recessive; contacts sharp	1	79
47	Sandstone, dolomitic; light tan; fine-grained; well sorted; limonitic staining; conspicuous thin flaggy to platy parting throughout; very hard; somewhat recessive	4	78
46	Siltstone, sandy, slightly argillaceous; dark reddish-maroon in some places, light green in upper half; where maroon there is some green mottling; gradational contacts; massive with curved fracture; very hard; somewhat recessive	2	74
45	Dolomite, highly sandy; light tan-grey; very fine crystalline; uniform; contains an irregular, discontinuous zone of chert 1-4 inches thick; numerous silicified, red, very fine brachiopod fragments similar to those below; massive; light brown weathering; very hard	2	72
44	Dolomite, calcitic; highly sandy; partly argillaceous; light tan in upper 3 feet, lower 7 feet maroon from intercrystal clay; fine to coarsely crystalline; granular; tight; very fine and fine, angular to rounded quartz sand extremely abundant, irregularly distributed; a few thin layers of maroon chert, in part preserving small skeletal grains; numerous silicified, red and white, fragmented brachiopods, Spirifer and Composita; brachiopods irregularly distributed; very thin shelled Composita seem to predominate; 1-12 inch parting; maroon and tan weathering; moderately soft; recessive	10	70
43	Dolomite, slightly calcitic; very sandy; tan-grey to light tan; fine to medium crystalline, partly coarse; tight; sand is very fine and fine, angular to rounded, unevenly disseminated; fairly even textured; abundant very fine silicified brachiopod fragments; massive; light tan-grey weathering; moderately hard; moderately resistant	3	60
42	Dolomite, highly calcitic; sandy; light tan; medium to coarsely crystalline; granular; extremely porous, finely vuggy; vugs are lined with sparry calcite; sand is fine, not too abundant, angular to rounded; light tan-grey weathering; coarsely ribbed and pitted; rather soft; somewhat recessive	1	57

Lower Part

41	Sandstone, dolomitic; fine- to very fine-grained; well sorted; contains disseminated medium to coarse rounded sand grains in lower part in a 1 foot zone; massive with discontinuous 3 to 12 inch parting; light tan weathering; hard	7	56
40	Sandstone, dolomitic; light grey; very fine-grained; well sorted; a few long lenticular chert masses up to several		

	inches thick, light grey; massive; light brown to light tan-grey weathering; very hard; resistant	7	49
39	Siltstone, argillaceous; maroon and green; gradational contacts; laterally forms a single unit 3 feet thick by combining with the upper 2 feet of underlying unit, and total unit becomes maroon; platy to flaky; highly recessive	1	42
38	Sandstone, dolomitic; grey-white; very fine- and fine-grained; well sorted; even textured; mostly strongly cross-bedded; parts readily into non-uniform blocks and plates from 1 to 6 inches thick; upper two feet green, silty, argillaceous; from 5 to 6 feet below top is a flaky green and maroon shale and siltstone, recessive; light brown to light grey weathering; hard; resistant	39	41
37	Covered	2	2
	Total Thickness of Tobermory Formation	139	

Contact conformable

RUNDLE GROUP

Etherington Formation

Ewin Creek Member

36 Dolomite, extremely sandy; grey; microcrystalline; surface has strongly etched laminae and fine ribs of sandstone; extremely cherty; extremely hard; massive; light tan weathering; highly resistant.

SECTION 26

Location: This section is located at the southwest corner of Mount Storelk on the west side of the Elk Mountains, B. C. The sandstones and Kananaskis Formation are completely exposed in a deep, narrow canyon opening to the southwest about one-half mile northeast of the mouth of Tobermory Creek. This canyon can be identified by a very large, low alluvian fan at its mouth where coarse gravel and boulders are overgrown with low vegetation.

Bed		Thickness	Height Above Base
	ROCKY MOUNTAIN SUPERGROUP		
	Kananaskis Formation		
236	Dolomite, extremely sandy; medium-light grey; microcrystalline; extremely abundant very fine quartz sand evenly disseminated; extremely numerous impure, grey, chert nodules; massive; light tan-brown weathering; brittle, fractures readily; moderately resistant	3	969
235	Dolomite, exceedingly sandy; medium grey; microcrystalline; very abundant, evenly disseminated, very fine, well sorted quartz sand; a few zones are dolomitic sandstone; numerous large grey-white, rounded to irregular chert nodules up to 6 inches long, with some irregular layers up to 6 inches thick; top 1 foot is mainly chert; massive; medium to light brown weathering; hard; resistant; cliff-forming	10	966
234	Dolomite, very sandy; medium-light grey; microcrystalline; even textured; most contains abundant very fine, well sorted, evenly disseminated quartz sand; some zones are nearly sand-free; a few zones contain some siliceous spines; fairly numerous scattered chert nodules from less than ½ inch up to 2 inches thick; upper 6 inches is chert; massive; light tan weathering; hard; resistant; cliff-forming	27	956
233	Dolomite, silty; medium grey; microcrystalline; even textured; abundant evenly disseminated silt; extremely cherty, about half chert; many of the nodules are thin 1/4 inch shells of chert; some scattered siliceous spines; massive; medium brown weathering; hard; resistant	2	929
232	Dolomite, highly sandy; medium grey; microcrystalline; sand content varies in different zones, most is very fine, very abundant and evenly disseminated, and as numerous etched, very thin parallel laminae; a few thin zones contain very fine to well rounded fine and medium quartz sand; a few small rounded chert nodules, some very thin layers of chert; upper 6 inches mostly chert; massive; medium to light brown weathering; hard; resistant; cliff-forming	13	927

231	Dolomite, medium grey; microcrystalline; even textured; very little disseminated silt; massive; light brown weathering; hard; resistant	1	913
230	Dolomite, exceedingly sandy; medium-light grey; microcrystalline; consists of about half fine and less very fine quartz sand; massive; medium brown weathering; hard; resistant; cliff-forming	6	913
229	Dolomite, partly sandy; medium-light grey; microcrystalline; some zones contain extremely abundant very fine, disseminated quartz sand; much is entirely sand free; lower half contains abundant chert as irregular layers 1-3 inches thick; upper 1½ feet contains chert breccia fragments, some are subrounded, scattered abundantly through a microcrystalline dolomite matrix containing abundant disseminated very fine through highly rounded medium to coarse quartz sand; many of the chert fragments nearly interlock, many are slivers and chips alligned parallel to the stratification; also a few large masses of chert up to 6 inches long and 3 inches thick; massive; light brown weathering; hard; resistant; cliff-forming	11	907
228	Sandstone, highly dolomitic; light grey; very fine- to fine grained; fairly well sorted; lower 6 inches contains very numerous disseminated rounded to subrounded coarse chert grains; massive; medium brown weathering; hard; resistant; cliff-forming	3	896
227	Dolomite, sandy; medium grey; microcrystalline; abundant disseminated very fine to extremely fine quartz sand; many rounded chert nodules 1/4 to 4 inches long; massive; medium-light brown weathering; hard; resistant; cliff-forming	8	893
226	Sandstone, quartzitic; light grey; very fine-grained; well sorted; numerous thin white, porcellaneous lenticular layers of chert-cemented sand; massive; grey weathering; hard; brittle	1	885
225	Dolomite, extremely sandy; medium-light grey; microcrystalline; sand is very fine and fine, with many medium and a few coarse chert and quartz grains; poorly sorted; numerous irregular to rounded grey-white porcellaneous chert nodules from ½ up to several inches thick, filled with sand grains; lower foot almost entirely chert; massive; medium-light brown weathering; hard; resistant; cliff-forming; some parts of this unit are nearly sandstone	7	884
	Total Thickness of Kananaskis Formation	92	
	Contact Conformable		

Tobermory Formation

224	Sandstone, dolomitic; light grey; fine- and very fine-grained; moderately well sorted; upper 2 feet is microcrystalline dolomite with extremely numerous fine to coarse, rounded quartz sand grains, disseminated; top 6 inches consists of		

	a layer of grey-white chert containing very abundant, poorly sorted, fine to coarse well rounded quartz and fewer chert grains, a few silicified calcareous algae?, and rare tiny foraminifera; very massive; medium brown weathering; hard; resistant; cliff-forming	23	877
223	Dolomite, highly sandy; medium grey; microcrystalline; very abundant very fine, well sorted quartz sand evenly disseminated; fairly numerous layers of chert 1-3 inches thick; chert regularly distributed from 1 to 12 inches apart; upper foot almost entirely chert; massive; light brown weathering; hard; resistant; cliff-forming	14	854
222	Sandstone, highly dolomitic; medium grey; mostly very fine to fine; fairly well sorted; a few zones are poorly sorted with scattered highly rounded fine, medium and a few coarse quartz grains; a few zones of quartzitic sandstone from 1-12 inches thick; some zones are sandy, dense dolomite; massive; medium brown weathering; hard; resistant; cliff-forming	13	840
221	Sandstone, quartzitic; light grey; very fine-grained; well sorted; massive; light grey weathering; hard; resistant	2	827
220	Sandstone, dolomitic, quartzitic; light grey; very fine- and fine-grained; fairly well sorted; grades upward; a one foot quartzitic zone near middle; massive; medium-light brown weathering; hard; resistant; cliff-forming	5	825
219	Sandstone, highly dolomitic; medium-light grey; very fine- to fine-grained; well sorted; some zones are half sand and half dolomite; contains 5 or 6 layers of grey-white chert 1-4 inches thick, some spicules and abundant sand; very massive; medium brown weathering; hard; resistant	9	820
218	Sandstone, dolomitic; light grey; very fine-grained, a few rounded fine, and rare medium-coarse, rounded quartz grains; contains a one foot zone of porcellaneous white chert-cemented sand; grades downward; massive; medium brown weathering; hard; resistant; cliff-forming	4	811
217	Sandstone, quartzitic; white; very fine-grained; well sorted; massive; grey-white weathering; hard; resistant; cliff-forming	4	807
216	Sandstone, dolomitic; light grey; very fine-grained; well sorted; massive; medium-light brown weathering; hard; resistant; cliff-forming	4	803
215	Sandstone, chert-cemented; medium-dark grey; mottled; bedded to nodular; very fine- to fine-grained; obscure texture; contacts very sharp	1	799
214	Sandstone, quartzitic; light grey; fine-grained; well sorted; very massive; very light brown weathering; hard; resistant; cliff-forming	4	798

213	Sandstone, highly dolomitic; medium-light grey; very fine- to extremely fine-grained; few fine grains; high proportion of dolomite cement, some zones are sandy dolomite; contacts very sharp; massive; medium-light brown weathering; hard; resistant; cliff-forming	3	794
212	Sandstone, dolomitic, quartzitic; light grey; grain size variable; very fine to fine grains predominate, but many zones contain abundant highly rounded medium to coarse grains; zones range from well sorted to poorly sorted; lower foot poorly sorted with very fine to coarse sand; both dolomite and quartz evenly cement the sand; extremely massive; brown weathering; hard; resistant; cliff-forming	17	791
211	Sandstone, dolomitic and quartzitic; light grey; very fine; well sorted; very massive; brown weathering; hard; resistant; cliff-forming	5	774
210	Sandstone, dolomitic, quartzitic; medium-light grey; mainly very fine-grained; dolomitic with very numerous thin etched, parallel laminae; numerous thin layers of grey-white weathering quartz-chert cemented zones from very thin laminae up to several inches thick, differentially etched; a few thin zones contain extremely numerous coarse sand grains of quartz and chert; massive; medium brown weathering; hard; resistant; cliff-forming	5	769
209	Sandstone, quartzitic; light grey; very fine- to fine-grained; well sorted; massive; light grey weathering; hard; resistant; cliff-forming	2	764
208	Sandstone, quartzitic and dolomitic; light grey; very fine with much fine sand; well sorted; many very thin laminae of quartz cement etched to relief; alternating zones of dolomitic and quartzitic sand with some layers of light grey weathering quartzitic sand up to 1 inch thick; thins to zero laterally; very massive; brown to grey weathering; hard; resistant; cliff-forming	2	762
207	Dolomite, extremely sandy; medium-light grey; very fine to extremely fine crystalline; very abundant fine to coarse disseminated sand; contacts sharp; thins to zero with unit 208; where underlying units thicken to eight feet, this unit absent; massive; brown weathering; hard; resistant	2	760
206	Sandstone, quartzitic; light grey-white; very fine- to fine-grained; well sorted; within 25 feet thickens to 8 feet and upper contact becomes indistinct; extremely massive; light grey weathering; hard; resistant; cliff-forming	2-8	758
205	Dolomite, highly sandy; medium-light grey; microcrystalline; sand is very fine, some fine, evenly disseminated; thins laterally to zero; contacts very flat and sharp; massive; brown weathering; hard	1	756

204	Sandstone, mostly quartzitic; light grey; very fine- to medium-grained with some coarse grains scattered in zones; poorly sorted; some zones are finer and better sorted; very strongly cross-bedded; cross-sets truncated at upper contact which is very sharp and flat; massive; brown to light grey weathering; hard; resistant; cliff-forming	17	755
203	Sandstone, quartzitic; white; very fine- to fine-grained; well sorted; massive; hard; resistant; cliff-forming	2	738
202	Sandstone, dolomitic and quartzitic; light grey; very fine-grained; a few scattered fine grains; well sorted; alternating zones of dolomite and quartz cement; massive; brown weathering; hard; resistant; cliff-forming	9	736
201	Sandstone, quartzitic; light grey-white; very fine- and fine-grained; well sorted; conspicuous thin to medium parting 6-12 inches; light grey weathering; hard; cliff-forming	11	727
200	Sandstone, dolomitic; light grey; very fine-grained; well sorted; contacts sharp; massive; light brown weathering; hard	1	716
199	Sandstone, quartzitic; light grey-white; very fine-grained; well sorted; massive; light grey weathering; hard; resistant	1	715
198	Sandstone, highly dolomitic; medium grey; very fine-grained; well sorted; almost half dolomite; lower contact indistinct, upper contact sharp; massive; light tan-grey weathering; hard	1	714
197	Sandstone, quartzitic; light grey; very fine-grained; well sorted; massive; light grey weathering; hard; brittle; resistant cliff-forming	4	713
196	Sandstone, quartzitic, dolomitic; medium-light grey; very fine; well sorted; very massive; light brown weathering; hard; resistant; cliff-forming	4	709
195	Sandstone, quartzitic; light grey-white; very fine-grained; well sorted; massive; light greyish-tan weathering; brittle; finely fractured; hard; resistant; cliff-forming	6	705
194	Sandstone, quartzitic; light grey; very fine; well sorted; upper 3 feet have very numerous very thin parallel laminae of poorly sorted fine to coarse sand; upper half strongly cross-bedded; extremely massive; no weathered surfaces; very finely fractured; hard; resistant; cliff-forming	22	699
193	Chert, extremely finely fractured; white and dark grey mottled; contains a 6 inch quartzitic, very fine sandstone zone; massive; resistant;	3	677
192	Sandstone, quartzitic; light grey; fine- to medium-grained with some coarse sand grains; medium to poorly sorted; contacts very sharp; extremely massive; finely fractured; hard; resistant; cliff-forming	6	674

191	Dolomite, exceedingly sandy; medium-light grey; very finely-crystalline, granular; sand is fine to medium, some coarse, disseminated; very locally at base is a fine granule conglomerate composed of sandstone fragments, up to 6 inches thick; the fragments are subrounded, medium grey, ranging from sand to very fine pebble size, rarely reaching ½ inch; the fragments are composed of well sorted, quartzitic, very fine- to fine-grained quartz sand; the matrix of the conglomerate is light tan, granular, sandy dolomite; massive; not maturely weathered; hard; resistant; cliff-forming	7	668
190	Covered; narrow gully may be due to faulting or slippage along bedding surface	2	661
	Total Thickness of Tobermory Formation	218	

Storelk Formation

189	Sandstone, quartzitic; light grey; very fine- through coarse-grained; many alternating zones of different grain size and sorting; these zones range in thickness from laminae up to many feet thick, and the unit is typically highly variable texturally; the lower 90 feet is very fine-grained and well sorted, with some fine grains, becomes slightly dolomitic towards the base; at 94 to 96 feet are several thin, uneven layers up to 1 inch of black chert, alternating with very fine-grained sandstone, forms small gully; from 100 to 125 feet well sorted, fine- to medium-grained with a few to many coarse well rounded grains, medium-poorly sorted; overlying part well sorted and very fine-grained zones alternate with medium to poorly sorted zones; upper 21 feet fine to medium with a few scattered coarse grains, medium sorting to poor sorting in some zones; uppermost few feet medium grey, fine-grained with a few medium and very fine grains; lower 135 feet strongly cross-bedded; ½ mile south along strike is much cross-bedding, ranging from sets only a few feet long up to 30-40 feet throughout the formation; at Mt. Storelk much of the unit has a distinct, apparently normal stratification which probably is actually very large scale, low-angle cross-stratification; except for parting along the cross-sets, unit is exceedingly massive; where maturely weathered light grey-white with very heavy black lichen cover, and some orange staining; where measured in canyon no surfaces are maturely weathered; exceedingly hard; highly resistant; exposure complete; underlying sandstones much less resistant and the canyon widens out conspicuously where these beds outcrop	306	659
	Total Thickness of Storelk Formation	306	

Tyrwhitt Formation

188 Sandstone, dolomitic; light grey, slightly tan; very fine-grained; well sorted; at the top on the south side of the gully is a fairly marked truncation of 3 feet of beds over a distance of 25 feet by the overlying Storelk; these 3 feet of beds consist of dolomitic, very fine-grained, light brown sandstone, containing fairly numerous small oxidized pyrite nodules, and numerous extremely thin, dark oxidized pyritiferous films and stringers which are anastomosing and subparallel to the bedding; across the gully on the north side at the top of this unit is 1½ feet of very light tan, fine-crystalline containing very numerous rounded fine and a few medium quartz grains and a few highly rounded light brown phosphorite grains of fine grade, also fairly numerous white, silica vugs from 1/4 to 1/2 inch, mainly in thin zones, contact with overlying sandstone extremely abrupt with no evidence of erosion; normal stratification, parting 1-4 feet; light brown weathering; hard; resistant; overlying sandstone unit contains large-scale to small-scale cross-stratification; this and underlying units are fairly regularly, and normally stratified 20 353

187 Sandstone, dolomitic; light grey, slightly tan; very fine-grained; well sorted; idetnical to overlying unit; contacts are distinct bedding surfaces that form small, distinct ledges; very massive; light brown weathering; very hard; resistant; cliff-forming 21 333

186 Sandstone, dolomitic, slightly quartzitic; light tan-brown to grey; very fine-grained; well sorted; similar to overlying unit; very massive; light brown weathering; hard; resistant; cliff-forming 8 312

185 Sandstone, dolomitic; very light tan-grey; very fine- and fine-grained; fairly well sorted; a few disseminated very fine and fine highly rounded, light to dark brown phosphorite grains; contains several 1-3 inch thick layers of fine crystalline dolomite, very vuggy, highly porous, rather soft, containing abundant, fine to coarse, poorly sorted, well rounded quartz grains, also a very few Orbiculoidea shell fragments; these dolomite layers coalesce laterally in a very irregular manner; this is a transitional zone between underlying dolomite and overlying sandstone; massive; light brown weathering; hard; resistant; cliff-forming 2 304

184 Dolomite, sandy; light grey; very fine- to fine-crystalline; parts are tight, nonporous, hard, even textured; many parts are granular, soft, exceedingly porous, finely vuggy; moderately abundant disseminated quartz sand from fine to coarse, well rounded; also a few very highly rounded fine to medium, brown phosphorite grains; gradational upwards; possibly originally a coquina, there are a few casts and molds of shells; massive; medium to light grey weathering 6 302

183	Sandstone, dolomitic, slightly quartzitic; light grey, slightly tan; very fine-grained; very well sorted; uniform throughout; massive, normal medium to thick regular parting; light brown weathering; hard; resistant	54	296
182	Sandstone, quartzitic; light grey; very fine- to fine-grained, with a few medium grains; fairly well sorted; contacts sharp; massive, thick parting; light grey weathering; hard; moderately resistant; brittle	6	242
181	Sandstone, dolomitic; light grey, lower part darker; very fine- and fine-grained, with some well rounded medium quartz grains, and a few coarse grains; very few highly rounded, very fine- to fine, dark phosphorite grains; massive, thin to medium parting; hard; medium brown weathering; resistant	9	236
180	Dolomite, sandy; tan; fine- to coarsely crystalline; texture variable, uneven; parts are highly porous with a little sparry calcite; lower 5 feet is sandstone; unit contains several thin zones up to 6 inches thick of exceedingly numerous Orbiculoidea ranging from highly fragmented to complete; finely fragmented shells range down to sand sizes and are disseminated throughout; also a few white, silicified, very poorly preserved articulate brachiopods occur in some parts; upper few feet is the most coarsely crystalline part; massive; lower sandstone medium brown weathering, dolomite is light tan-light brown; hard; resistant; upper contact is exceedingly abrupt	11	227
179	Sandstone, quartzitic; light grey; very fine-grained; upper contact fairly abrupt; well sorted; very massive; light grey weathering; brittle; hard; moderately resistant	3	216
178	Siltstone, dark greenish-grey; uniform; argillaceous; fine muscovite flakes disseminated throughout; basal and top few inches flaky, probably silty shale, dark greenish-grey; contacts very abrupt; massive, blocky; considerable amount of rusty weathering; brittle; somewhat recessive; hard	4	213
177	Sandstone, dolomitic, quartzitic; light grey; very fine-grained, with some fine and medium quartz grains, and very few coarse grains; medium sorting; upper 2 feet quartzitic; lower 3 feet dolomitic; massive; medium brown weathering, upper part light grey; hard; resistant	5	209
176	Sandstone, quartzitic; light grey; very fine-grained, some fine grains, few well rounded medium grains; medium sorting; very porous, leached of most cement; gradational contacts; massive; light grey weathering	2	204
175	Sandstone, dolomitic; light tan-grey; poorly sorted; basically very fine-grained with some fine grains; there are a few thin laminae and stringers containing fine to coarse, well rounded quartz sand grains, disseminated; upper contact indistinct; massive; light brown-tan weathering; hard; resistant	13	202

174 Sandstone, light grey; poorly sorted; very fine-grained with many fine and fewer medium, rounded quartz grains; rare coarse quartz grains; leached, very porous; soft; friable; contacts sharp; light grey weathering; moderately recessive 1 189

173 Sandstone, dolomitic; light tan-grey; poorly sorted; mainly very fine-grained, but with numerous well rounded fine to coarse quartz grains occurring mainly in thin zones; massive; medium brown weathering; irregular fracture; hard; resistant 3 188

172 Sandstone, dolomitic; light grey; very poorly sorted; very fine through coarse grains present; coarser grains abundant; thins laterally; contacts indistinct to abrupt; massive; light grey weathering; rather soft 1 185

171 Sandstone, dolomitic; medium-light grey; very fine-grained, few fine grains; well sorted; very numerous layers and lenses of pure, green and bluish-grey chert 1-3 inches thick, spaced 1-12 inches apart; very massive; medium brown weathering; hard; resistant 8 184

170 Sandstone, dolomitic, siliceous; medium-light grey; very fine-grained; well sorted; some diffuse chert cementation; lower 5 feet contains much highly irregular, indistinct chert layers; upper contact very sharp; very massive; medium brown weathering; hard; resistant 10 176

169 Sandstone, dolomitic, slightly quartzitic; light tan; very fine-grained, with some fine grains; well sorted; very deeply and coarsely pitted on weathered surfaces; upper 5 feet quartzitic and dark lichen covered; exceedingly massive; light greyish-tan weathering; upper part light grey; hard; resistant 17 166

168 Sandstone, dolomitic, very slightly quartzitic; medium-light grey; very fine-grained; well sorted; fairly numerous poorly preserved, white, silicified Spirifer brachiopods; scattered oxidized pyrite nodules; grades upwards; massive; distinct 3 to 24 inch parting; medium to light brown weathering; hard; cliff-forming 22 149

167 Sandstone, quartzitic; very light grey-white; very fine-grained; well sorted; upper contact exceedingly abrupt and flat; massive, distinct parting 2-12 inches; light grey weathering; hard; resistant; cliff-forming 13 127

166 Siltstone, dolomitic; medium brown; very even textured; uniform; top 1-2 inches argillaceous and flaky; lower 6 inches very thin irregular parting and recessive; massive; dark brownish weathering; contacts very sharp; rather recessive 2 114

165 Sandstone, evenly quartzitic and dolomitic; light tan; poorly sorted; very fine to medium grains present with fine grains being the average; some zones are coarser than others; lower contact exceedingly sharp and flat; weathered surfaces very

strongly laminated due to etching of extremely thin, parallel quartzitic and dolomitic zones; very strongly cross-bedded, almost no normal stratification; extremely massive; tan-brown weathering; hard; resistant; cliff-forming 29 112

164 Sandstone, dolomitic, slightly quartzitic; light grey; very fine-grained; very well sorted; contains some patches of light grey weathering quartz-cemented sand; 2 feet from base is a thin recessive zone several inches thick, and on the bottom of the superjacent bedding surface and within the lower few inches of the overlying layer are numerous silicified productoid brachiopods, difficult to recover; massive; tan-brown weathering; hard; resistant; cliff-forming 8 83

Total Thickness of Tyrwhitt Formation 278

Todhunter Formation

Middle Part

163 Sandstone, dolomitic; light tan; poorly sorted; averages fine to medium-grained, but some very fine and a few coarse grains are present; grains subrounded to rounded; massive; light tan-brown weathering; hard; resistant; cliff-forming 6 75

162 Sandstone, evenly dolomitic and quartzitic; light tan-grey; very fine- to fine-grained; well sorted; contacts sharp; light tan weathering; hard; resistant; cliff-forming; underlying dolomite absent laterally 7 69

161 Dolomite, sandy; light tan-grey; fine- and medium crystalline; tight; very abundant very fine to fine quartz sand, rare medium grains, unevenly disseminated throughout; top surface is chert with poorly preserved, silicified spiriferid brachiopods; lower contact very sharp; massive; blocky parting; light brown weathering; hard; not entirely exposed 3 62

160 Limestone, sandy; light grey; skeletal calcarenite; poorly sorted; coarse and very coarse skeletal grains; moderately abundant very fine to medium quartz sand; numerous spiriferid brachiopods; massive; medium to light grey weathering; hard; resistant 1 59

159 Limestone, highly sandy; light brown; skeletal calcarenite; mainly extremely fine-grained, partly micrograined, with abundant fine to some very coarse disseminated skeletal fragments; very poorly sorted; extremely abundant evenly disseminated very fine and some fine quartz sand with a few medium-sized grains; very numerous silicified brachiopods; numerous irregular, light brown weathering, impure chert nodules; upper contact distinct and sharp; similar to underlying bed; massive; medium grey to tan weathering; hard; moderately resistant 4 58

158	Limestone, highly sandy; grey to maroon; skeletal calcarenite; poorly sorted; all contains micrograined matrix with abundant disseminated fine to very coarse skeletal grains of echinoderms and bryozoa; lower 6 feet is medium grey, highly sandy, very fine-fine, and contains a few maroon, argillaceous limestone zones ½ to 2 feet thick which are highly variable laterally, very poorly sorted, extremely sandy, and each maroon zone is characteristically underlain by a thin zone a few inches up to 6 inches thick of brown weathering, very fine- to fine-grained, calcareous sandstone in which are scattered fine to very coarse skeletal grains; upper part is mostly maroon, poorly sorted, highly sandy, fine- to coarse-grained skeletal limestone with little grey colour; upper contact very gradational over 1 to 2 feet; exceedingly numerous red, silicified brachiopods, many highly fragmented, many are entire and well preserved; very massive; medium grey to maroon weathering; hard; resistant; maroon weathering colour makes this bed very distinctive from a long distance	9	54
157	Dolomite, sandy; light tan-grey; very fine- to medium-crystalline; texture variable; a little very fine sand; lower 1 foot incompletely dolomitized fine- to coarse-grained skeletal limestone, the dolomite being light tan, very fine and fine; lower contact very sharp; upper contact gradational over several inches; very sandy at top; massive, blocky; light tan weathering; hard; resistant, but less so than overlying limestone bed	5	45
156	Limestone, medium grey; skeletal calcarenite; partly microtextured with very abundant disseminated very fine to very coarse skeletal grains, mainly echinoderms; contacts very sharp; scattered small rounded tan chert nodules; very massive; medium grey weathering; hard; resistant; cliff-forming	4	40
	Lower Part		
155	Sandstone, dolomitic; medium grey; very fine-grained with some fine grains in some parts; fairly well sorted; fairly abundant very thin etched laminae; some small scale cross-stratification, made conspicuous by etched laminae; upper contact very sharp; very massive; medium brown weathering, upper 3-4 feet grey; hard; resistant	11	36
154	Sandstone, dolomitic; medium-light grey; very fine-grained, some fine grains; well sorted; parts are fairly strongly cross-bedded; lower contact sharp;, but a few stringers of sand occur in the upper 6 inches of the underlying limestone; massive with thin to medium parting, some parts flaggy; light brown to greyish-brown weathering; hard; resistant	25	25
	Total Thickness of Todhunter Formation	75	

SECTION 28

Location: This section is located on the west side of Highwood Range, at the head of Lantern Creek, a tributary to the Highwood River. The section outcrops in the southernmost of two westward-trending gullies at the head of Lantern Creek, 0.7 miles due south of the largest lake at the head of Picklejar Creek, and 2.3 miles E. 10° N. from the mouth of Picklejar Creek. The section is readily reached by means of a good pack trail high on the side of the valley along the north side of Lantern Creek, between the seismic road and the creek.

Bed		Thickness	Height Above Base
	Overlying beds belong to the Triassic Spray River Formation that consist of dark brown weathering siltstone, very fine-grained sandstone, and black shale. The lower 50 to 100 feet of beds consist of highly recessive, shaly sediments that contrast in composition, colour and resistance to erosion with the underlying Paleozoic strata, being much less resistant and forming a conspicuous gully.		
87	Sandstone, calcitic, quartzitic; medium grey, faintly purplish; very fine- and fine-grained; well sorted; somewhat impure; finely lustre-mottled; lower contact sharp; brittle; medium to thin parting; medium brown weathering; moderately hard; resistant; overlain by soft black shale; this is probably a basal Spray River sandstone; a similar bed occurs at the base of the Spray River in sections in the Crowsnest Pass area	3	
	ROCKY MOUNTAIN SUPERGROUP		
	Tobermory Formation		
86	Sandstone, siliceous; light grey; very fine-grained; well sorted; from 5 to 8 feet above base are fairly numerous thin chert layers 1-3 inches thick; upper half is mostly mottled white due to dull, porcellaneous chert cement in the form of diffuse whisps, dense clots and patches that contain abundant sand, these look superficially like pebbles and granules; most parts are entirely white, sandy, porcellaneous chert with thin streaks and laminae of quartzitic sandstone; some zones are non-sandy, white chert; the basal 1 foot is fine-grained, partly quartzitic sandstone containing fairly abundant, scattered highly rounded chert pebbles up to ½ inch, some reach 1 inch, that are white and contain numerous very fine sand grains, also contains many soft, chalky, tan to light brown grains that range from very fine sand through to fine pebbles that		

	may be dolomite or weathered chert; basal contact may represent an unconformity; very thinly stratified; moderately resistant; slope-forming	19	187
85	Sandstone, siliceous or sandy chert; almost entirely white, dull, porcellaneous; contains extremely numerous fine spicules; upper contact appears gradational; brittle; much yellow-brown staining; massive; moderately resistant	5	168
84	Conglomerate, black; fragments consist of very highly rounded, fairly numerous, light grey-white, even textured chert, mostly granules and fine pebbles, a few reach several inches in diameter, and some are sandy; a few dull, black, slightly sandy, well rounded phosphorite pebbles of fine pebble size; very numerous thin, black clay films throhgout; matrix is very abundant and consists of dark, phosphatic, fine-grained sandstone; upper contact very sharp and undulatory; conglomerate seems to grade downwards in most places but the precise relationships are not easily detected; at one point the lower contact is definitely gradational through a thin, fine to medium, rather poorly sorted, light brown wsandstone that contains scattered fine pebbles of chert and phosphorite	1	163
	Total Thickness of Tobermory Formation	25	

Tyrwhitt Formation

83	Sandstone, quartzitic; light tan-grey; very fine- to fine-grained; fairly well sorted; very many soft, chalky, tan, very fine altered chert grains; base is mainly fine-grained; top is fine with extremely numerous altered chert grains; massive with very uneven, thin to very thick, highly irregular parting; brownish weathering, mostly dark lichen covered; hard; brittle; moderately resistant	6	162
82	Dolomite, sandy; light grey; microcrystalline; exceedingly abundant very fine through coarse sand, evenly to unevenly distributed throughout; sand mostly fine; great abundance of irregular, very thin to thin, brown weathering quartzitic sandstone laminae and streaks throughout; coarse, well rounded quartz grains occur, particularly at the base; contacts sharp, upper highly undulatory; massive; thick parting; light tan-grey weathering; hard; resistant	6	156
81	Sandstone, dolomitic; light grey; very poorly sorted; alternating laminae and bands of sandy dolomite similar to that in unit 82 and dolomitic to quartzitic sandstone; bands range from thin laminae up to 1 inch of quartzitic sandstone with recessed sandy dolomite laminae; sand is very fine through coarse, much medium to coarse well rounded quartz and chert; massive; light brown weathering; hard; resistant; upper contact gradational; closely related lithologically to overlying bed	2	150

80	Dolomite, sandy; light grey; very fine to fine crystalline; very abundant very fine and fine disseminated sand; massive; medium to light grey weathering; hard; resistant; contacts exceedingly sharp	2	148
79	Sandstone, quartzitic; light grey; very fine-grained; well sorted; slightly dolomitic; very massive; brownish-grey weathering; hard; resistant; cliff-forming	5	146
78	Siltstone, sandy, argillaceous; light greenish-grey; very abundant extremely fine disseminated sand; very argillaceous; lower 5 feet covered, probably highly shaly; from 5-6 feet is very rusty siltstone; remainder mostly very platy, rather soft, highly recessive; upper few inches highly recessive, platy and shaly; forms very distinct gully; upper contact very sharp	13	141
77	Sandstone, quartzitic; light tan-grey; very fine; fairly well sorted; slightly dolomitic; irregular thin to medium parting; slightly brown weathering, heavily lichen covered; hard; resistant	8	128
76	Sandstone, quartzitic; light grey; very fine, a few fine grains; well sorted; basal 1 foot microcrystalline dolomite, medium grey, highly sandy, containing at least half very poorly sorted very fine through coarse, highly rounded quartz and chert sand; contacts very sharp; massive, conspicuous uneven 3 to 12 inch parting; medium to light brown weathering; hard; resistant	13	120
75	Sandstone, dolomitic; light grey; very fine-grained; well sorted; irregular uneven patchy distribution of quartz and dolomite cement; much is half sand and half dolomite; much of weathered surface is rough and pitted from etching of unevenly cemented sand; very massive; medium brown weathering; hard; resistant; cliff-forming	10	107
74	Sandstone, exceedingly dolomitic; light grey; very fine to fine; fairly well sorted; many tiny patches of highly sandy dolomite which is microcrystalline, giving weathered surfaces a patchy appearance; at the top are base are 1-2 foot zones containing poorly preserved, silicified brachiopods GSC loc. 53472 ?<u>Spirifer occiduus</u>; contacts sharp; massive, with 3 to 12 inch parting, well stratified; light grey, somewhat brownish weathering; hard; resistant; cliff-forming	8	97
73	Sandstone, dolomitic, quartzitic; light grey; very fine-grained; some fine grains; well sorted; upper contact extremely sharp; massive with distinct regular to somewhat irregular parting 6 to 12 inches thick; medium brown weathering; hard; resistant; cliff-forming	17	89

72	Sandstone, chert cemented; light grey; extremely fine-grained; relations of sand and chert obscure from abundant rusty staining; brittle; contacts extremely sharp; tends to be recessive; very rusty weathering	1	72
71	Sandstone, dolomitic; light grey; fine-grained; moderately well sorted; a few medium to coarse well rounded quartz grains; very slightly quartzitic in parts; well stratified; conspicuous 3 to 6 inch parting; contacts sharp; light brownish-grey weathering; hard; resistant	5	71
	Total Thickness of Tyrwhitt Formation	96	

Todhunter Formation

70	Dolomite, highly sandy; light grey; finely crystalline; abundant disseminated fine to well rounded medium, and a few coarse quartz grains throughout; scattered silicified brachiopod fragments; contacts sharp; medium parting; medium to light grey weathering; hard; resistant	2	66
69	Dolomite, highly sandy; light grey; microcrystalline; very abundant very fine to medium and a few coarse sand grains disseminated throughout; some zones are highly dolomitic sandstone; uneven, irregular, thin to thick parting; light grey to grey to brownish-grey weathering; hard; resistant; cliff-forming	17	64
68	Dolomite, silty-sandy; medium grey; microcrystalline; even textured; fairly abundant silt and very fine sand unevenly disseminated throughout; contacts very sharp; massive, with medium parting; light grey weathering; hard; resistant	3	47
67	Sandstone-siltstone; pale greenish-light grey; extremely fine; may be all sandy siltstone; even textured; very slightly argillaceous; slightly pyritic; upper contact extremely sharp; irregular 6 to 12 inch parting; laterally thin flaky shale partings present; mostly rusty and very distinctive weathering colour; very hard; moderately resistant but somewhat recessive	5	44
66	Sandstone, highly dolomitic; very fine-grained; extremely abundant dolomite; light brownish-grey; massive; light brown weathering; hard; upper contact sharp	1	39
65	Covered	1	38
64	Dolomite, highly sandy; light grey; microcrystalline; very abundant disseminated coarse silt and very fine sand; few coarse highly rounded sand grains; very massive; light brown weathering; hard; resistant	1	37

63	Dolomite, silty; light grey; microcrystalline; even textured; contacts exceedingly sharp and flat; thins laterally to only a few inches; massive; light grey weathering; hard	1	36
62	Sandstone, dolomitic, quartzitic; light grey; mostly very fine-grained but with numerous fine and a few medium grains; medium sorting; contains a thin zone in which are numerous medium and some coarse, well rounded quartz grains; weathered surface etched and laminated with 1/2 to 1 inch wide bands; massive with an even 6 inch parting; basal contact sharp and welded; upper contact exceedingly sharp; medium brown weathering; hard; resistant	5	35
61	Dolomite, light tan-grey; microcrystalline; lower 3-4 inches contain very abundant silt to very fine sand that is evenly disseminated; upper half contains abundant fragments of light grey, very fine-grained, well sorted, quartz cemented sandstone rock fragments, ranging from small granules up to 1/2 inch pebbles, angular through rounded; clastic fragments not in contact, most of granule size; massive; light grey, slightly tan weathering; hard; lower contact extremely sharp	1	30
60	Siltstone, sandy, slightly argillaceous; light grey, faintly greenish; even textured; abundant disseminated extremely fine sand; upper half is the most argillaceous, and platy to flaky; from 8 to 13 feet above base poorly exposed, in part light green and platy; lower 5 feet contain many oxidized pyrite nodules up to 1 inch, produce much rusty staining; upper contact very sharp; at top is a thin platy to flaky, highly argillaceous siltstone that is very recessive; both dolomitic and quartzitic zones are present; generally non-resistant; slope-forming; medium brown weathering	25	29
59	Covered	4	4
	Total Thickness of the Todhunter Formation	66	

RUNDLE GROUP

Etherington Formation

58	Dolomite, extremely sandy; light grey; microcrystalline; very abundant, very fine to medium sand evenly disseminated; sand is mostly very fine; locally at top is a very uneven zone of light greyish weathering quartzitic sandstone, very fine-grained, the upper surface of which is greenish; lower contact very sharp; very massive; medium brown weathering; hard; resistant	2	
57	Dolomite, silty; medium-light grey; microcrystalline; very even textured; abundant silt and some very fine sand disseminated		

throughout; fairly numerous very thin, etched laminae of silt; very sharp contacts; massive; light grey, very slightly tan weathering; very hard 1

56 Dolomite, sandy-silty; medium-light grey; microcrystalline; abundant silt to very fine sand unevenly disseminated throughout; fairly numerous irregularly shaped chert nodules up to several inches long; upper contact sharp; very massive; light grey weathering; hard; resistant 4

Remainder of Etherington consists of dense, sandy, grey dolomite with a few thin sandstone interbeds. Near the base are some fine to coarse grained skeletal limestone beds underlain by a few feet of dense yellowish-brown weathering dolomite and a 4 foot green, highly recessive shale.

SECTION 32

Location: This section is located on the west side of Misty Range adjacent to Storm Creek, tributary to Highwood River. The section outcrops on the north side of a long, narrow spur trending to the southwest off the southern end of Storm Mountain, 0.8 miles S. 16° W. from the peak. The section is most easily reached from the Kananaskis-Coleman Highway where it crosses Storm Creek.

Bed		Thickness	Height Above Base
	Overlying beds belong to the Triassic Spray River Formation which consists of dark brown weathering, platy to flaggy siltstone, shaly siltstone and silty black shale. The lowermost 50-100 feet are highly shaly and very recessive, and form a distinctive saddle in the ridge. The underlying Rocky Mountain sandstones contrast readily in resistance, colour and stratification.		
	ROCKY MOUNTAIN SUPERGROUP		
	Storelk Formation		
51	Sandstone, quartzitic; light grey; lower 40 feet light tan; averages fine to very fine, some zones contain more fine to fine grains, others more very fine; a few zones are fine to medium; coarse sand grains almost entirely absent, only a few observed; unit as a whole is slightly coarser grained than underlying sandstones; white, porcellaneous chert grains fairly numerous; sorting ranges from good to medium in alternating zones; some parts rather strongly cross-bedded; contact with overlying Spray River not examined, but no evidence observed of any white chert or conglomerate at the top; extremely massive; an irregular fracture may follow cross-sets; accurate measurement of thickness difficult; grey-white weathering, very heavy black, grey and green lichen cover; much orange staining; very hard; highly resistant; very conspicuous from a long distance because of the peculiar dark greyish colour; forms western dip-slope of Misty Range.	209	528
	Total Thickness of Storelk Formation	209	
	Tyrwhitt Formation		
51A	Sandstone, dolomitic; light tan; very fine to fine; moderately well sorted; lower 1½ feet contain extremely numerous medium to coarse, highly rounded quartz and abundant rounded to poorly rounded, tan, maroon, and		

	and grey chert grains; massive; light brown weathering; hard; resistant	4	319
51B	Sandstone, evenly quartzitic and dolomitic; light tan; predominantly very fine-grained; some zones contain a few to many fine grains; well sorted; average grain size near the very fine and fine grade boundary; some cross-bedding at 60 to 80 feet from base; some zones more quartzitic than dolomitic; very massive, medium to very thick parting; lower 25 feet more quartzitic; lower 10 feet light grey to grey-white weathering; remainder light tan to light brown-tan; hard; resistant; this unit is quite similar to the Storelk Formation and may easily be considered the lower part of it	137	315
50	Sandstone, argillaceous, silty; light tan-grey; lower 3 inches flaky light green shale, overlain by 1 foot of sandstone, very fine-grained, slightly argillaceous, massive, in the centre of which is a 2 inch flaky green shale layer; remainder very dolomitic, very fine with many fine grains; moderately well sorted; upper contact exceedingly flat, sharp; platy to flaggy parting; light brown weathering; moderately hard; somewhat recessive; gully-forming	4	178
49	Sandstone, quartzitic and dolomitic; light brown very fine- to fine-grained; well sorted; contacts sharp; some fairly coarse cross-bedding; similar to underlying bed; very massive; medium brown weathering; hard; resistant	5	174
48	Sandstone, quartzitic and dolomitic; light greyish; very fine-grained; well sorted; massive; parts medium brown weathering, others grey-white; very hard; resistant; bold cliff-forming	7	169
47	Siltstone, argillaceous, silty; dark grey; very fine sand is disseminated; upper few inches light green, flaky silty shale; contains a few oxidized pyrite nodules; upper contact exceedingly sharp, very flat over a long distance; very massive; medium brown weathering; very hard but recessive, gully-forming	6	162
46	Sandstone, quartzitic, slightly dolomitic; light tan-grey; very fine to fine; well sorted; some fine cross-stratification; contacts very sharp; mainly quartzitic; extremely massive; medium to light brown to light greyish weathering; hard; resistant; cliff-forming	9	156
45	Sandstone, quartzitic and dolomitic; light tan; poorly sorted; averages fine sand, some zones range from very fine through coarse, others fine and medium with a few coarse, and others mainly fine-grained and better sorted; larger grains well rounded, fine grains moderately well rounded; some thin zones are more quartzitic and greyish weathering; fairly strongly cross-bedded throughout; weathered surfaces		

	etched to long, thin cross-laminae; very massive; medium brown weathering; hard; resistant; cliff-forming	15	147
44	Sandstone, dolomitic; light grey; mainly very fine-grained but many disseminated fine grains and a few medium and coarse chert and quartz grains; poorly sorted; basal foot contains very abundant coarse, highly rounded quartz and chert grains, finer grains well rounded, highly dolomitic; upper foot contains numerous silicified brachiopod, poorly preserved; upper contact very sharp; probably grades down; massive; medium to light brownish weathering; medium parting; hard; resistant	3	132
43	Sandstone, extremely dolomitic; light tan to tan-grey; mainly fine-grained, some medium and very few coarse grains; poorly sorted; most grains well rounded; very high proportion of very fine crystalline dolomite cement; very porous; soft and friable in some zones with very fine vuggy porosity; some zones very hard; contains some thin indistinct silicified layers up to about 1 inch with highly irregular, indistinct boundaries; massive; tan to grey weathering; somewhat recessive	4	129
42	Sandstone, mainly quartzitic, also dolomitic; light grey; mainly very fine-grained, some fine grains; average size near very fine and fine sand boundary; one foot from top is a 6 inch zone of dolomitic sandstone similar to unit 41; massive; medium brown weathering; hard; resistant; cliff-forming	5	125
41	Sandstone, dolomitic; light grey; mainly very fine-grained, but much is near the very fine and fine grade boundary; some fine grains; in centre is a 6 inch zone of light grey, very fine to medium, extremely porous, very friable sandstone with well rounded grains, and fairly numerous fine to coarse dark brown to black phosphorite grains; upper foot is fine-grained with some medium and a few coarse grains also with numerous fine to coarse phosphorite grains; weathered surface greatly pitted; contacts very sharp; massive; light brown weathering; hard; resistant; cliff-forming	6	120
40	Sandstone, dolomitic, quartzitic; light grey; mainly very fine-grained; average grade falls on very fine and fine sand boundary; some fine grains; well sorted; much crusty, even quartz cementation etched to relief; weathered surfaces knobby, pitted, rough; extremely massive; medium brown weathering; hard; resistant; bold cliff	20	114
39	Sandstone, quartzitic; light grey; very fine-grained, many very fine to fine grains; contacts very sharp; very massive; light grey to brownish-grey weathering; hard; resistant; cliff-forming	3	94

38	Sandstone, dolomitic; light grey; very fine- and fine-grained; a few medium grains; medium sorting; very numerous white, silicified brachiopods GSC loc. 53441 *Spirifer curvilateralis*, most seem to be fragmented, scattered throughout; lower foot strongly laminated, remainder knobby and finely pitted; massive; thick to very thick parting; medium brown weathering; hard; resistant; cliff-forming	8	91
	This bed may be the lateral facies equivalent of part of the Middle Todhunter *Spirifer* tongue in Elk Range, section 26 Mount Storelk.		
37	Sandstone, quartzitic; medium-light grey; fine- and very fine-grained; moderately well sorted; lower 6 inches very vuggy; upper contact exceedingly sharp; very massive; grey-white weathering; heavily lichen covered; hard; resistant; cliff-forming	2	83
36	Sandstone, dolomitic; very light tan; very fine- and fine-grained with abundant medium grains; medium to poorly sorted; upper contact gradational; very massive, uneven fracture; medium brown weathering; hard; resistant; cliff-forming	7	81
	Total Thickness of Tyrwhitt Formation	245	

Todhunter Formation

Middle Part

35	Dolomite, sandy; light tan-grey; very fine crystalline; compact; much is very fine granular and extremely porous; fairly abundant poorly sorted quartz sand from very fine to coarse, highly rounded; fairly numerous fine to coarse black phosphorite sand grains; similar to unit 33; upper contact very flat and sharp; massive; light grey weathering; soft; moderately recessive	2	74
34	Sandstone, highly dolomitic; light grey; very fine-grained; well sorted; upper contact gradational; lower contact indistinct; uniform; massive, blocky; dark brownish weathering; hard; resistant; cliff-forming	4	72
33	Dolomite, highly sandy; light grey; some zones are highly dolomitic sandstone; dolomite is very fine crystalline, compact to very fine granular and porous; sand is quartz, very fine, fine, some medium grains and very few coarse, mostly highly rounded; some thin zones are silicified and have preserved an obscure fragmental, skeletal, calcarenitic texture in which crinoid columnals and stems are fairly numerous, together with a very few ossicles, spines, and bryozoa; fairly numerous vugs from fine up to 2 inches; quite porous throughout; boundaries abrupt to indistinct; massive; medium to greyish weathering; parts are rather soft; somewhat recessive	1	68

32	Dolomite, highly sandy; medium-light grey; finely crystalline; tight; very abundant poorly sorted, unevenly distributed fine to coarse, mainly fine quartz sand; all sand grains highly rounded; fairly numerous black, discontinuous lenses of chert 1-6 inches thick, some rounded nodules; may grade downwards; very massive; medium brownish-grey weathering; hard; resistant; cliff-forming	5	67
31	Sandstone, dolomitic; light grey; well to poorly sorted; some zones mainly very fine-grained, others very fine to fine, others fine and very fine with some medium grains, and others mainly fine with some medium grains; fine and medium grains highly rounded; upper contact gradational; finely cross-bedded; very massive; very finely fractured; medium brown weathering; hard; resistant; cliff-forming	10	62
30	Dolomite, highly sandy; light grey; very fine granular; soft; consists of half sand and half dolomite; sand is fine and medium, well rounded; some vugs up to several inches; contacts highly irregular, indistinct; almost friable; massive; light greyish weathering; soft; recessive; seems to thin to zero laterally	2	52
29	Sandstone, dolomitic; light grey; parts very fine-grained; well sorted; other parts poorly sorted, very fine- to medium-grained and grains highly rounded; numerous thin etched laminae define fine-medium cross-stratification; upper contact indistinct; massive; medium to light brown weathering; hard; resistant	3	50
28	Sandstone, dolomitic; light grey; very fine-grained, some fine grains; well sorted; very highly dolomitic; many zones are half dolomite and half sand; contains a few zones 1-6 inches thick of light grey weathering, soft, somewhat recessive, mainly fine-grained sandstone; very numerous silicified, fragmented brachiopods GSC loc. 53442 <u>Spirifer occiduus</u>; fossils scattered throughout; top 3-4 inches quartzitic, light grey weathering; massive; medium brown weathering; hard; resistant; cliff-forming	7	47
27	Dolomite, light grey; exceedingly fine to cryptocrystalline; even textured; a very few fine rounded quartz grains; upper part contains some very elongate chert nodules 1-4 inches thick, brownish weathering; upper contact rapidly gradational, lower sharp; massive, 1 foot parting; light grey, slightly tan weathering; hard; resistant; cliff-forming	6	40

Lower Part

26	Sandstone, quartzitic-dolomitic; light grey to dark grey; very fine-grained; somewhat silty; abundant very fine muscovite flakes; numerous thin shaly-silty partings 1-3 inches thick; alternating with sandstone, producing a concpicuous thin stratification; essentially alternations of units 24 and 25;		

	upper contact very sharp; medium brown weathering; hard; moderately resistant, but somewhat recessive relative to unit 27	10	34
25	Siltstone, argillaceous; black; even textured; very abundant very fine muscovite flakes; top few inches greenish; upper contact exceedingly sharp; lower contact sharp; fine vubbly parting; fairly recessive; forms a distinct narrow gully between more resistant units	3	24
24	Siltstone, dolomitic, slightly argillaceous; dark grey; very slightly greenish; even textured; very faint and very thin lamination throughout; slightly micaceous; very massive; coarse curved fracture; medium brown weathering; hard; resistant	6	21
23	Sandstone, quartzitic and dolomitic; light tan-grey; some dark grey mottling from bitumen; very fine-grained; well sorted; lower 2 feet contain a few large rounded quartz-cemented nodules; upper contact very sharp; massive; medium brown weathering; hard; resistant; cliff-forming	3	15
22	Sandstone, mainly dolomitic; light grey; predominantly very fine-grained, but some very fine to fine sand grains; well sorted; basal few inches quartzitic; many exceedingly thin, parallel slightly etched laminae; contacts very sharp; massive; medium brown weathering; hard; resistant but slightly recessive	3	12
21	Sandstone, dolomitic; light grey; very fine-grained; very well sorted; very massive; thick parting; medium brown weathering, distinctive colour; surfaces finely knobby and finely pitted; hard; resistant; cliff-forming	9	9
	Total Thickness of Todhunter Formation	74	

Contact conformable

RUNDLE GROUP

Etherington Formation

Ewin Creek Member

20	Dolomite, highly sandy; medium-light grey; microcrystalline; very abundant disseminated very fine to fine, rounded quartz sand; fairly numerous black, white weathering chert layers 1-6 inches thick, and a few large rounded nodules; massive; light yellowish-grey to light grey weathering; hard; resistant; cliff-forming; contact appear gradational	8	
19	Sandstone, dolomitic; light grey; very fine-grained; well sorted; uniform; extremely massive; medium brown weathering; hard; resistant; cliff-forming	11	

18 Sandstone, dolomitic; light grey; very fine- to fine-grained; grains well rounded; well sorted; lower 6 inches is a medium grey, quartzitic siltstone and a second 1-2 inch layer is present near the middle; contains a few very thin crusty layers of silica cemented; contacts very sharp; massive; light tannish-grey weathering; hard; resistant; cliff-forming 3

17 Sandstone, dolomitic; silty; medium grey; very fine-grained; abundant coarse silt; moderately well sorted; even textured; contacts sharp; massive; medium to light grey weathering; hard; resistant 1

16 Dolomite, highly sandy; medium grey; microcrystalline; sand well rounded, mostly very fine, some fine, fairly evenly disseminated; fairly numerous irregular, smoky-grey chert nodules up to about 6 inches thick and 1 foot long; contacts very sharp; massive; light grey weathering; hard; resistant; cliff-forming 3

15 Sandstone, dolomitic; medium-light grey; very fine-grained; well sorted; weathered surface very strongly laminated due to differential etching of very thin, but uneven alternating laminae of slightly quartzitic and dolomitic cemented zones; upper contact very sharp; massive; medium brown weathering; hard; resistant; cliff-forming 6

14 Dolomite, sandy; medium grey; cryptocrystalline; abundant very fine and very little fine, well rounded quartz sand; contacts very sharp; massive; light grey weathering; hard 1

13 Sandstone, dolomitic; medium-light grey; very fine-grained; parts laminated and deeply etched; most surfaces finely pitted and knobby; contacts very sharp; massive; medium brown weathering; hard; resistant; cliff-forming 4

12 Sandstone, highly dolomitic, slightly quartzitic; light grey; very fine-grained; mostly strongly laminated; laminae quite variable, mostly cross-laminae; laminae are made conspicuous by differential etching of alternating sandy dolomite or dolomitic-quartzitic zones ranging from exceedingly thin laminae up to thick laminae; several thin zones of quartz cement up to about 1 inch thick; some thin dolomitic zones; upper contact very sharp; massive; upper half has 1-2 foot parting; medium brown weathering; hard; resistant; cliff-forming 9

Most of the remainder of the Ewin Creek Member is dense, sandy, medium grey dolomite. Total measured thickness of Ewin Creek Member is 102 feet. In fault contact with sandstones of the Tyrwhitt Formation.

SECTION 33

Location: This section is located on the west side of Misty Range in the cirque which forms the headwaters of Storm Creek. The section outcrops on the south side of the cirque, and along the north side of a southwesterly-trending ridge off the peak of Mount Arethusa. The section is completely exposed and is readily accessible by means of a short walk east of the summit of Highwood Pass. The uppermost part of the Storelk Formation may be faulted and should not be included as part of a detailed section.

Bed		Thickness	Height Above Base
	ROCKY MOUNTAIN SUPERGROUP		
	Tyrwhitt Formation		
136	Sandstone, dolomitic, quartzitic; light tan; fine- and very fine-grained; moderately well sorted; lower contact fairly sharp; extremely fine fracture parallel to contacts; parting 1/4 to 1 inch thick; medium to light grey weathering; somewhat recessive	9	115
135	Sandstone, quartzitic, slightly dolomitic; light tan; very fine-grained; well sorted; massive with variable parting from 1 inch up to medium; mostly very light brown weathering but grey-white where quartzitic and maturely weathered; heavily lichen covered; fairly widespread orange-brown weathering stain; very hard; brittle; highly resistant; cliff-forming; easily mistaken for the Storelk Formation	33	106
	Todhunter Formation		
134	Sandstone, dolomitic and quartzitic; light tan-grey; very fine-grained; well sorted; upper contact very sharp; very fine cross-laminae etched to conspicuous relief; flaggy to medium parting; upper foot flaky and recessive; medium brown weathering; extremely hard; moderately resistant	3	73
133	Shale, silty; slightly sandy; maroon; flaky; highly recessive; contacts very sharp	1	70
132	Sandstone, quartzitic; medium green; upper 1 foot mottled grey-white and green; very fine- and fine-grained; well sorted; tight; very brittle; lower part finely fractured; massive; coloured green by traces of green clay; lower half light tan; moderately resistant	2	69

131	Sandstone, dolomitic; light tan; very fine- and fine-grained; well sorted; at base is a 6 inch bed of slightly maroon-grey, very finely fractured chert; massive; irregular blocky fracture; medium brown weathering; hard; resistant	4	67
130	Sandstone, dolomitic; light tan; fine-grained, some very fine and medium grains; few Orbiculoidea shell fragments; medium sorting; few coarse sand grains in upper 2 feet; massive, irregular thin to medium parting; medium to light brown weathering; hard; resistant	7	63
129	Sandstone, chert-cemented; medium grey; very fine-grained; contacts sharp; massive; grey-white weathering; hard; brittle	1	56
128	Siltstone-sandstone, argillaceous; deep maroon; in part sandy siltstone, in part silty sandstone; rather poorly sorted; massive; hard; resistant	2	55
127	Siltstone-sandstone; mostly deep maroon, lowermost part light tan; in part sandy siltstone, in part very fine silty sandstone; at top is a 2-3 inch quartzitic zone; weathered surfaces very finely laminated from differential etching of poorly sorted argillaceous, silty, sandy layers; massive; uneven zones weather dark maroon, medium to dark brown to maroon; very hard; resistant; cliff-forming	9	53
126	Sandstone, dolomitic; light tan-grey; very fine-grained; well sorted; contains some thick, pale maroon to light grey cherty layers, long, lenticular, up to 4 inches thick; upper contact sharp; massive; medium brown weathering; hard; resistant	2	44
125	Sandstone, cherty; greyish to pale greenish-grey; very fine-grained; well sorted; consists of alternating zones of rather porous, only partly cemented sand 1/2 to 1 inch and similar layers of slightly greenish-grey to pale maroon, hard, chert-cemented layers; lower contact sharp; upper contact indistinct; irregular flaky to platy parting; brittle; recessive	2	42
124	Sandstone, dolomitic and quartzitic; light grey; very fine-grained; well sorted; massive, blocky; medium grey, slightly brown weathering; hard; resistant	2	40
123	Dolomite, exceedingly sandy; medium-light grey; microcrystalline; sand ranges from extremely fine to fine, a few well rounded medium and coarse grains, poorly sorted; sand is unevenly distributed throughout as extremely thin, discontinuous brown weathering sandstone laminae; parts are dolomitic sandstone; very massive, 1 foot parting; contacts sharp; medium brown weathering; hard; resistant; cliff-forming	4	38
122	Dolomite, silty; light tan; microcrystalline; silt abundant, evenly disseminated; contacts sharp; finely fractured; incompletely weathered; recessive; gully-forming	2	34

121	Dolomite, silty; medium grey; microcrystalline; abundant silt disseminated; massive, 1 foot parting; very light tan weathering; very hard; resistant; cliff-forming	3	32
120	Sandstone, dolomitic; medium-light grey; very fine-grained; well sorted; upper contact very sharp; flaggy parting; medium brown weathering; hard; resistant; cliff-forming; upper half slightly recessive	11	29
119	Sandstone, dolomitic; medium grey to tan; very fine-grained; well sorted; some bitumen staining; massive, very platy parting throughout; medium to light brown weathering; hard; resistant; cliff-forming	11	
118	Dolomite, extremely sandy; medium grey; microcrystalline; sand is poorly sorted, very fine to medium, well rounded; sand occurs in very thin etched laminae up to laminae 1/4 inch thick, etched to high relief; sand also evenly disseminated; some parts are half sand; in middle is a zone from 1/8 to 1 inch thick of brown weathering, finely comminuted, silicifed skeletal debris, including shell fragments, bryozoa, crinoid columnals; massive; tan weathering; hard; resistant; cliff-forming	2	7
117	Sandstone, dolomitic; medium grey; very fine-grained; well sorted; at top is a 2-3 inch flaky maroon, argillaceous siltstone or very fine sandstone; weathered surfaces exceedingly finely laminated; upper contact very sharp; upper argillaceous zone grades down rapidly; very platy; medium brown weathering, slightly grey; very hard; resistant; cliff-forming	5	5
	Total Thickness of Todhunter Formation	73	

Contact conformable

RUNDLE GROUP

Etherington Formation

Ewin Creek Member

116	Dolomite, very sandy; medium-light grey; microcrystalline; sand ranges from very fine to fine, even to unevenly distributed; massive, parting 1-2 feet; light tan to brown weathering; extremely hard; resistant; cliff-forming	9	
115	Dolomite, siliceous, silty; medium-light grey; microcrystalline; clastics range from silt to very fine sand, fairly abundant, disseminated; chert abundant, from impure to pure nodules, ranging from tiny streks up to 2 inch thick nodules several inches long; nodules mostly smoky-grey, some are maroon, many flecked with jasper and some preserve a few bryozoan		

fronds which also occur in the dolomite; many impure brown weathering chert nodules of partly silicified dolomite; two feet from base is a 6 inch bed of chert which thins laterally to zero; massive; medium-light to very light tan tan weathering; exceedingly hard; highly resistant; cliff-forming; very prominent 11

114 Sandstone, quartzitic; light grey; very fine-grained; well sorted; lower foot dolomitic; massive, 1-6 inch parting; light grey weathering; hard; resistant; upper contact sharp 3

113 Sandstone, highly dolomitic; medium grey; very fine-grained; well sorted; parts consist of half dolomite, half sand; lower foot contains scattered pink silicified masses; upper contact sharp but slightly gradational; massive, thin to medium parting; medium to light brown weathering; very hard; resistant; cliff-forming 4

112 Dolomite, silty; medium grey; microcrystalline; abundant silt evenly disseminated; lower foot contains a few black chert nodules; contacts sharp; massive, thin to rubbly parting; medium to light brown weathering; hard; somewhat recessive 3

111 Dolomite, extremely sandy; medium-light grey; microcrystalline; half dolomite and half sand; sand is very fine to fine, some medium, rare coarse grains; sand fairly evenly disseminated; contacts sharp; very massive; light grey to brownish-grey weathering; hard; resistant; cliff-forming 4

110 Dolomite, medium-light grey; microcrystalline; massive; light tan-grey weathering; contacts sharp; hard 1

109 Sandstone, dolomitic; medium-light grey; very fine-grained; well sorted; deep differential etching produces thin discontinuous ribs on weathered surface; very massive; medium brown weathering; hard; resistant; cliff-forming 4

108 Dolomite, sandy; medium-light grey; microcrystalline; very abundant very fine to fine quartz sand evenly disseminated; contacts very sharp; very massive; medium brown weathering; hard; resistant; cliff-forming 3

107 Sandstone, dolomitic; medium-light grey; extremely fine to very fine; moderately well sorted; some faint etched very thin laminae; contacts very sharp; very massive; medium brown weathering; hard; resistant; cliff-forming 4

106 Sandstone, highly dolomitic; light grey; very fine-grained; well sorted; much is half dolomite; weathered surfaces etched to discontinuous thick laminae and irregular thin laminae; some zones have very distinct, deeply etched, thin sandy laminae; upper half contains a few thin layers of discontinuous chert nodules; massive; medium to thick parting; light brown weathering; hard; resistant; cliff-forming 22

105 Dolomite, sandy; medium-light grey; very fine crystalline; numerous ghost-like remnants of altered skeletal fragments in lower few inches ranging from fine to very coarse sand grades; upper part rather soft, porous, with much sparry calcite and skeletal material; irregular block fracture; medium grey weathering; in part very hard; slightly recessive; contacts distinct 2

Remainder of Ewin Creek Member consists of grey, sandy to nonsandy, microcrystalline, hard, resistant, cliff-forming light grey weathering dolomite. In the lower part are six beds of partly dolomitized to unaltered skeletal, echinodermal calcarenite ranging from 1 to 10 feet in thickness.

SECTION 41

Location: This, the type section of the Tunnel Mountain Formation, is exposed along the west bank of Bow River opposite the mouth of Spray River, on the south side of Tunnel Mountain at Banff, Alberta. The section is almost completely exposed, and both upper and lower contacts are clearly defined.

Bed		Thickness	Height Above Base
	Overlying beds belong to the Kananaskis Formation which consists of dense, sandy dolomite with abundant chert as nodules and thick beds. Ten feet above the base is a six foot bed of light grey, finely fractured chert which forms a prominent outcrop that juts out beyond adjacent beds into the river.		
	ROCKY MOUNTAIN SUPERGROUP		
	Tobermory Formation		
84	Sandstone, quartzitic; white; fine- and very fine-grained; moderately well sorted; upper contact with Kananaskis abrupt but very uneven; massive; lower foot incipient platy parting; light grey weathering; brittle; hard; resistant	3	296
83	Sandstone, quartzitic; medium grey; very fine-grained; well sorted; upper 3-4 inches fine, flaky, argillaceous, very recessive, grades down; very massive; greyish weathering; some iron staining; hard; brittle	2	293
82	Sandstone, dolomitic; light grey; very fine-grained; well sorted; slightly friable; upper few inches quite argillaceous; fine uneven parting; brownish weathering; moderately hard; recessive	2	291
81	Sandstone, dolomitic; light grey; very fine-grained; well sorted; blocky to thin parting; medium brownish-grey weathering; hard; resistant	2	289
80	Sandstone, dolomitic; argillaceous; light grey; very fine-grained; flaky to fine platy parting; somewhat recessive	2	287
79	Sandstone, quartzitic; very light grey; very fine-grained; well sorted; massive; medium brown weathering; very hard; resistant	2	285
78	Sandstone, dolomitic; light grey; very fine-grained; well sorted; at top is a 1-2 inch argillaceous flaky zone; massive; medium brown weathering; very hard; resistant	2	283

77	Sandstone, dolomitic; light grey; very fine-grained; well sorted; lower 6 inches quartzitic; layers 1-6 inches thick are separated by thin argillaceous partings; brown weathering-greyish-brown; hard; moderately resistant	3	281
76	Sandstone, quartzitic-dolomitic; light grey; very fine-grained; well sorted; contacts sharp; massive; medium brown weathering; hard; resistant	1	278
75	Sandstone, quartzitic, slightly dolomitic; medium grey; very fine-grained; upper contact very sharp; medium grey weathering; massive; very hard, brittle; recessive	1	277
74	Covered	1	276
73	Dolomite, extremely sandy; medium grey; very fine crystalline; extremely abundant disseminated very fine to medium, well rounded sand; some zones are dolomitic sandstone; few coarse grains, medium grains numerous; considerable amount of irregular light grey weathering quartz-cemented masses with very sharp boundaries constitute one-third to one-half the bed; basal contact exceedingly sharp, with no evidence of erosion, but surface of Storelk broadly undulatory; massive; medium to light brown weathering; hard; resistant; top surface forms small deep gully directly opposite northernmost of two large outcrops across Bow River	5	275
	Total Thickness of Tobermory Formation	26	

Contact probably unconformable

Storelk Formation

72	Sandstone, quartzitic; very slightly dolomitic; light grey to white; mostly very fine to fine-grained; well sorted; a few zones are slightly coarser and slightly poorer sorted; even textured; lower 5 feet very fine-grained, light grey, very well sorted; extremely massive; may be cross-bedded in parts; mostly light grey weathering, lower part more brown; heavy dark lichen cover; very hard	105	270
	Total Thickness of Storelk Formation	105	

Tyrwhitt Formation

71	Siltstone, sandy; light tan-grey; even textured; fine sand is fairly abundant; may be very slightly argillaceous; platy; brownish-grey weathering; recessive	3	165
70	Sandstone, dolomitic and quartzitic; light grey; very fine-grained; a few scattered fine to medium grains; well sorted; dolomite and quartz cement in zones; massive; dolomitic zones medium-light brown weathering, quartzitic zones light grey; hard; resistant	18	162

69	Siltstone, dolomitic; light grey; even textured; lower foot covered; uneven flaggy to platy parting; brown weathering; recessive	2	144
68	Chert, slightly sandy; smoky-grey; lower contact sharp; massive; very heavily lichen covered; brittle; very hard; resistant	1	142
67	Sandstone, dolomitic, parts partzitic; light grey; very fine-grained and well sorted at top and base; mostly fine-grained and moderately well sorted; fairly numerous irregular zones of quartz cement as stringers up to layers 1-2 inches thick; 1-2 foot parting; dark brown weathering, heavy lichen cover; quartzitic zones weather light grey; hard; resistant	13	141
66	Covered	4	128
65	Sandstone, dolomitic, partly quartzitic; light grey; very fine-grained; well sorted; at base is a fine crystalline dolomite with very abundant rounded fine, some medium and very few coarse, highly rounded quartz sand grains; fairly numerous irregular zones of light grey weathering quartz cement from thin stringers to layers 1-2 inches thick; 1-2 foot parting; dark brown weathering; hard; resistant	7	124
64	Sandstone, dolomitic; light grey; lower half very fine-fine grained; well sorted; upper 2 feet dolomite, light grey, fine to coarsely crystalline with abundant fine to medium well rounded sand, grades downwards; massive; dark brown weathering; heavily lichen covered; hard; resistant; exposed at water level	7	117
63	Covered	15	110
62	Sandstone, dolomitic; very light grey; very fine-grained; well sorted; a few zones with few disseminated larger grains; at top very fine- to fine-grained with a few medium grains, medium sorted; medium to dark brown weathering; extremely hard; largely covered; exposed at water level	43	95
61	Sandstone, dolomitic and quartzitic; light grey; very fine-grained, some fine grains; well sorted; lower contact very sharp; massive; medium brown weathering; hard; resistant	1	52
	Total Thickness of the Tyrwhitt Formation	114	

Contact arbitrarily placed

Todhunter Formation

60	Dolomite, highly sandy; medium-light grey; microcrystalline; silt, very fine sand, some fine, and very few medium quartz grains disseminated; massive; light grey weathering; hard; resistant	2	51

59	Dolomite, highly sandy; medium-light grey; microcrystalline; part extremely fine crystalline; very abundant silt and very fine sand, some fine, and a few medium grains; upper contact sharp; abundant fine chert as irregular, light grey masses; massive; medium brown weathering; very hard; resistant	2	49
58	Sandstone, quartzitic, dolomitic; light grey; mainly very fine-grained with some fine grains; well sorted; massive; grey-white weathering quartzitic parts, dolomitic zones greyish-brown; hard; resistant	10	47
57	Dolomite, extremely sandy; light grey; microcrystalline; very abundant very fine, well sorted sand disseminated; lower few inches contain in addition many fine and a few medium grains; upper contact sharp; massive; medium to light brown weathering; hard	4	37
56	Dolomite, exceedingly sandy; light grey; half sand, half dolomite; dolomite is extremely fine crystalline, sugary; sand is very fine and fine, with a few medium and rare coarse; within lower foot is a thin zone a few inches thick containing extremely abundant very fine to medium well rounded dark grey chert grains, and fairly numerous small Orbiculoidea sp. shell fragments; in middle are some very irregular white silica masses; appears to grade upwards; massive; light tan-light brown weathering; hard; moderately resistant	2	33
55	Sandstone, dolomitic; light grey; very fine-grained; well sorted; slightly micaceous; contains several thin platy zones of siltstone which may be slightly argillaceous; upper foot highly recessive, very argillaceous siltstone which grades upwards; mostly platy and very thin parting; light tan-brown weathering; very hard	4	31
54	Sandstone, dolomitic, quartzitic; light grey; mainly very fine-grained, some zones very fine- and fine-grained; well sorted; at 17 feet from base scattered fine and medium sand with rare coarse grains; lower 2 inches very fine-fine with a few scattered medium and coarse grains; some zones are dolomitic, others quartzitic; some fine cross-lamination; at top is a 1/2 to 2 inch flaky, green, argillaceous parting; lower contact very sharp; very massive; light tan-grey weathering, heavy dark lichen cover; very hard; resistant	27	27
	Total Thickness of Todhunter Formation	51	

RUNDLE GROUP

Etherington Formation

53 Dolomite, highly sandy; light grey; microcrystalline; contains little to very abundant very fine and fine and a little medium quartz sand, unevenly distributed, some in very thin

laminae; upper half essentially sandstone, very fine-grained, well sorted, with very thin alternating sandy dolomite and quartzitic sandstone laminae, the dolomite laminae being deeply recessed producing conspicuous banding; at the top is a 1/2 to 12 inch thick layer of very fine-grained, quartz-chert cemented sandstone to sandy chert with some iron staining; fairly numerous chert nodules and long lenticular layers up to 3 inches thick; some white silica cauliflower-like masses; massive; light tan-grey weathering; hard; resistant 7

PLATE I

A. Unconformable contact between the Etherington and Mount Head Formations, head of Daisy Creek. Basal Etherington bed consists of highly dolomitic, green and maroon conglomerate composed of rounded fragments of claystone and some grey limestone. The uppermost Mount Head Formation (Carnarvon Member) consists of very dense, microcrystalline grey limestone with pale green weathering stringers and laminae of clay. Contact is at the point of the hammer.

B. Sandy dolomite in the upper Etherington Formation (Ewin Creek Member) at the head of Alexander Creek. Differential etching of the dolomitic and quartzitic brown weathering sandstone laminae contrast with the recessed, tan to light grey weathering, dense dolomite laminae. This lamination and ribbing is characteristic of many beds in the upper Etherington Formation.

PLATE I

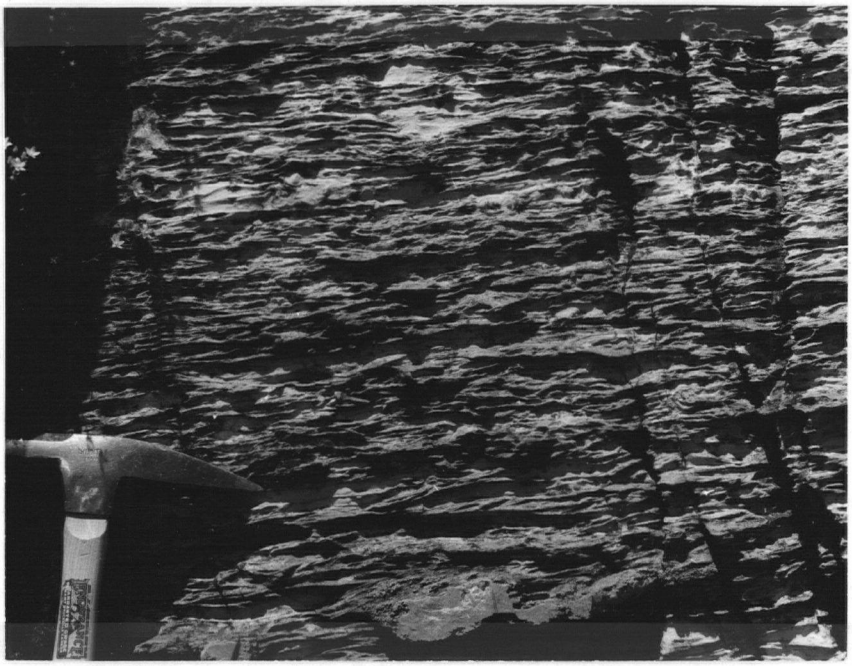


PLATE II

White, coarsely crystalline, banded limestone bed within the lower Rocky Mountain (Tobermory Formation) sandstones at the head of Daisy Creek, west side of Livingstone Range. Note the very sharp, undulatory contacts with surrounding sandstone. Hammer for scale.

PLATE II

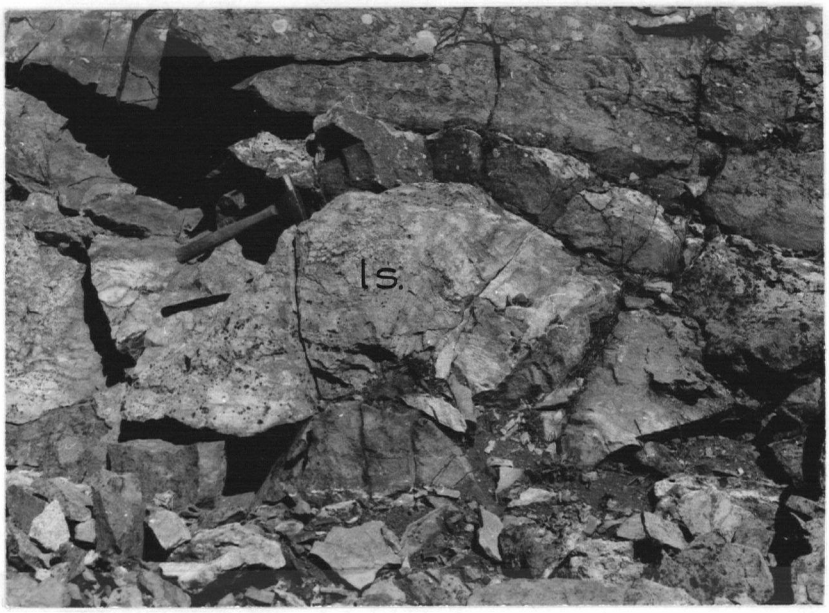


PLATE III

A. Lenticular, white limestone layers in sandstones of the lower Rocky Mountain (Tobermory Formation) at the head of Daisy Creek, west side of Livingstone Range. The irregularly bedded, light grey layer at the base is white, coarsely crystalline calcite, and the light grey weathering bed at the top is the overlying limestone bed shown in Plate II. Laterally to the left the overlying limestone bed in Plate II truncates the sandstone containing the thin lentils and comes to lie immediately above the 1 foot limestone layer in the lower part of the photograph. Hammer for scale.

B. Detail of banded limestone shown in Plate II.

PLATE III

PLATE IV

A. Basal breccia of the lower Rocky Mountain (Tobermory Formation) succession at Savanna Creek, north side of valley, 1/4 mile east of the axis of the Plateau Mountain Anticline. The breccia is composed of light grey chert and dolomite with a sandstone matrix. The breccia rests sharply on microcrystalline, sandy and cherty dolomite of the Etherington Formation (Ewin Creek Member.

B. Detail of contact of quartz sandstones of the lower Rocky Mountain (Tobermory Formation) with the dolomite-chert breccia shown in the above photograph

PLATE IV

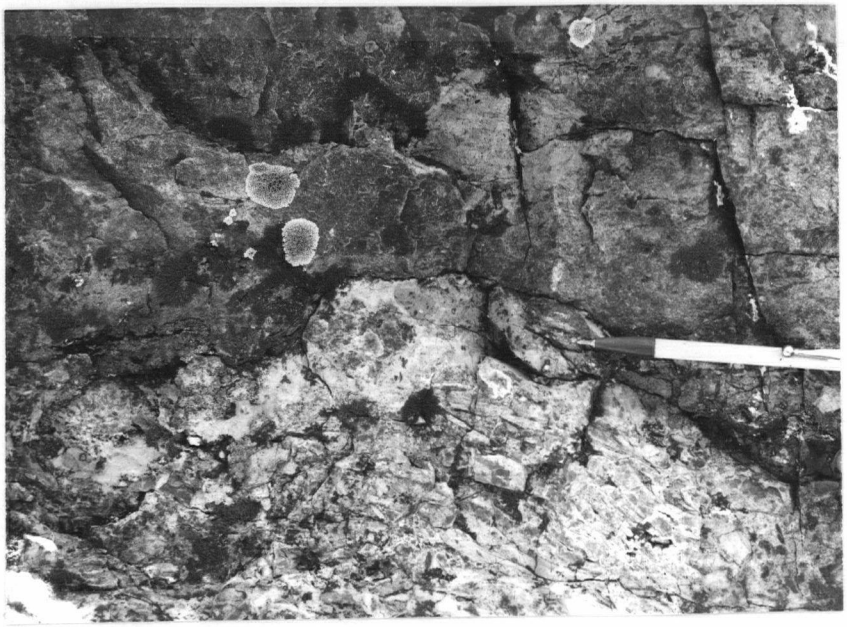


PLATE V

Chert layers interbedded with calcitic and quartzitic, very fine- and fine-grained sandstone of the lower Rocky Mountain (Tobermory Formation) sandstones at The Gap, west side of Livingstone Range. This cherty zone may be approximately equivalent to the Plagioglypta novaculite described by McGugan and Rapson from the Bow Valley region.

PLATE V

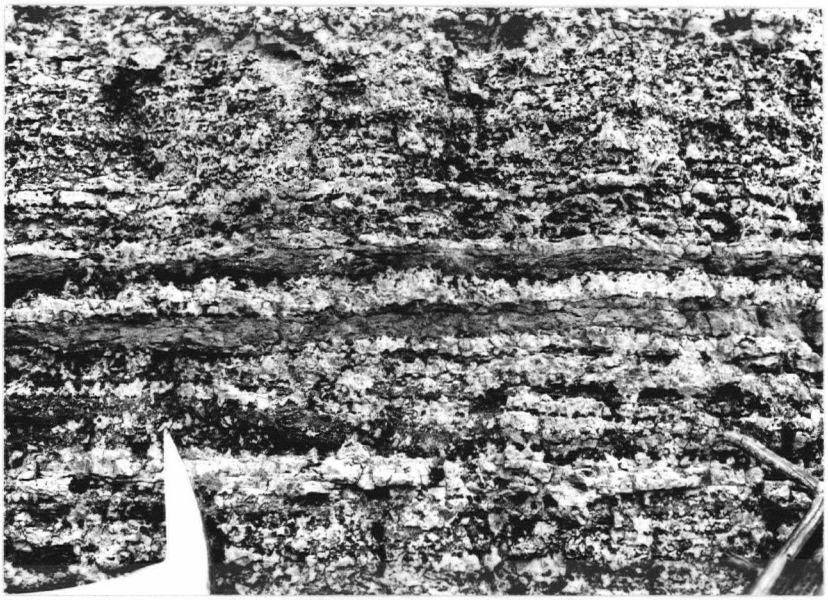


PLATE VI

A. Upper contact of lower Rocky Mountain (Tobermory Formation) sandstones in Livingstone Range with overlying beds of uncertain age (possibly Permian or Jurassic). The blocky weathering Rocky Mountain sandstones at the lower right are overlain by 4 feet of black, nodular, bedded chert which is in turn overlain by calcitic, dolomitic and some quartzitic sandstones that contain chert nodules. Immediately beneath the chert bed is a 1 foot zone that contains many poorly preserved, silicified pelecypods identified as Schizodus sp. Headwaters of Daisy Creek, west side Livingstone Range.

B. Contact between the Storelk and Tyrwhitt Formations, in canyon on the southwest corner of Mount Storelk. Note the apparent angular truncation of the uppermost Tyrwhitt sandstones. Five-foot staff for scale.

PLATE VI

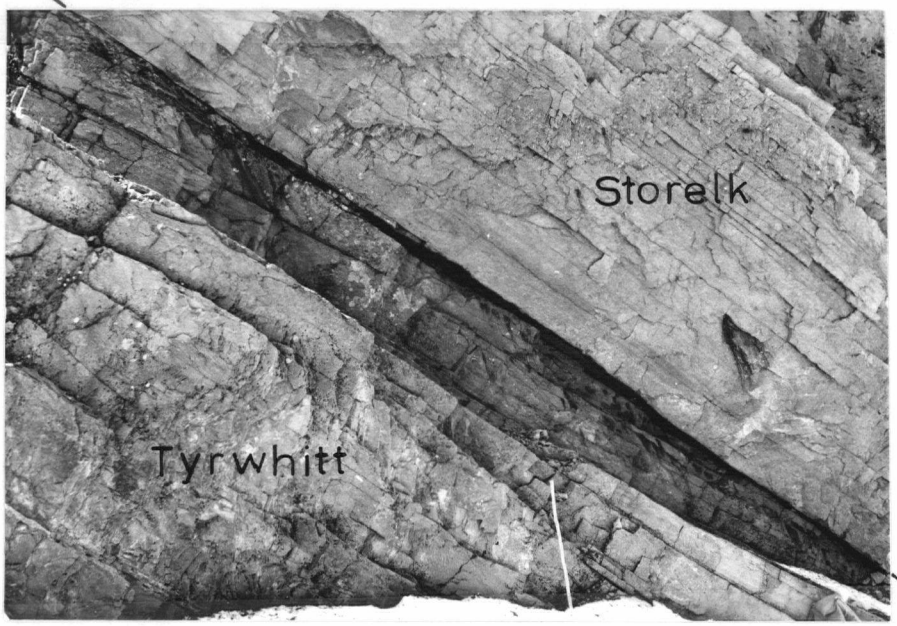


PLATE VII

A. Cross-stratification in poorly sorted, dolomitic and quartzitic sandstone bed, 29 feet thick, and 8 feet above the base of the Tyrwhitt Formation at the type section.

B. Cross-stratification in the Storelk Formation, Elk Mountains, between Mount Storelk and Mount Odlum.

PLATE VII

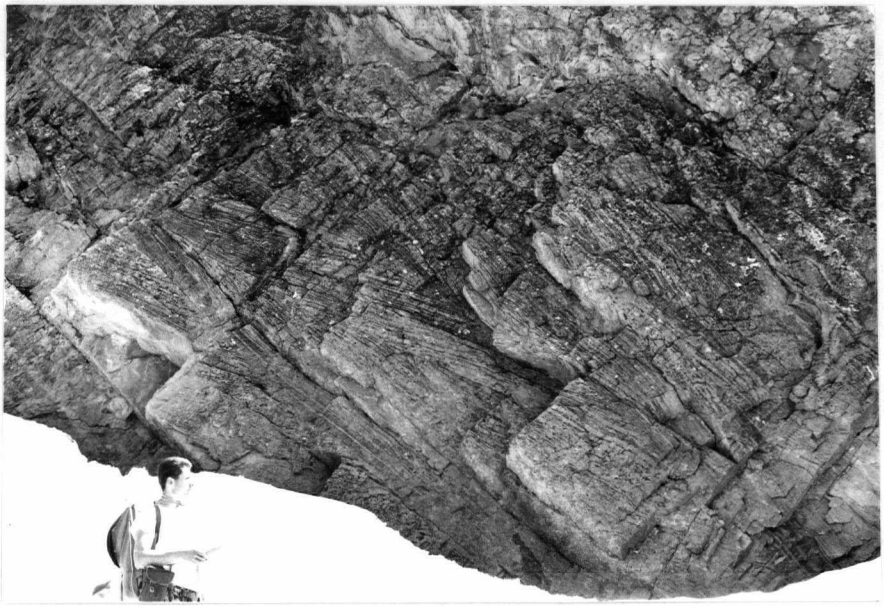


PLATE VIII

A. View looking east from upper Elk Valley at west side of Elk Mountains and Mount Storelk with "Storelk Canyon" (arrow) to the lower right of Mount Storelk. The type section of the Tyrwhitt, Storelk, and Tobermory formations is exposed in the canyon. Low ridges at tree-top formed by Triassic Spray River siltstones and shales. Western vegetated slopes underlain by the lower Rocky Mountain sandstones. Light grey rocks above timberline are composed of Etherington Formation limestones. Dark grey strata along the top of the range belong to the Mount Head Formation and consist of limestone.

B. View looking westward toward upper Elk Valley from the head of "Storelk Canyon", from point of arrow in above photograph. This is the type section of the Tyrwhitt, Storelk and Tobermory Formations. Strata in the foreground are sandstones of the Tyrwhitt Formation.

PLATE VIII

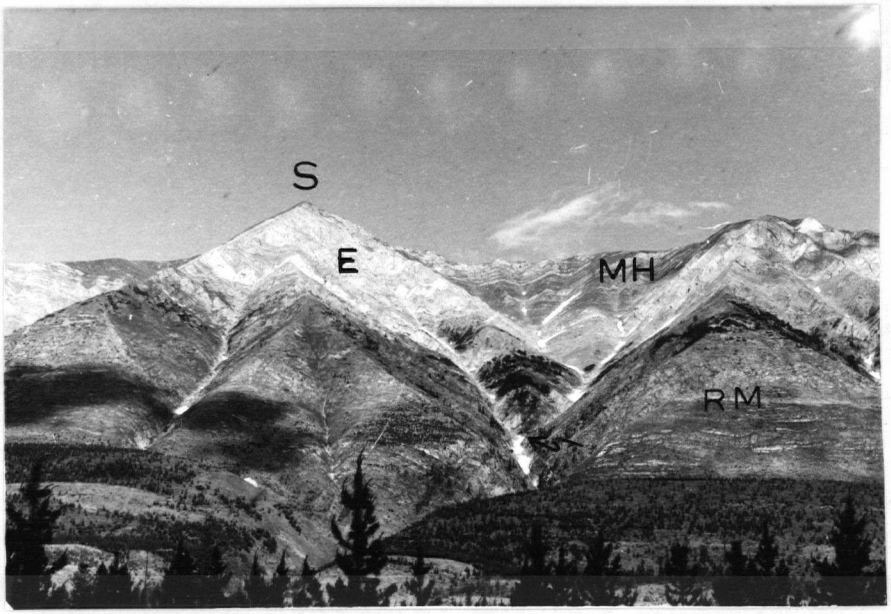


PLATE IX

A. View of uppermost Etherington, Todhunter, and basal Tyrwhitt Formations, south side of north fork of Ewin Creek and Beehive Pass pack trail. This view shows the lower part of measured section 18, and is located about 3 miles south along strike from the type section of the Todhunter. Remainder of the section was measured to the left. Note the contrast between the stratification of the Todhunter and Tyrwhitt Formations, and the similarity between that of the Todhunter and upper Etherington Formation (Ewin Creek Member). This is the type section of the Ewin Creek Member of the Etherington Formation.

B. View of cliff exposure immediately to the right of the above photograph. Note contrast in stratification between the Todhunter and Tyrwhitt Formations.

PLATE IX

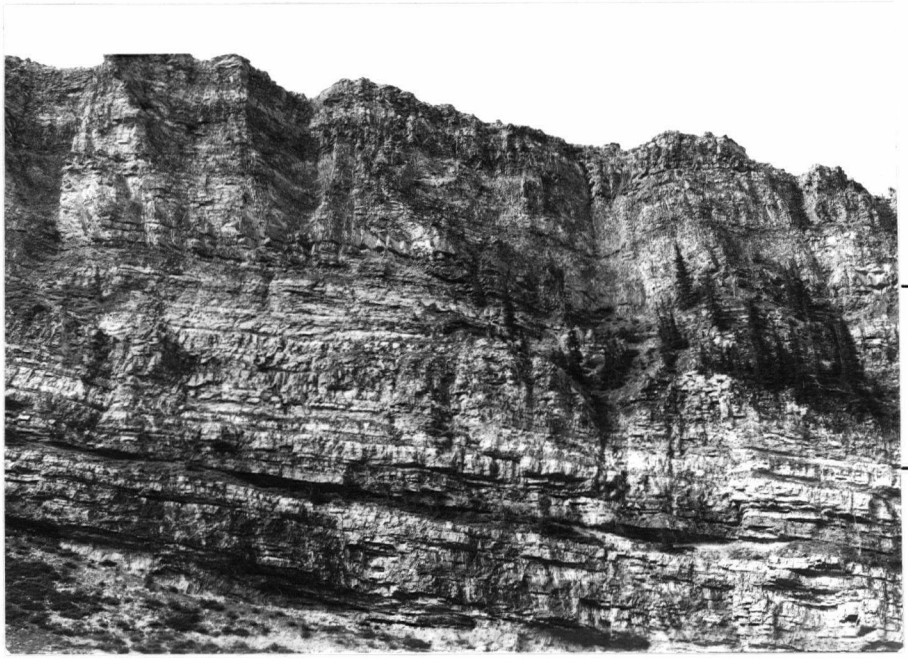
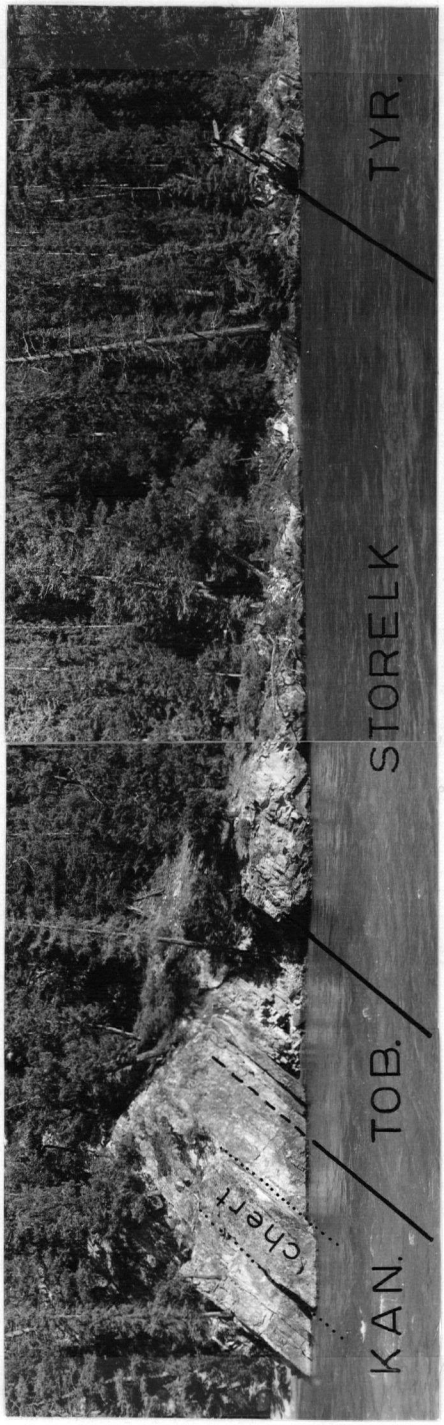


PLATE X

Panoramic views of part of the type section of the Tunnel Mountain Formation along Bow River, south side of Tunnel Mountain at Banff. Arrows locate fossil collections GSC loc. 55607 at right; and GSC loc. 55606 at left. B - marks the base of Beales' Rocky Mountain Fm. (1950).


KAN.
chert
TOB.
STORELK
TYR.

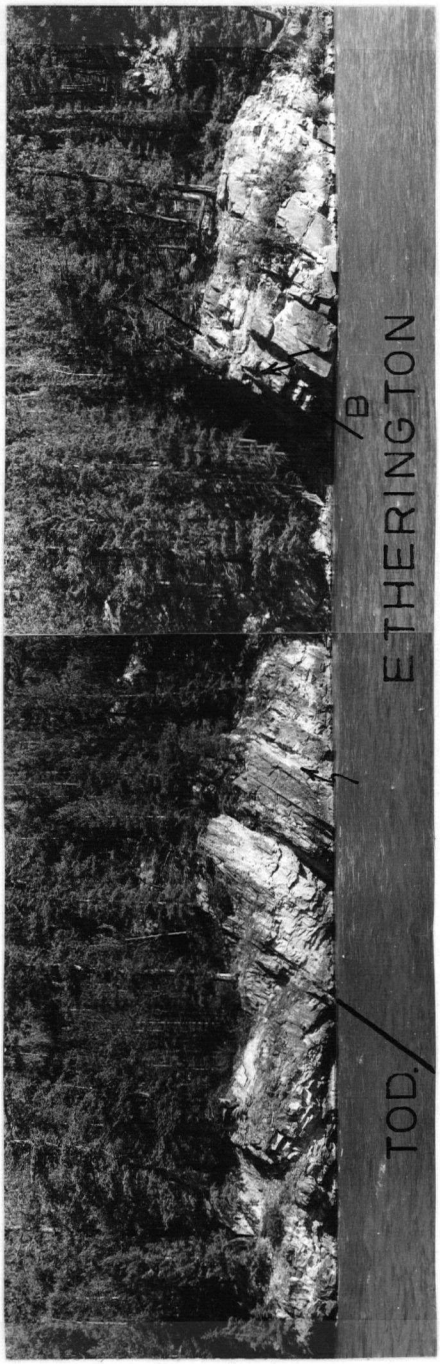

TOD.
ETHERINGTON
B

PLATE XI

View looking southward at the north side of a ridge extending northwestwards from Mount Arethusa, Misty Range, headwaters of Storm Creek, east side of Highwood Pass. This measured section (33) is also the same section measured by Raasch (1956, 1958). Note the superior resistance to erosion of the Etherington Formation limestones and dolomites compared to the resistance to erosion of the overlying sandstones of the lower Rocky Mountain and underlying limestones of the Mount Head Formation.
Ca - Carnarvon Member; Cy - Cyclamen Member; EC - Ewin Creek Member; To - Todhunter Formation; Ty - Tyrwhitt Formation; St - Storelk Formation.

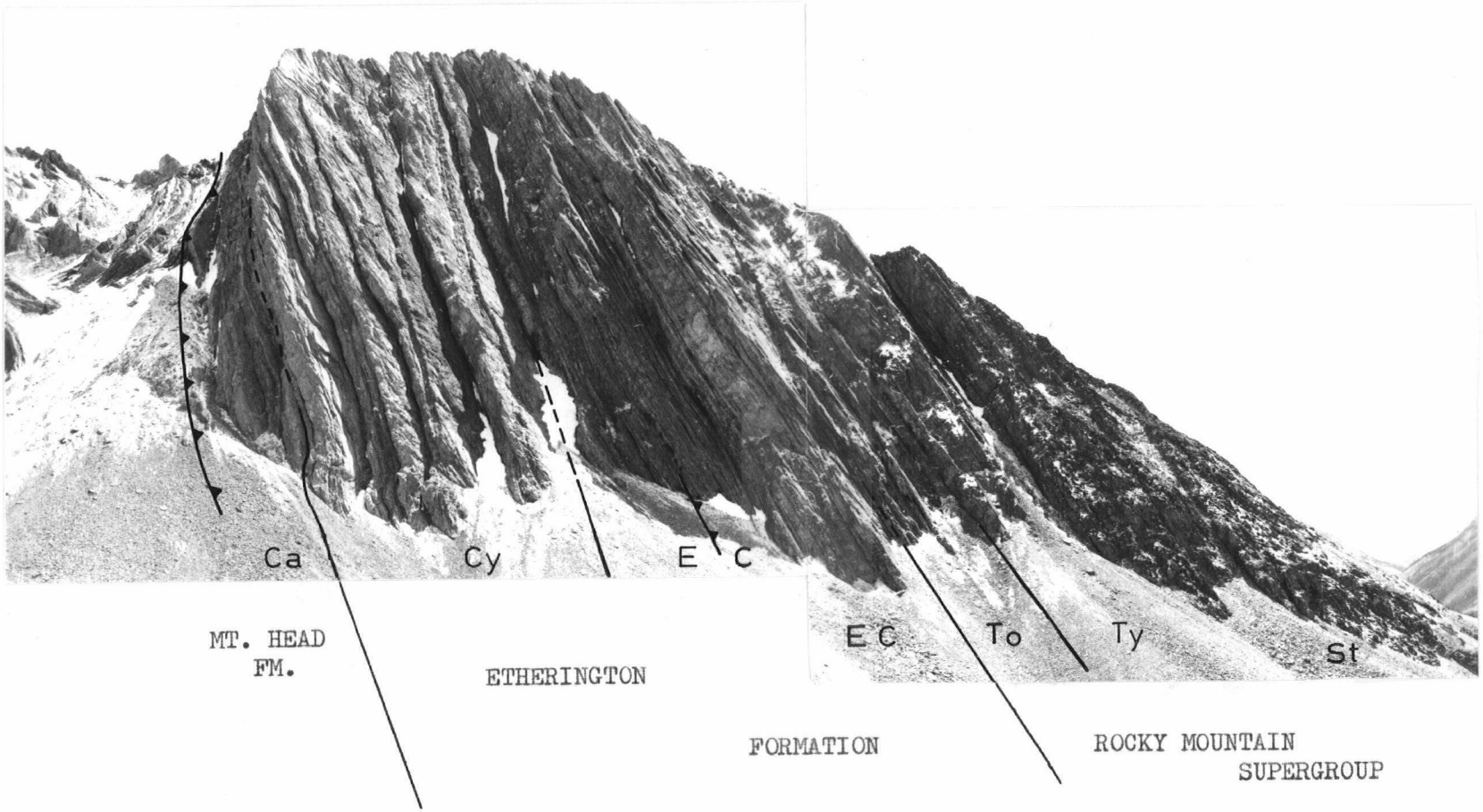
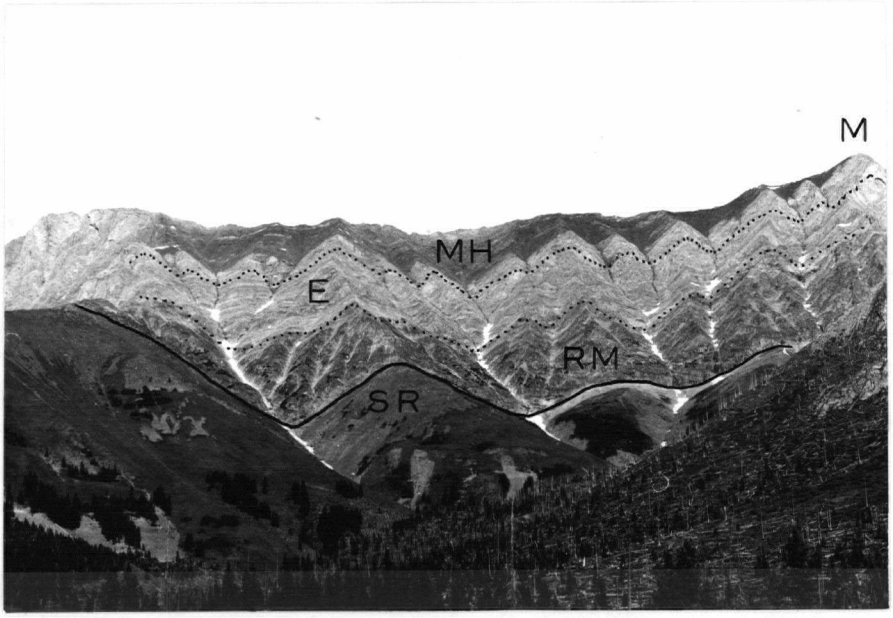

Ca
Cy
E
C
EC
To
Ty
St
MT. HEAD
FM.
ETHERINGTON
FORMATION
ROCKY MOUNTAIN
SUPERGROUP

PLATE XI

PLATE XII

A. View looking east at the west side of the southern end of Misty Range from Kananaskis-Coleman Highway. Peak at extreme right is Mist Mountain (M). Note the superior resistance to erosion of the Mississippian limestones and inferior resistance of the siltstones and shales of the Triassic Spray River Formation. The intermediate position of the lower Rocky Mountain sandstones is typical of exposures throughout the Front Ranges. SR - Spray River; RM - Rocky Mountain; E - Etherington; MH - Mount Head.

B. View looking northeast at the west side of Palliser Range from Cascade River valley. Measured section 44 is located in the second deep valley. Note the intermediate topographic position of the dark weathering lower Rocky Mountain sandstones between the grass-covered, slope-forming Triassic Spray River siltstones, and the highly resistant, light grey weathering limestones of the Mississippian.


M
MH
E
RM
SR

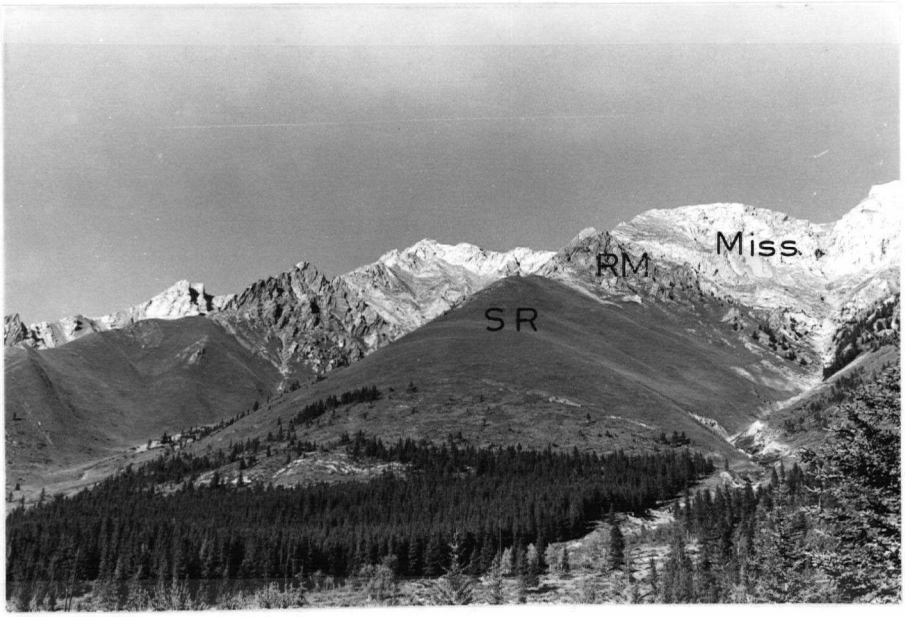

Miss.
RM
SR

PLATE XIII

View looking northward at the southwest flank of Storm Mt. Measured section 32 is directly opposite this exposure. Note recessive, saddle-forming black shales at the base of the Triassic Spray River Formation at the far left (SR). At this locality the Spray River rests directly upon the Storelk Formation of Early Pennsylvanian age. The contacts between the Etherington, Todhunter, Tyrwhitt and Storelk formations are indistinct in this exposure. S - Storelk; Ty - Tyrwhitt; To - Todhunter; E - Etherington

PLATE XIII

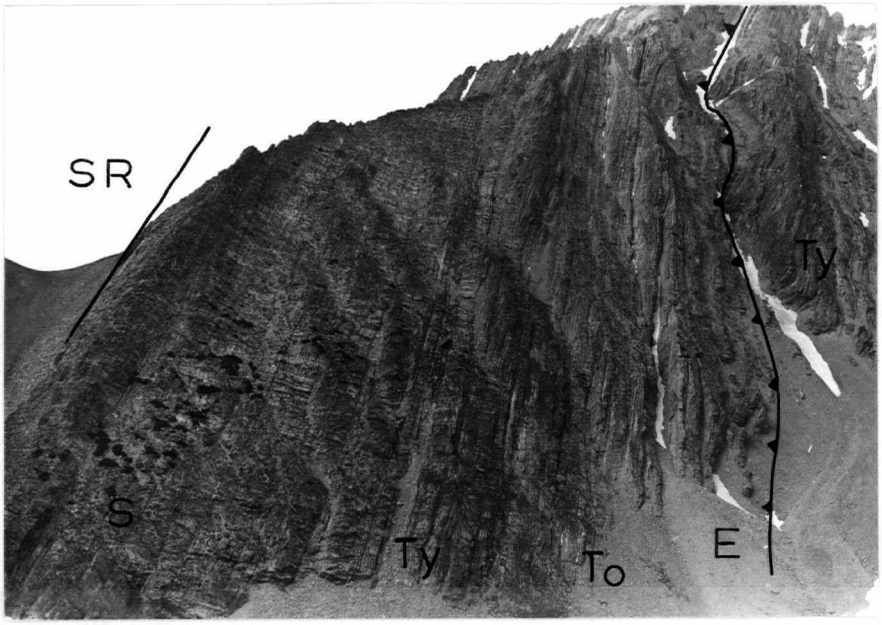


PLATE XIV

A. Photomicrograph of bed 25-158U of the lower Spirifer tongue of the middle Todhunter Fm. Sandy skeletal (echinoderm) calcarenite. Skeletal grains almost entirely echinodermal, rounded due to abrasion, range from fine to very coarse, most are medium and coarse, and a few are partly replaced by chalcedony. The bonding material consists in part of a small amount of dark micrite, and in part of calcite spar, which in the upper righthand corner forms overgrowths on the echinoderm grains. The quartz sand is very fine and fine, some is medium, and ranges from angular to well rounded. Plain light. Magnification 9X

B. Photomicrograph of bed 5-67 of the lower Spirifer tongue of the middle Todhunter Fm. Sandy, skeletal calcarenite. Skeletal fragments consist mostly of echinoderms, but there are many bryozoa, and some brachiopod fragments. Most skeletal grains are medium to coarse sand grade. The matrix is micrite and is very slightly argillaceous. The disseminated quartz sand is mostly very fine and angular to subangular. Plain light. Magnification 9.5X

PLATE XIV

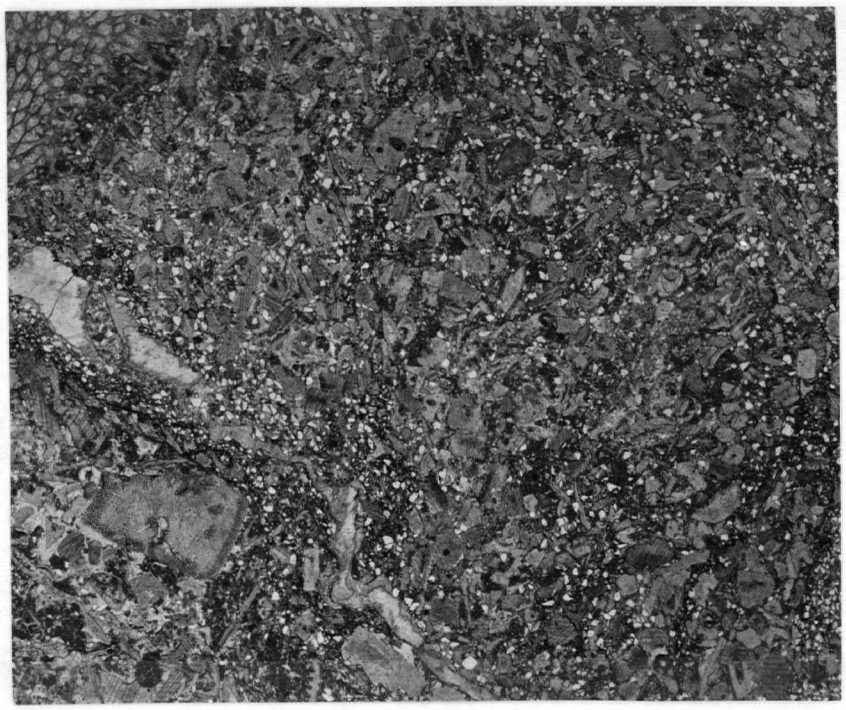
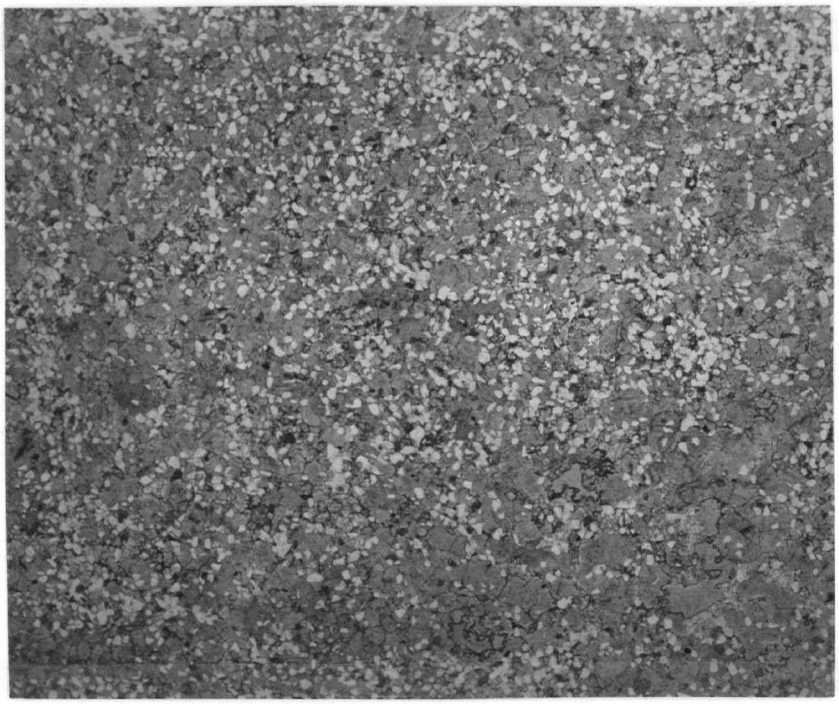


PLATE XV

A. Photomicrograph of bed 18-43b of the lower Spirifer tongue of the middle Todhunter Fm. This shows the structureless interlocking mosaic of anhedral medium and coarse dolomite crystals which represents the dolomitized equivalent of the limestones shown in Plate XIV. The very abundant disseminated quartz sand is mostly of fine grade and is mostly angular to subangular. Plain light. Magnification 9.5X

B. Photomicrograph of bed 18-52 of the upper Todhunter Fm., just above the upper Spirifer tongue. This thin bed of sandy dolomite is similar to that forming the Spirifer tongues below. The dolomite is texturally a very fine and fine, granular, anhedral mosaic with some intercrystalline maroon clay (arrows). The sand is abundant, disseminated, poorly sorted, very fine to coarse. The clear quartz grains are very fine to medium, some are coarse, and the larger grains are rounded to well rounded. The chert grains are grey, medium and coarse, well rounded, and many are rimmed with dark films of maroon clay. Plain light. Magnification 10X

PLATE XV



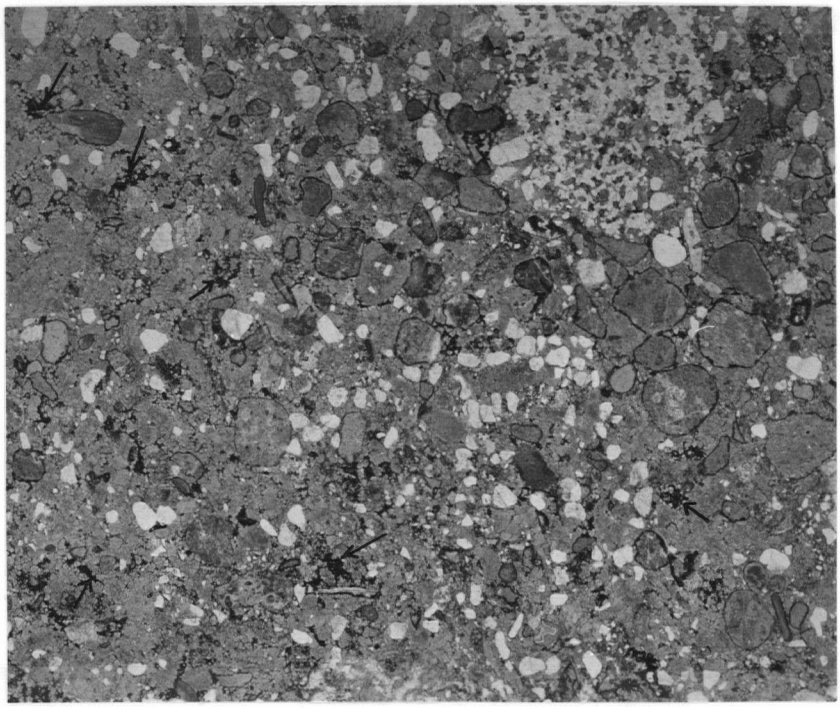


PLATE XVI

Photomicrograph of bed 8-41, top bed of Todhunter Formation where unconformably overlain by the Tyrwhitt Formation. Mainly a fine-grained, calcite-cemented quartz sandstone containing some medium grains, a few coarse sand grains, and a few chert grains. Shows a few of the very numerous detrital, sandy phosphorite and phosphatic sandstone pebbles, granules and sand grains which characterize this bed. The large rounded pebble at the top is 10 mm. in diameter and is pelletoidal. Also present are numerous clear, lath-like fragments of Orbiculoidea shells (arrows), but most are not clearly discernible in this photograph. Plain light. Magnification 8.5X

PLATE XVI

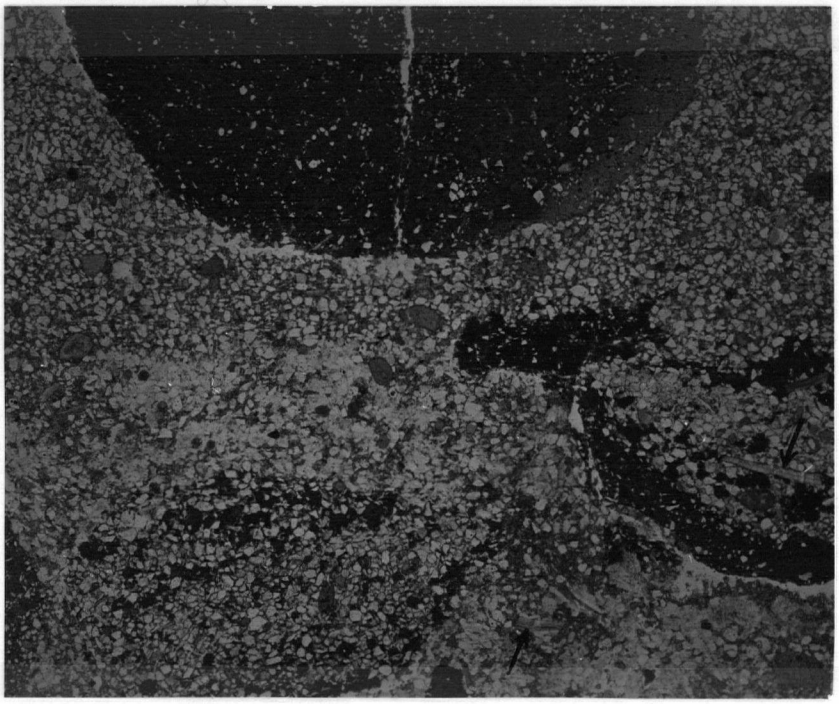
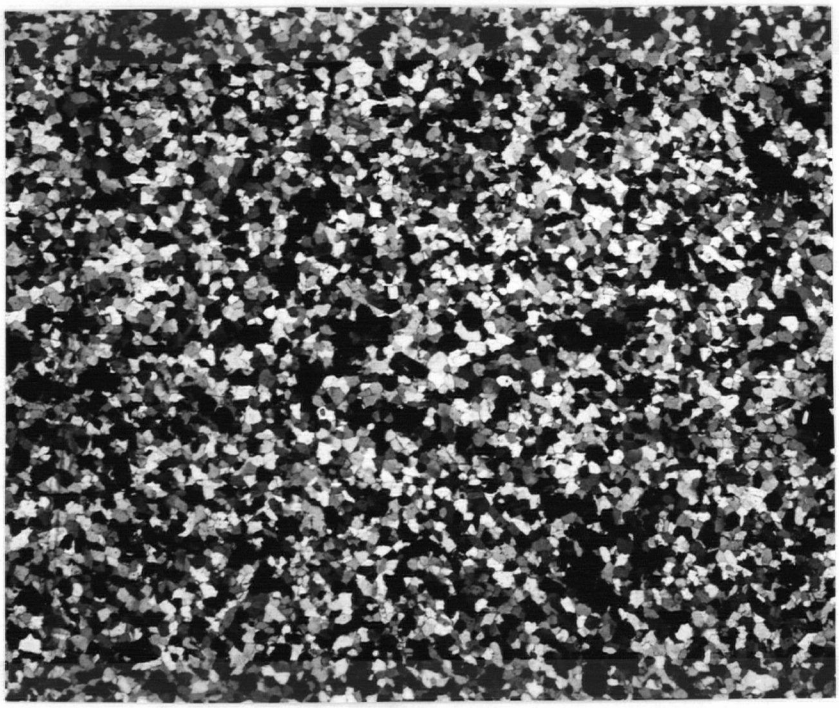


PLATE XVII

A. Photomicrograph of bed 11-33 (145 feet below top) of Storelk Fm. Predominantly fine-grained, well sorted, quartz arenite. Quartz cement is virtually absent, and the grains are bonded by pressure welding and interpenetration. Much of the Storelk Formation in Misty Range is similar to this or finer grained. Cross-nicols. Magnification 10X

B. Photomicrograph of bed 11-33 of Storelk Fm. Consists of quartz-cemented, quartz-chert sandstone. Chert constitutes from one-quarter to one-third of the grains, and many of the chert grains are white and chalky but appear black in this photograph. The interlocking mosaic is produced by quartz cementation in the form of secondary overgrowths on the quartz grains and by pressure welding and interpenetration along grain contacts. All grains were probably originally well rounded. The larger grains are of medium sand grade, but some coarse quartz and chert grains are present in the hand specimen. Cross-nicols. Magnification 10X

PLATE XVII



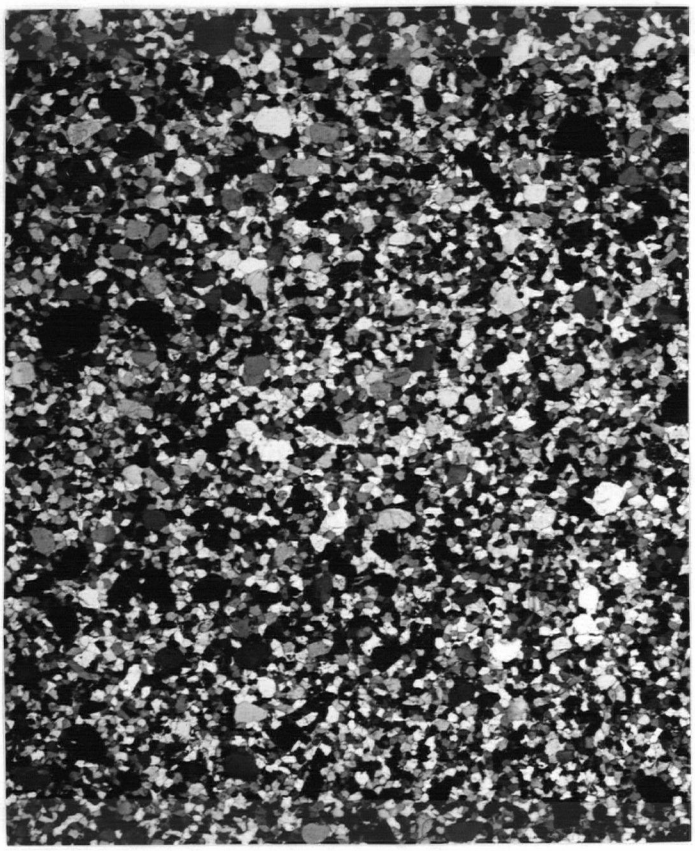
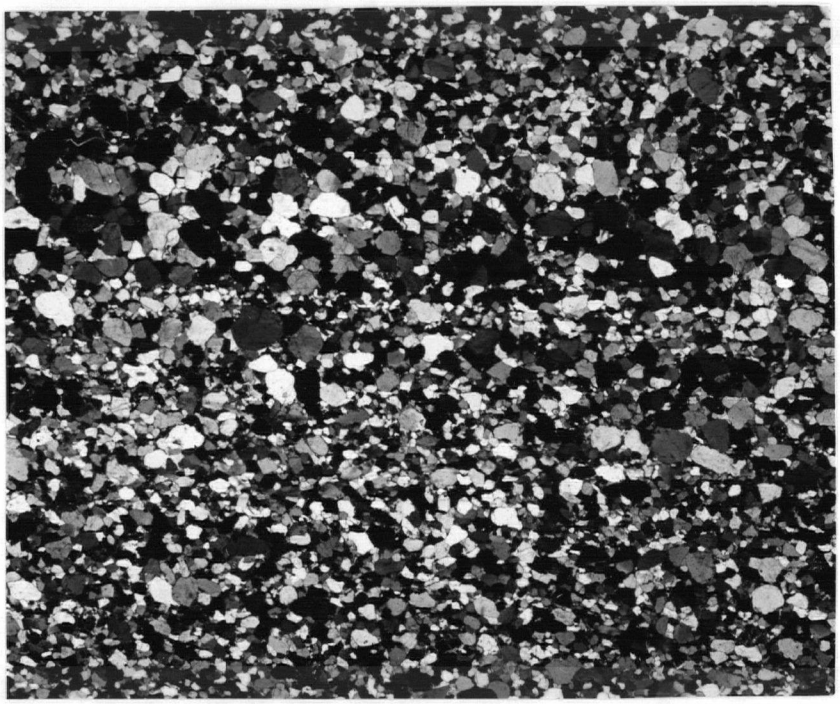


PLATE XVIII

A. Photomicrograph of bed 11-33 (30'-37') from near top of Storelk Fm. This is a poorly sorted, very fine- to coarse-grained, quartz-cemented, quartz-chert sandstone. The largest grains are of coarse sand grade. Note the presence of several zones composed of grains of various grades. Cross-nicols. Magnification 10X

B. Photomicrograph of bed 39-60 (245') of Storelk Fm. This is a quartz-chert sandstone in which chert constitutes about one-quarter of the total. Grains range from very fine to medium grade. Cementation is largely by welding and interpenetration. Note several poorly defined zones characterized by various degrees of sorting. Cross-nicols. Magnification 10X

PLATE XVIII



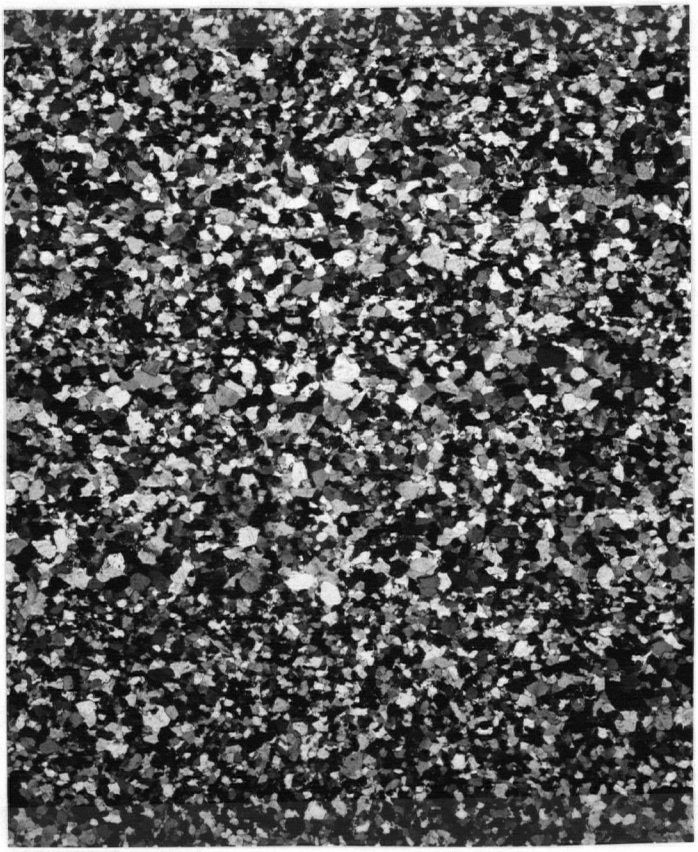
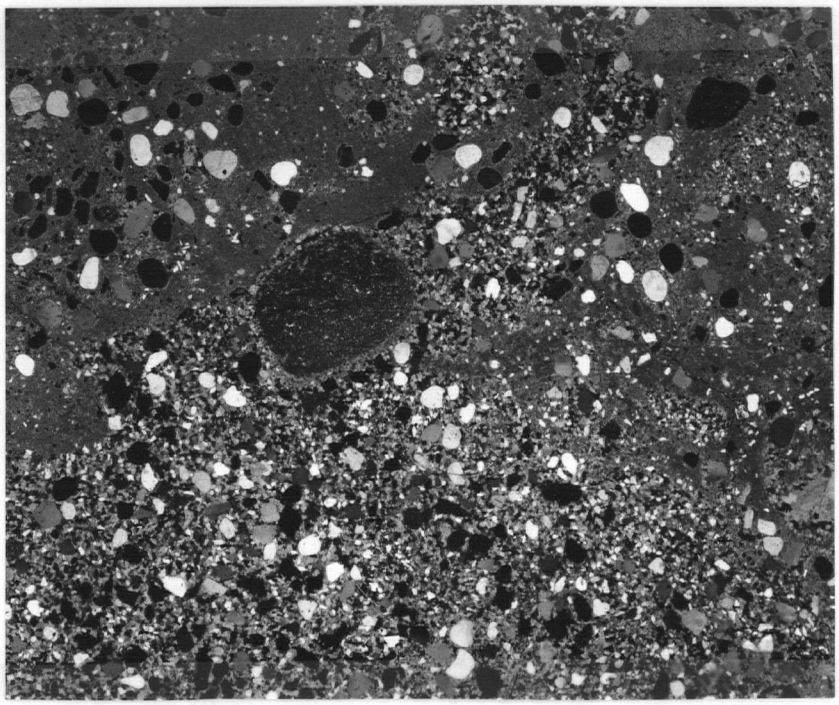


PLATE XIX

A. Photomicrograph of bed 11-32, basal conglomeratic bed of the Tobermory Fm. Shows patches of poorly sorted, dolomite-cemented, quartz-chert sandstone and dolomicrite containing scattered sand grains. The dolomite is not part of detrital pebbles, but may represent original mud. Note the high degree of rounding of the quartz grains. Large rounded chert granule is 3 mm. long. Cross-nicols. Magnification 7X

B. Photomicrograph of bed 5-35, basal conglomerate of Tobermory Fm. Poorly sorted, dolomite-cemented, conglomeratic, fine- to coarse-grained quartz sandstone. Some carbonate grains are present, together with many detrital phosphorite grains of pebble to sand grade. Large dark, triangular phosphorite grain is very silty and sandy, and is 5 mm. in diameter. Phosphorite grains are marked (p). Plain light. Magnification 7X



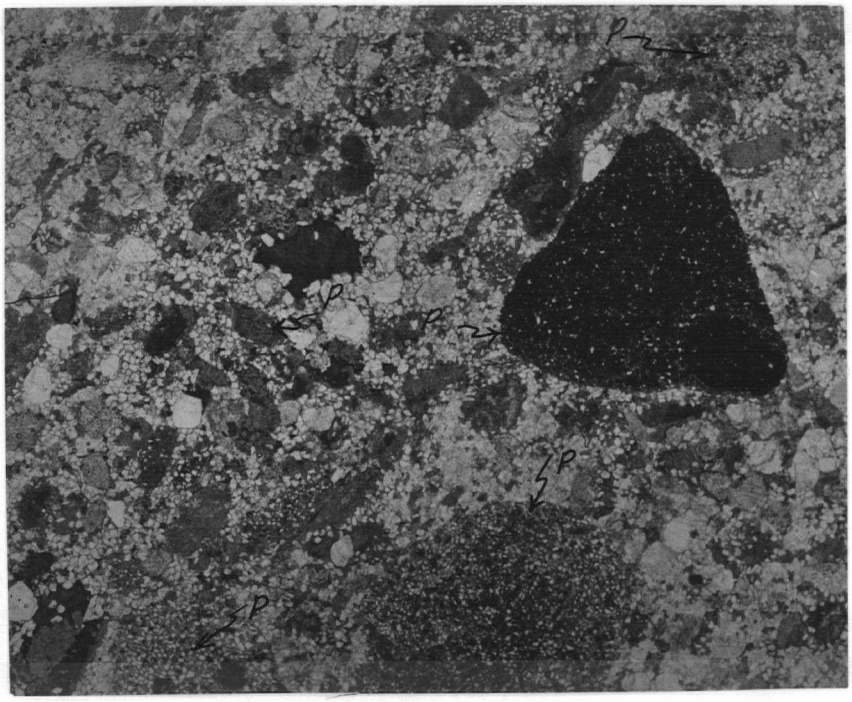

P
P
P
P
P

PLATE XX

Photomicrograph of bed 11-23 of the Tobermory Formation. This is part of a thin dolomite zone, within a bed of sandstone, which consists of a tight mosaic of granular, anhedral crystals of mainly very fine, and some fine dolomite (in upper part of photograph). This dolomite zone is characterized by the presence of sand-, granule-, and fine pebble-size fragments of chert and smaller amounts of quartz sand. The chert grains are composed of several different textural types. Small spines or spicules are visible in one of the grains. The large chert fragment at the left is 5.5 mm. long. In the lower part of the photograph is shown a highly dolomitic, quartz sandstone composed mainly of fine and fewer medium sand grains. Magnification 6.5X

PLATE XX

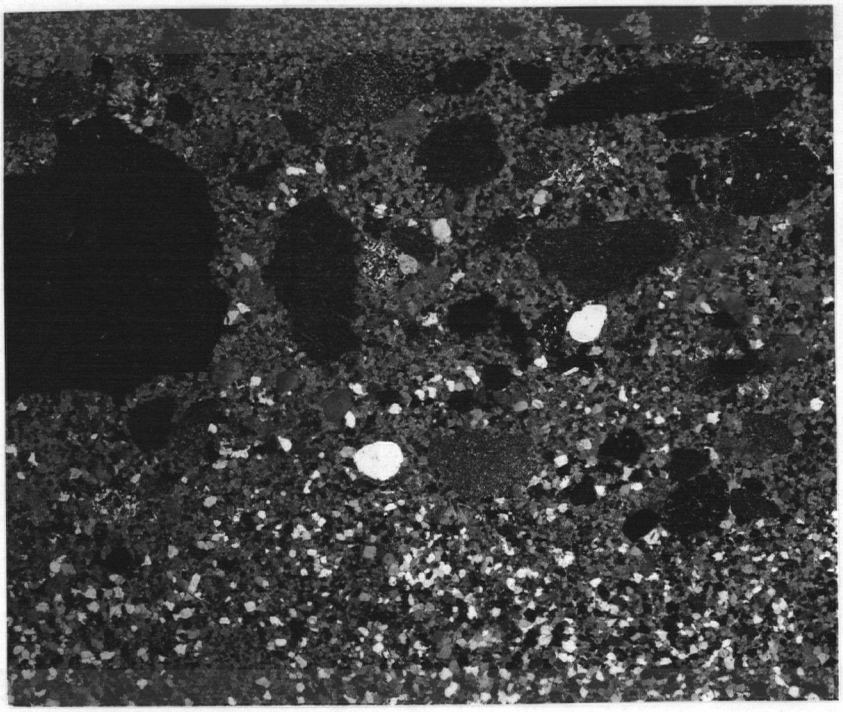
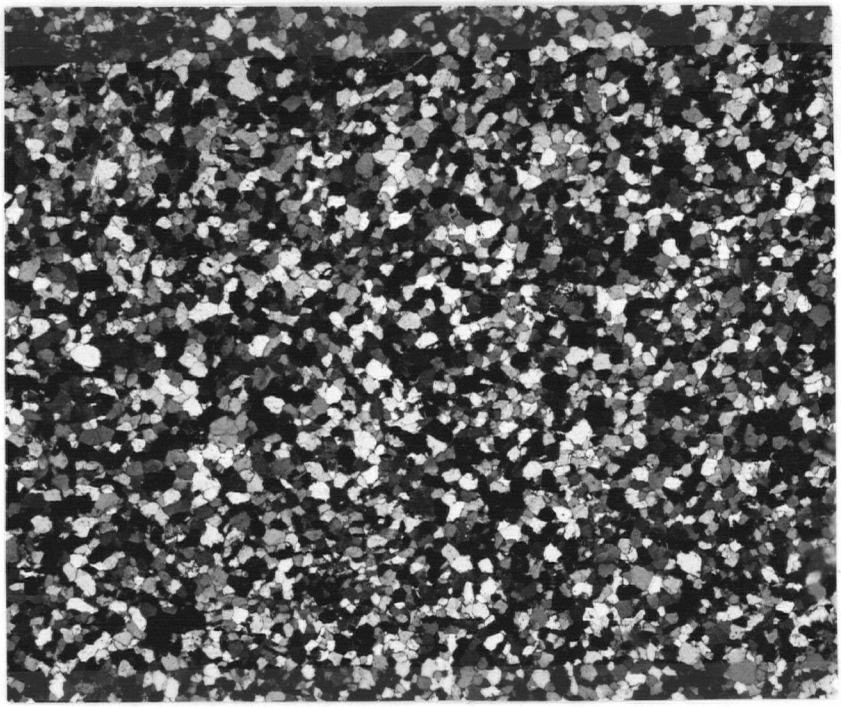


PLATE XXI

A. Photomicrograph of bed 16-28 of the Tobermory Fm., Livingstone Range. This is a quartz-chert sandstone, fine- to medium-grained, cemented entirely by quartz. The cementation and grain size of this bed is very similar to that characteristic of the Storelk Fm. Cross-nicols. Magnification 10X

B. Photomicrograph of bed 16-29 of the Tobermory Fm., Livingstone Range. This is a quartz-chert sandstone cemented with calcite. There are fairly numerous detrital phosphorite sand grains. Grains are fine to medium grade. The calcite cement occurs as large, single crystals that enclose and contain the sand grains, producing a lustre-mottled texture. The large dark and light patches are signle calcite crystals at various stages of extinction. Cross-nicols. Magnification 10X

PLATE XXI



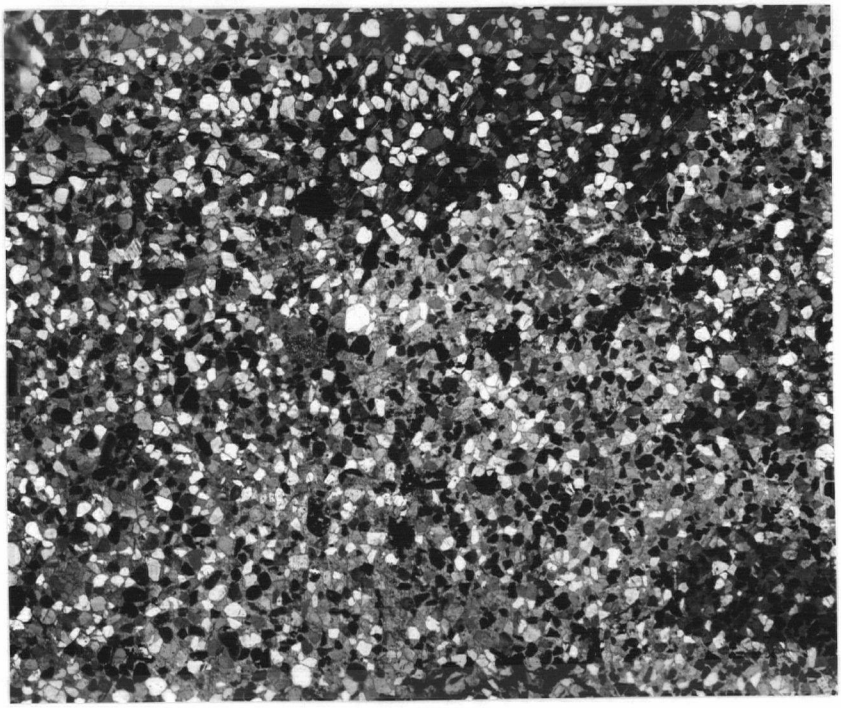


PLATE XXII

Photomicrograph of bed 18-111 of the Kananaskis Fm. This is a very fine-crystalline dolomite which has largely destroyed the texture of an original skeletal, clastic-textured limestone. Only ghost-like remnants of fossil or organic structures remain. Note the numerous fine vugs filled with black bitumen (arrows). Plain light. Magnification 9X

PLATE XXII

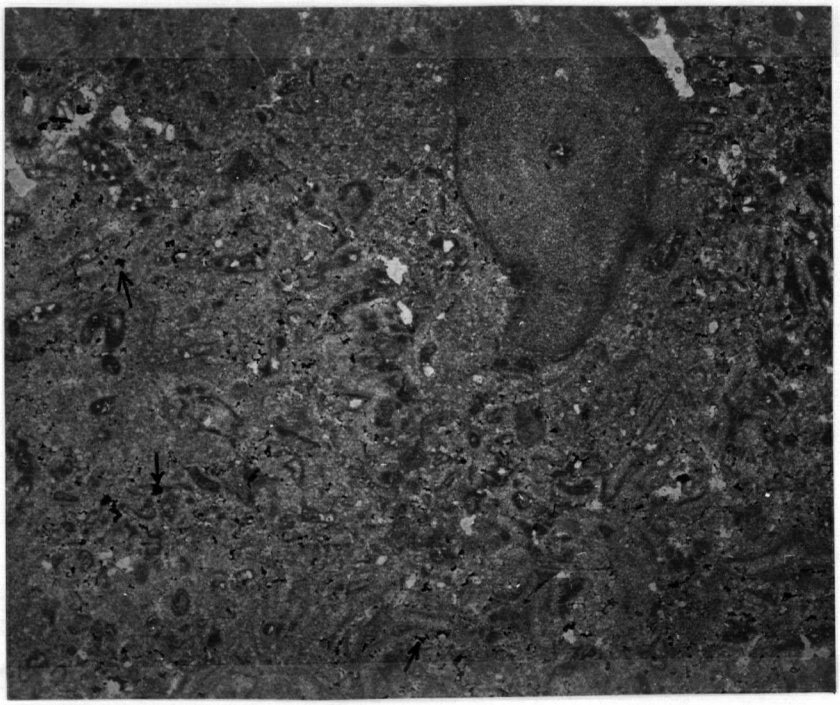
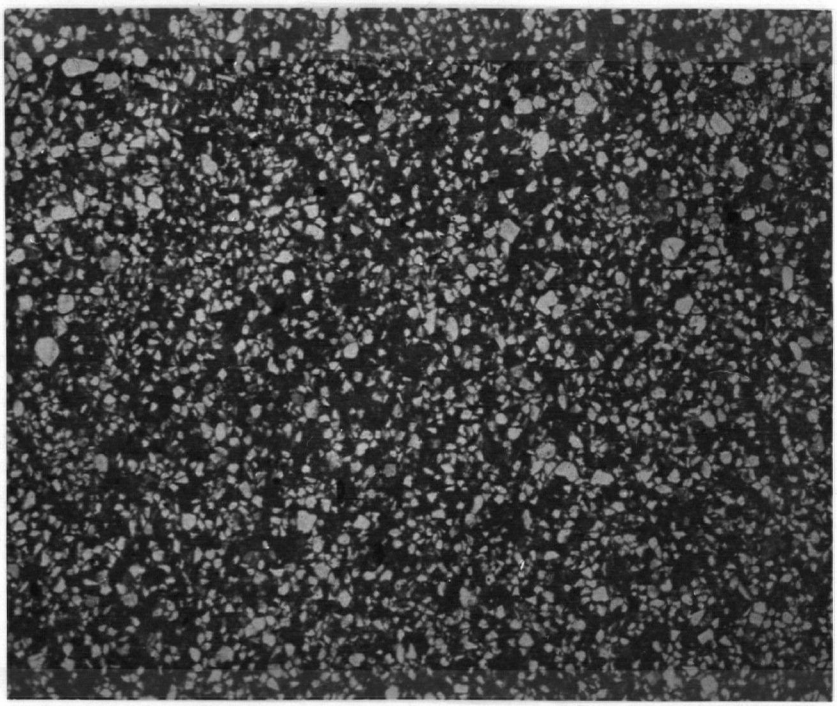


PLATE XXIII

A. Photomicrograph of bed 11-16 of the Kananaskis Formation. This is a highly sandy dolomite that contains subequal amounts of dolomite and sand. The dolomite fraction is microcrystalline or cryptocrystalline, but some may originally have been clastic sand-size carbonate grains. The sand fraction consists of quartz that is evenly disseminated throughout. With a small increase in the quantity of sand grains this becomes a dolomitic sandstone as in B below. Plain light. Magnification 11X

B. Photomicrograph of bed 11-14 of the Kananaskis Formation. This is a highly dolomitic sandstone composed of about two-thirds sand and one-third dolomite. The quartz sand is very fine to medium, angular to well rounded, and rather poorly sorted. The dolomite is dense, microcrystalline, and it appears in large part to have been composed originally of clastic carbonate grains of similar size to the quartz grains. Plain light. Magnification 11X

PLATE XXIII



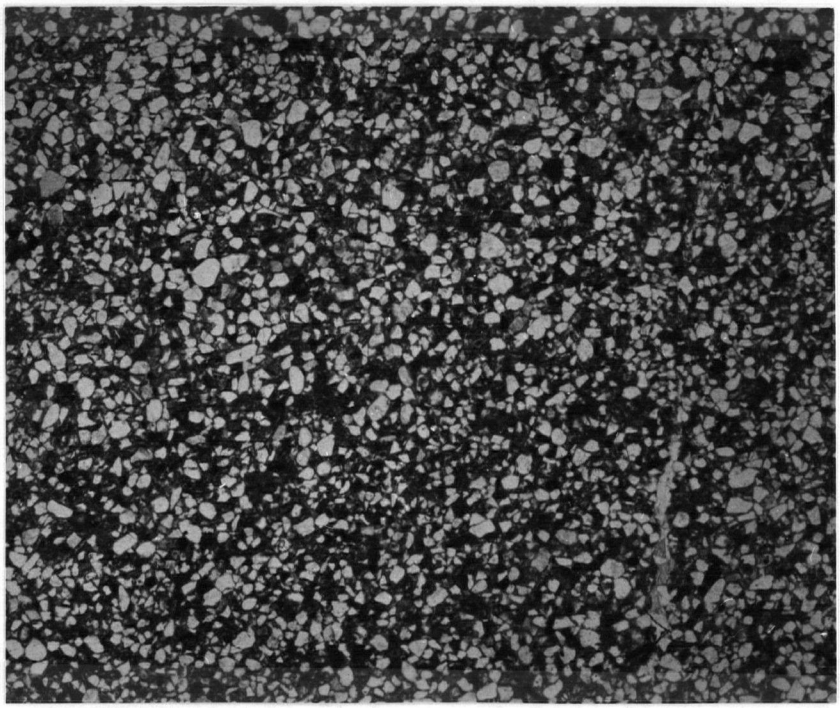


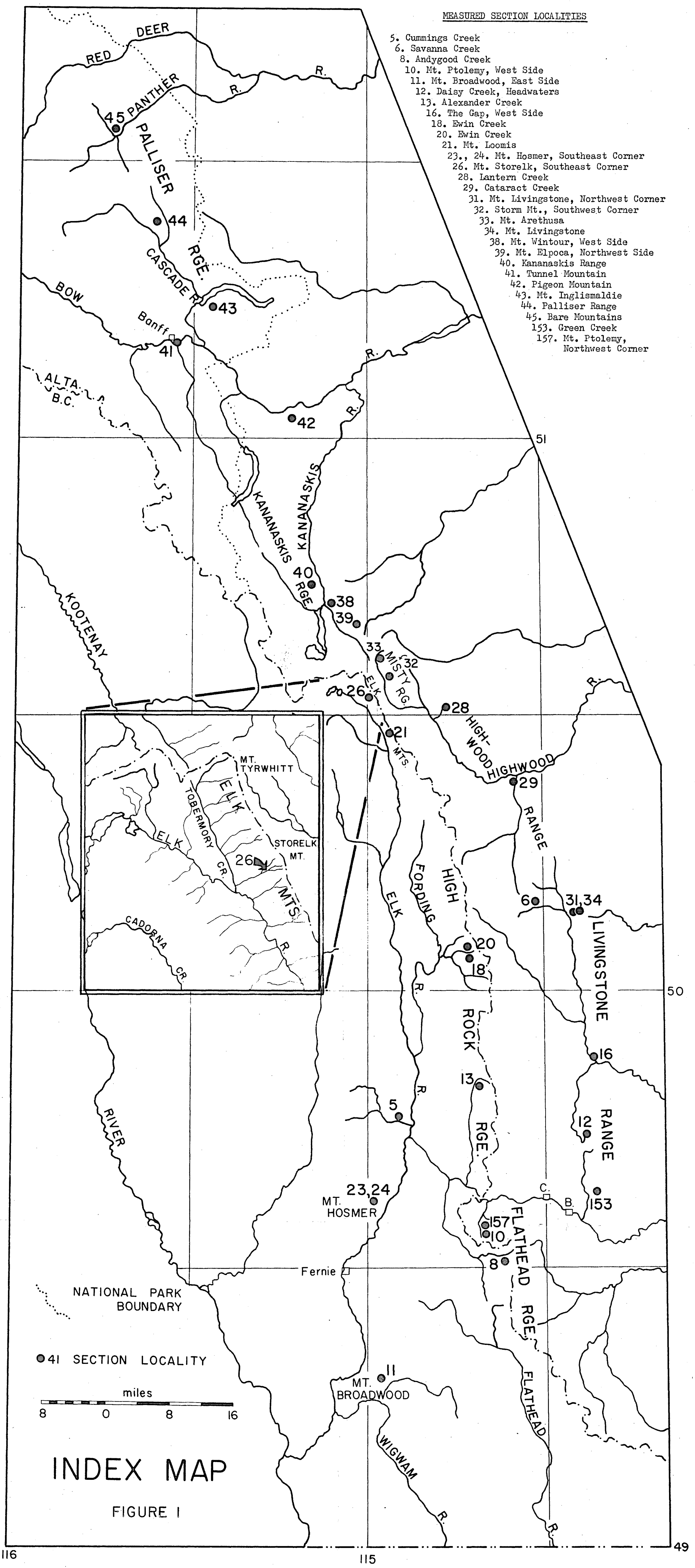
TABLE OF THICKNESSES

Section Number	153	12	16	29 31 34	28	42	43	44	45	41	40	38	39	32 33	26	18	13	10 157	5	23 24	11
KANANASKIS FM.						X	X	57	31	101	X	X	6	0	92	168	X	80			90
TOBERMORY FM.	77	56	98	59	25	X	X	9		26	X	X	3	0	218	294	X	333	?	182	107
STORELK FM.						X	X	40	130	105	170	X	207	209	306	277	X	242	131	154	200
TYRWHITT FM.					96	96	X	130		114	347	X	281	245	278	296	273	276	317	261	102
TODHUNTER FM.					66		X			51	79	X		74	75	139	128	96	156	125	94
ETHERINGTON FORMATION: Ewin Creek	234	298	X	257	210	232	281	232	198	220 +	X	171	X	276	204	189	218	152	X	662	235
ETHERINGTON FORMATION: Cyclamen										X	X	353	X	223	484	475	X	X	X		323
TOTAL THICKNESS OF SANDSTONE FORMATIONS	77	56	98	59	187			170	130	296	X	X	491	528	877	1006	X	947	X	722	503
TOTAL THICKNESS OF ETHERINGTON FM.	234	298		257	210	232	281	232	198	X	X	524	X	499	688	664	X	X	X	662	558

Formation Absent \\\ Formation Covered X

TABLE 9

No Thickness Values X



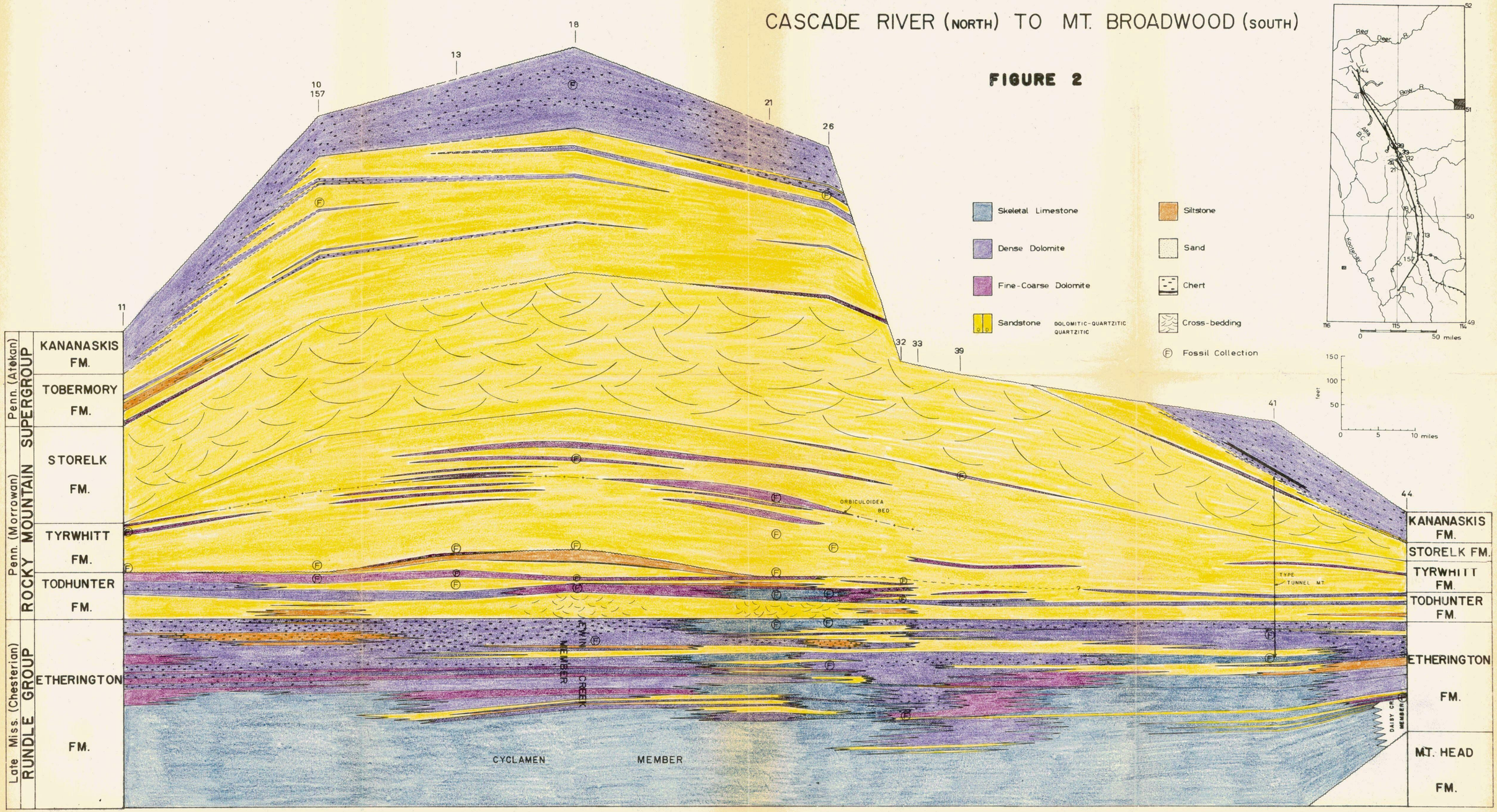
INDEX MAP

FIGURE 1

STRATIGRAPHIC CROSS-SECTION

CASCADE RIVER (NORTH) TO MT. BROADWOOD (SOUTH)

FIGURE 2



OBLIQUE NW-SE STRATIGRAPHIC CROSS-SECTION

KANANASKIS RANGE (NW) TO LIVINGSTONE RANGE (SE)

FIGURE 3