GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

BULLETIN 176

ORDOVICIAN AND SILURIAN STRATIGRAPHY OF THE SOUTHERN ROCKY MOUNTAINS

B. S. Norford

Ottawa,
Canada
1969

Price $2.75

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OF THE SOUTHERN ROCKY MOUNTAINS

1,450-1968-5731-7

Critical Reader
R. A. PRICE

Technical Editor
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Printed on No. 1 Enamel
Set in Times Roman with
20th Century captions by
CANADIAN GOVERNMENT PRINTING BUREAU

Artwork by CARTOGRAPHIC UNIT, GSC

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PLATE I. Ordovician rocks near Mount Wilson. The resistant Mount Wilson Quartzite forms the cliff above timber-line. (Photo. R. W. Macqueen).

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By
B. S. Norford

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ENERGY, MINES AND RESOURCES
CANADA

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Price: $2.75 Catalogue No. M42-176

Price subject to change without notice

The Queen's Printer
Ottawa, Canada
1969

PREFACE

The establishment of standard sequences of rock units and faunal zones within a region is a prerequisite of comprehensive investigations of stratigraphy, sedimentology, or palaeontology of the various units. This bulletin is a rigorous study of the Ordovician and Silurian rock units in an area of complex facies change in the southern Rocky Mountains. Formational nomenclature is established and contemporaneous rock units of different facies and faunas are correlated by means of intertonguing in critical stratigraphic sections.

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

OTTAWA, 18 March, 1966

BULLETIN 176 — Stratigraphie des Ordoviziums und des Silurs der südlichen Rocky Mountains

Von B. S. Norford

Stratigraphie der ordovizischen und silurischen Tonschiefer und Karbonate der südlichen Rocky Mountains. Teilweise Berichtigung der Nomenklatur. Einführung von vier neuen Namen für Gesteinsgruppen. Erörterung mehrerer Faunazonen und der Ablagerungsgeschichte der Region.

БЮЛЛЕТЕНЬ 176 — Стратиграфия ордовика и силура юга Скалистых гор

Б. С. Норфорд

Описывается стратиграфия ордовикских и силурских глинистых сланцев и карбонатов юга Скалистых гор, частично пересматривается их номенклатура, вводятся четыре новые литостратиграфические названия, а также обсуждаются несколько фаунистических зон и история осадконакопления района.

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ORDOVICIAN AND SILURIAN STRATIGRAPHY OF THE SOUTHERN ROCKY MOUNTAINS

Abstract

Platform carbonates covered the whole of the southern Rocky Mountains in Late Ordovician and Early Silurian times. The eastern part of the southern Rocky Mountains was the site of similar deposits in Middle Ordovician time, but miogeosynclinal shales and limestones accumulated to the southwest. The locus of facies change trends northwest and lies just west of the British Columbia–Alberta boundary.

Middle and Upper Silurian rocks are absent from the southern Rockies and Devonian rocks rest directly on Precambrian to Lower Silurian strata. The basal Devonian sediments laid down above this sub-Devonian unconformity were variable and laterally discontinuous. Rocks of probable Middle Devonian age overlie Lower Silurian beds in the western part of the southern Rocky Mountains, and, in the eastern part, Upper Ordovician strata are overlain by local deposits that may range in age from Early to Late Devonian.

Lower Ordovician stratigraphy is briefly reviewed. Stratigraphic nomenclature is revised for Middle Ordovician, Upper Ordovician, and Silurian rocks. The names Glenogle Shales, Mount Wilson Quartzite, and Skoki Formation are retained. The Beaverfoot Formation is restricted to carbonate rocks and includes both Upper Ordovician and Lower Silurian strata. The terms Wonah Quartzite and Brisco Formation are considered obsolete. Four new rock units are proposed: Ordovician Tipperary Quartzite, Owen Creek Formation, Whiskey Trail Member of the Beaverfoot Formation, and Silurian Tegart Formation.

Faunal studies allow the recognition of four brachiopod–coral–trilobite zones within the Beaverfoot Formation, and a conodont zone in the basal Beaverfoot and uppermost Mount Wilson. Three brachiopod zones are present within the Skoki Formation. Of these, the *Anomalorthis* and *Orthidiella* zones correlate with Whiterock zones in the Antelope Valley Limestone of Nevada. A new brachiopod zone can be recognized near the base of the Skoki and is considered uppermost Canadian. This zone of *Hesperonomia* may be partly equivalent to the *Pseudocybele* trilobite zone of Utah and Nevada.

Résumé

Des carbonates en plate-forme ont recouvert la partie Sud des Rocheuses au cours de l'Ordovicien supérieur et du Silurien inférieur. La partie orientale a été recouverte de dépôts semblables au cours de l'Ordovicien moyen, tandis que des schistes argileux et des calcaires miogéosynclinaux se sont accumulés au sud-ouest. L'endroit où s'est effectué le changement de faciès est orienté vers le nord-ouest et se trouve immédiatement à l'ouest de la ligne de démarcation entre la Colombie-Britannique et l'Alberta.

Les roches du Silurien moyen et supérieur sont absentes dans la partie Sud des Rocheuses et les roches du Dévonien reposent directement sur des couches du Précambrien et du Silurien inférieur. Les sédiments de base du Dévonien qui reposent sur cette discordance stratigraphique sont variables et latéralement discontinus. Des roches qui datent probablement du Dévonien moyen recouvrent des couches du Silurien inférieur dans la région occidentale de la partie Sud des Rocheuses et, dans la région orientale, les strates de l'Ordovicien supérieur sont recouvertes par des dépôts locaux dont l'âge varie du Dévonien inférieur au Dévonien supérieur.

L'auteur revoit brièvement la stratigraphie de l'Ordovicien inférieur. Il revise la nomenclature des roches de l'Ordovicien moyen et supérieur, et du Silurien. Il conserve les noms schistes argileux de Glenogle, quartzite de Mount Wilson et formation de Skoki. La formation de Beaverfoot, limitée aux roches carbonatées, comprend les couches de l'Ordovicien supérieur et du Silurien inférieur. L'auteur considère comme périmés les termes quartzite de Wonah et formation de Brisco. Il propose quatre nouvelles appellations de roches: la quartzite ordovicienne de Tipperary, la formation d'Owen Creek, le niveau Whiskey Trail de la formation de Beaverfoot et la formation silurienne de Tegart.

Des études sur la faune permettent de reconnaître quatre zones à brachiopodes, à coraux et à trilobites au sein de la formation de Beaverfoot, et une zone à conodontes à la base de la formation de Beaverfoot et dans les couches supérieures de la formation de Mount Wilson. Trois zones à brachiopodes sont présentes dans la formation de Skoki, dont l'*Anomalorthis* et l'*Orthidiella* qui correspondent à celles de Whiterock dans les calcaires d'Antelope Valley au Nevada. Une nouvelle zone à brachiopodes se présente près de la base de la formation de Skoki et on la situe dans le Canadien récent. Cette zone à *Hesperonomia* peut correspondre en partie à la zone à trilobites *Pseudocybele* de l'Utah et du Nevada.

INTRODUCTION

Ordovician and Silurian rocks have been reported from various parts of the southern Rocky Mountains during the past eighty years. This bulletin is a result of regional study of the interval Middle Ordovician to Silurian and establishes an effective stratigraphic nomenclature for the interval for the whole of the southern Rockies. Lower Ordovician stratigraphy is briefly reviewed. The study is based on six months field work during the period 1961 to 1965, primarily devoted to the examination of well-exposed stratigraphic sections. Further detailed faunal and sedimentary papers are projected for most of the formations and only type and standard stratigraphic sections are now presented (*see* Appendix).

Acknowledgments

J. D. Aitken, G. B. Leech, and J. O. Wheeler of the Geological Survey of Canada have supplied some of the data used in this paper, critically used the stratigraphic units in the field, and suggested improvements in the manuscript during the course of its preparation. C. J. Bruce and P. L. Gordy of Shell Canada Limited, R. G. Greggs of Queen's University, G. G. L. Henderson of Chevron Standard Limited, D. E. Jackson of the University of Alberta, and J. E. Reesor of the Geological Survey also assisted during the study. The author is indebted to many wardens of Banff, Jasper, Kootenay, and Yoho National Parks for their advice and co-operation during the course of the field work.

R. J. Ross, Jr., and F. G. Poole of the United States Geological Survey and Lehi F. Hintze of Brigham Young University showed the author representative stratigraphic sections of Ordovician and Silurian rocks in Idaho, Utah, and Nevada. Ross and Michael Churkin, Jr., also of the United States Geological Survey, criticized an early draft of that part of the manuscript that compares the Ordovician and Silurian rocks of the western United States with those of the southern Rocky Mountains.

D. J. McLaren and A. W. Norris identified all the Devonian invertebrate macrofossils collected; W. C. Sweet and T. T. Uyeno, some Ordovician conodonts; T. E. Bolton, some Ordovician trilobites; M. J. Copeland, all the ostracods collected; E. L. Yochelson, specimens of *Ceratopea*; D. L. Dineley, some fish; D. E. Jackson, some of the Ordovician graptolites; and R. Thorsteinsson, some of the Silurian graptolites. R. J. Ross, Jr., supplied manuscript identifications of some Lower Ordovician trilobites collected by Walcott. The author identified the remaining fossils.

Manuscript received 2 December, 1965

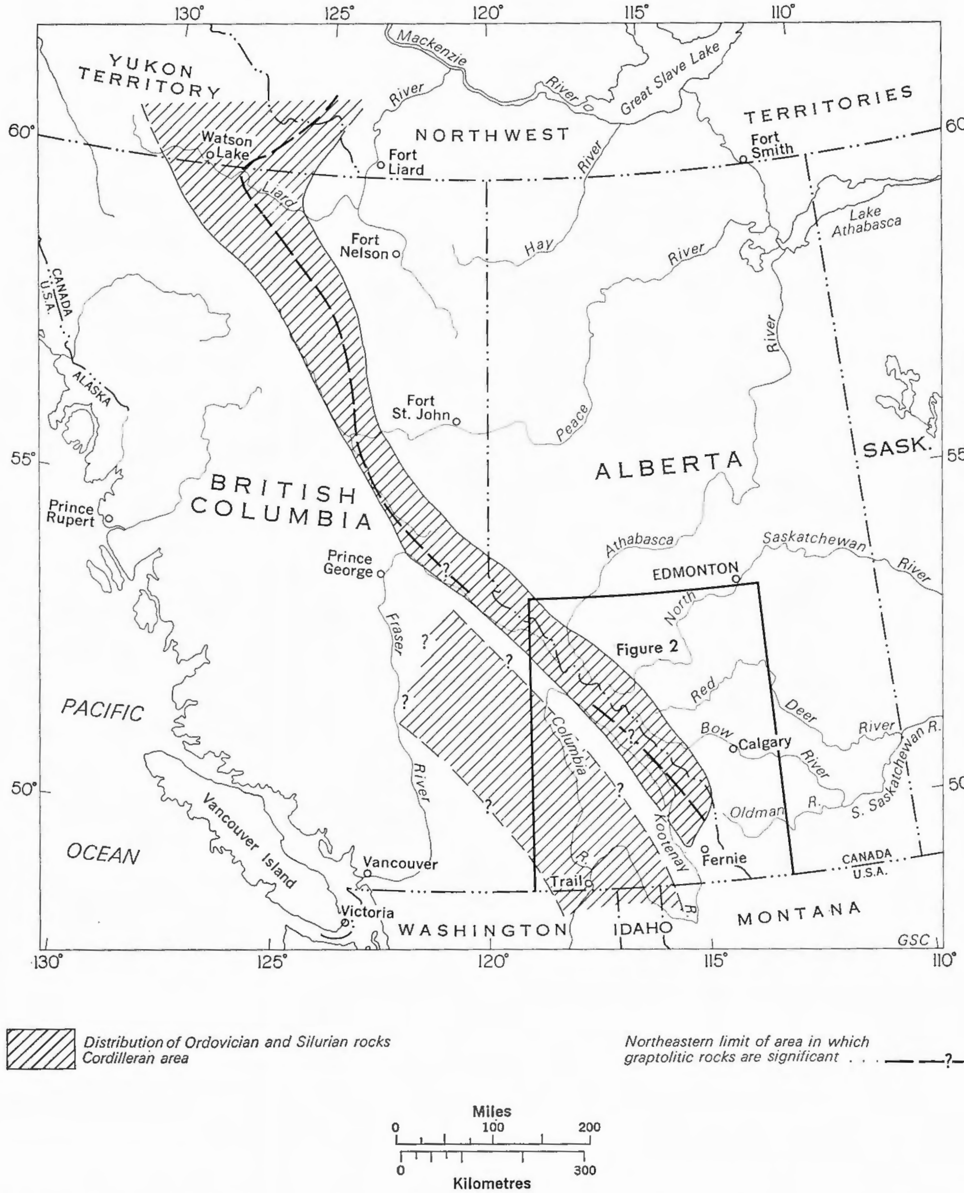


FIGURE 1. Distribution of Ordovician and Silurian rocks, Cordillera of Alberta and British Columbia (modified from Norford, 1965).

Geological Setting

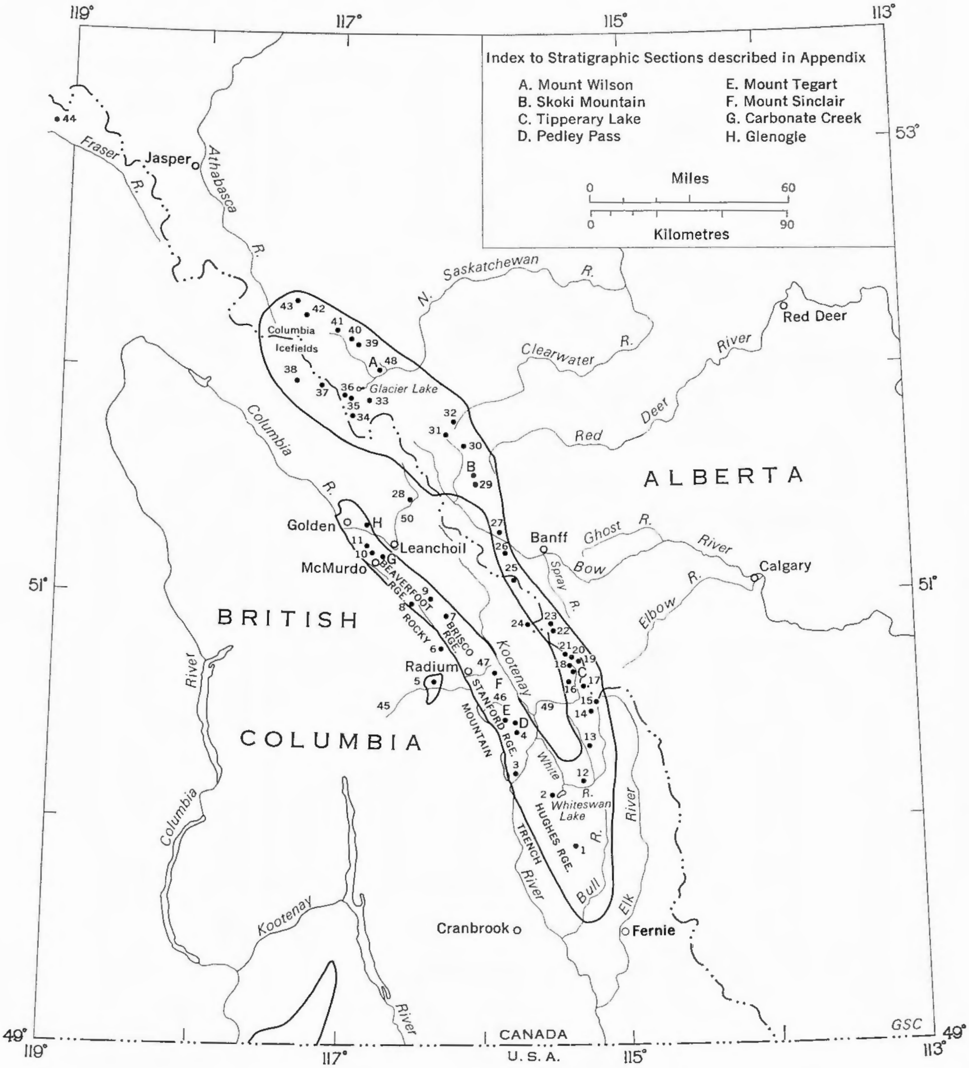
The southern Rocky Mountains present excellent outcrops of Palaeozoic rocks. Vegetation is sparse, relief is high, and most of the talus has been removed by Pleistocene valley glaciers. An extreme example of a stratigraphic section is that provided by Mount Forbes, which rises more than 6,000 feet above Glacier Lake and exposes a vast thickness of Cambrian, Ordovician, and Devonian carbonate rocks that dip gently into the mountain. The structure of the southern Rockies is dominated by a series of shallow thrusts that mostly follow a few select formations. The thrusting requires large and intricate palinspastic adjustments before meaningful palaeogeographic maps can be produced, but the stratigraphy of the rock units within the thrust plates is very rarely affected.

The patterns of mountain ranges, outcrops, thrust plates, and sedimentation all trend roughly parallel and to the northwest. Carbonates, shales, and sandstones are the common rocks. The sequences Lower Cambrian to Lower Ordovician and Upper Devonian to Upper Mississippian are thick, widely distributed, and probably give almost complete representation of these intervals. Unconformities in the latter part of the Palaeozoic and beneath Devonian rocks cause the rest of the Palaeozoic sequence to be very discontinuous and only locally preserved.

The unconformity below Devonian rocks is a major feature of the geology of western Canada. Within the southern Rocky Mountains the basal Devonian rocks above the unconformity are locally Lower Devonian, in a few places probably Upper Devonian, and elsewhere Middle Devonian. The unconformity rests directly on various horizons from Precambrian to uppermost Lower Silurian. The period of warping, uplift, and erosion reflected by the unconformity is thus dated as sometime within the interval Middle Silurian to Early Devonian. Less conspicuous unconformities can be detected within the Ordovician and Silurian sequence. These are at the base of the Owen Creek Formation, beneath the Mount Wilson Quartzite, and at the contact of the Whiskey Trail Member with the rest of the Beaverfoot Formation.

Along the southern Rocky Mountains, rocks of Middle Ordovician to Silurian age wedge out beneath the sub-Devonian unconformity southeast of Cranbrook and north of the Columbia Icefields (Figs. 2 and 6). Across the mountains, the sub-Devonian unconformity regionally truncates the subjacent rocks in a northeasterly direction away from the Rocky Mountain Trench (Mountjoy, 1963, p. 17). It rests on Lower Silurian rocks just east of the Trench, Ordovician rocks at the British Columbia–Alberta boundary, and (Aitken, 1963, p. 274) on Upper Cambrian rocks near Banff. Little Palaeozoic rock is preserved in the region immediately west of the Trench, but an outlier at Mount Forster has a thin Ordovician sequence.

A belt of Middle Ordovician facies change runs northwest, approximately through Mount King George and Mount Burgess, and separates graptolitic rocks of the Glenogle Shales to the southwest from shelf carbonates and quartzites to the northeast. The Mount Wilson Quartzite directly overlies both the graptolitic facies and the shelf carbonate–quartzite facies, indicating that the belt of facies change was no longer present in the southern Rocky Mountains in Mount Wilson time. The Beaverfoot Formation of shelf carbonates similarly shows no evidence of the influence of



Key to Localities

1. Top of the World
2. Alces Lake
3. Mount Sabine
4. Indianhead Mountain
5. Mount Forster
6. Steamboat Mountain
7. Pinnacle Creek
8. Jubilee Mountain
9. Hatch Creek
10. Pagliaro Creek
11. Horse Creek
12. Blackfoot Creek
13. North White River
14. Shatch Mountain
15. Mount Joffre
16. Mount King George
17. Mount Onslow
18. Mount Cradock
19. Mount Le Roy
20. Palliser Pass
21. Mount Leman
22. Mount Byng
23. Owl Lake
24. Mount Assiniboine
25. Sunshine
26. Copper Mountain
27. Castle Mountain
28. Mount Burgess
29. Fossil Mountain
30. Cataract Peak
31. Pipestone River
32. Devon Mountain
33. David Lake
34. Coronation Mountain
35. Mount Forbes
36. Division Mountain
37. Mount Lens
38. Mount Whiterose
39. Mount Coleman
40. Cirrus Mountain
41. Big Hill
42. Nigel Peak
43. Tangle Ridge
44. Mount Robson

Drainage (unnamed on Index Map)

45. Horsethief Creek
46. Windermere Creek
47. Sinclair Creek
48. Owen Creek
49. Palliser River
50. Kicking Horse River

FIGURE 2. Index Map. Outlined areas indicate gross areas in the southern Rocky Mountains and Interior Ranges where outcrops of the interval Middle Ordovician to Silurian are preserved.

this belt of facies change. The rugged central belt of the southern Rocky Mountains is dominantly composed of Cambrian rocks. Middle Ordovician to Silurian strata have been almost entirely removed by recent erosion (Fig. 6). The belt of Middle Ordovician facies change falls within this central belt and therefore cannot be precisely positioned. The central belt separates the southern Rocky Mountains into two parts. The eastern part was the site of shelf sedimentation during Middle Ordovician time while graptolitic rocks accumulated in the western part. Figure 3 shows typical stratigraphic sections developed in the two parts. The eastern part is almost entirely in Alberta whereas the western lies wholly in British Columbia. Previous geological studies have been restricted primarily to either one part or the other.

Previous Studies

Western Part of the Southern Rocky Mountains

McConnell (1887) first noted graptolitic shales underlying a sequence of quartzites and dolomites in the western part of the southern Rockies. Allan (1914) determined that the quartzites could be mapped separately from the overlying dolomites and assigned the graptolitic shales to the Ordovician (following Lapworth 1887) and the "*Halysites* beds" (quartzites and dolomites) to the Silurian (Fig. 4). Burling (1921 and 1922) introduced the formation names Glenogle Shales and Beaverfoot Formation for these rocks, but failed to designate the quartzites as a distinct unit. The Glenogle Shales were dated as Canadian and Chazy, and the Beaverfoot as Richmond.

Walcott proposed several new formations in 1924. The quartzite unit was segregated from the Beaverfoot Formation under the name Wonah Quartzite. The Sinclair Formation was erected for shales and arenaceous beds immediately underlying the Wonah, but was later discarded as a synonym of the upper part of the Glenogle Shales (Walcott, 1928, p. 220). Walcott realized that the dolomites were thicker near Radium than in the type section of the Beaverfoot Formation, and that faunas younger than the Richmond fossils collected by Burling were present. He therefore proposed a new term, the Brisco Formation, for a Silurian dolomite and argillaceous unit, and considered it lithologically distinct from the underlying Beaverfoot Formation. He failed to discuss the presence or absence of the Brisco within the Beaverfoot type section. All the 1924 formations, Sinclair, Wonah, and Brisco, are now discarded.

Subsequent workers (Walker, 1926; Evans, 1933; Henderson, 1954; North and Henderson, 1954; Leech, 1954, 1958, 1959, 1960, and 1962; Reesor, 1957; Norford, 1962a) were unable to differentiate Brisco from Beaverfoot on lithological grounds and used the name Beaverfoot–Brisco to cover the dolomites and shales of Upper Ordovician and Silurian age. Use of the term Wonah was continued, but North and Henderson and later authors have suggested its lithological equivalence to the Mount Wilson Quartzite.

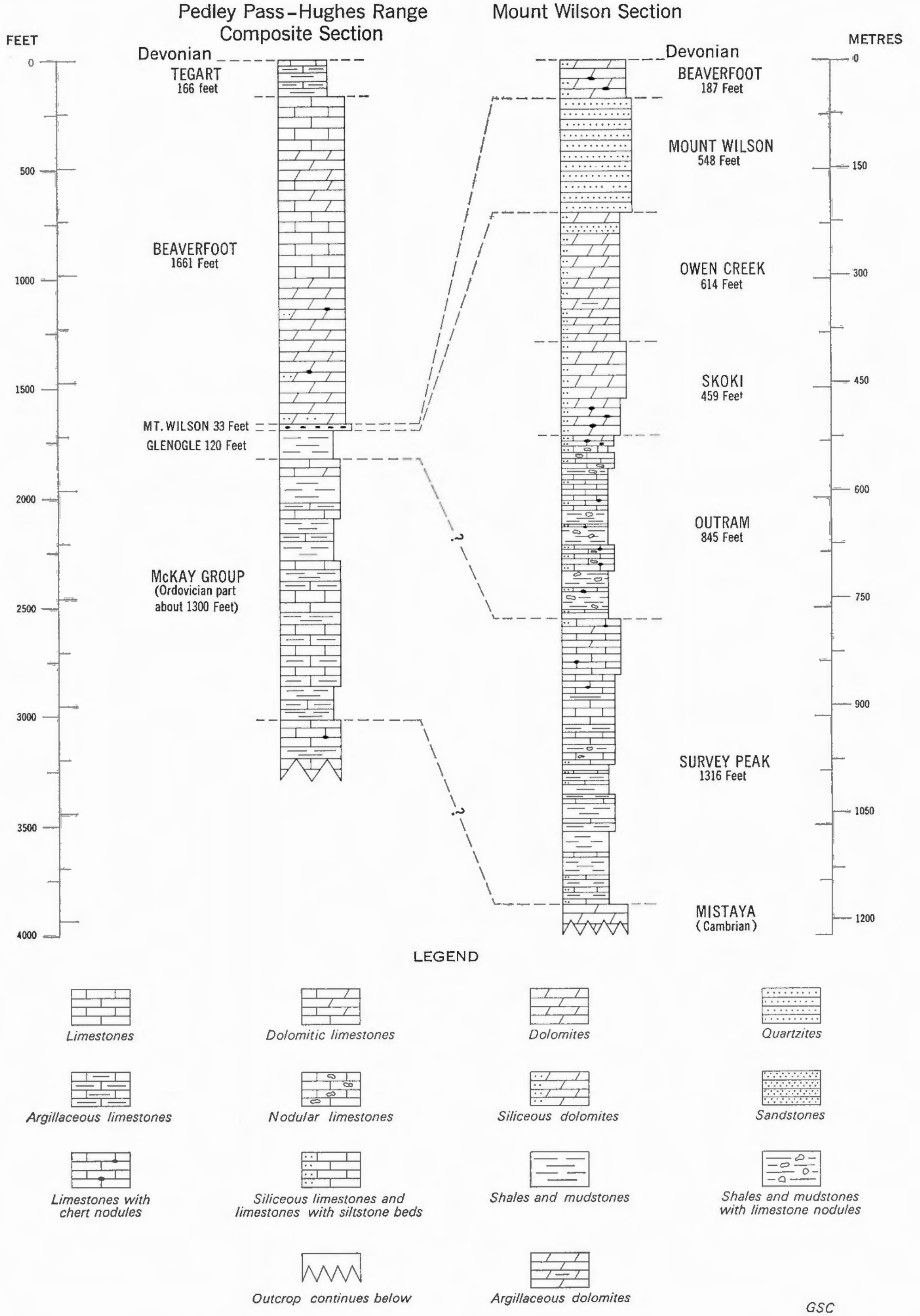


FIGURE 3. Representative sections, southern Rocky Mountains. The left-hand section shows the units typically developed in the western part of the southern Rocky Mountains; the right-hand section shows those typically developed in the eastern part. The Tipperary Quartzite is not present at Mount Wilson, but is developed in the Spray River–Palliser River region where it separates the Skoki and Outram Formations. (Data on the McKay Group of the Hughes Range from Leech, 1954).

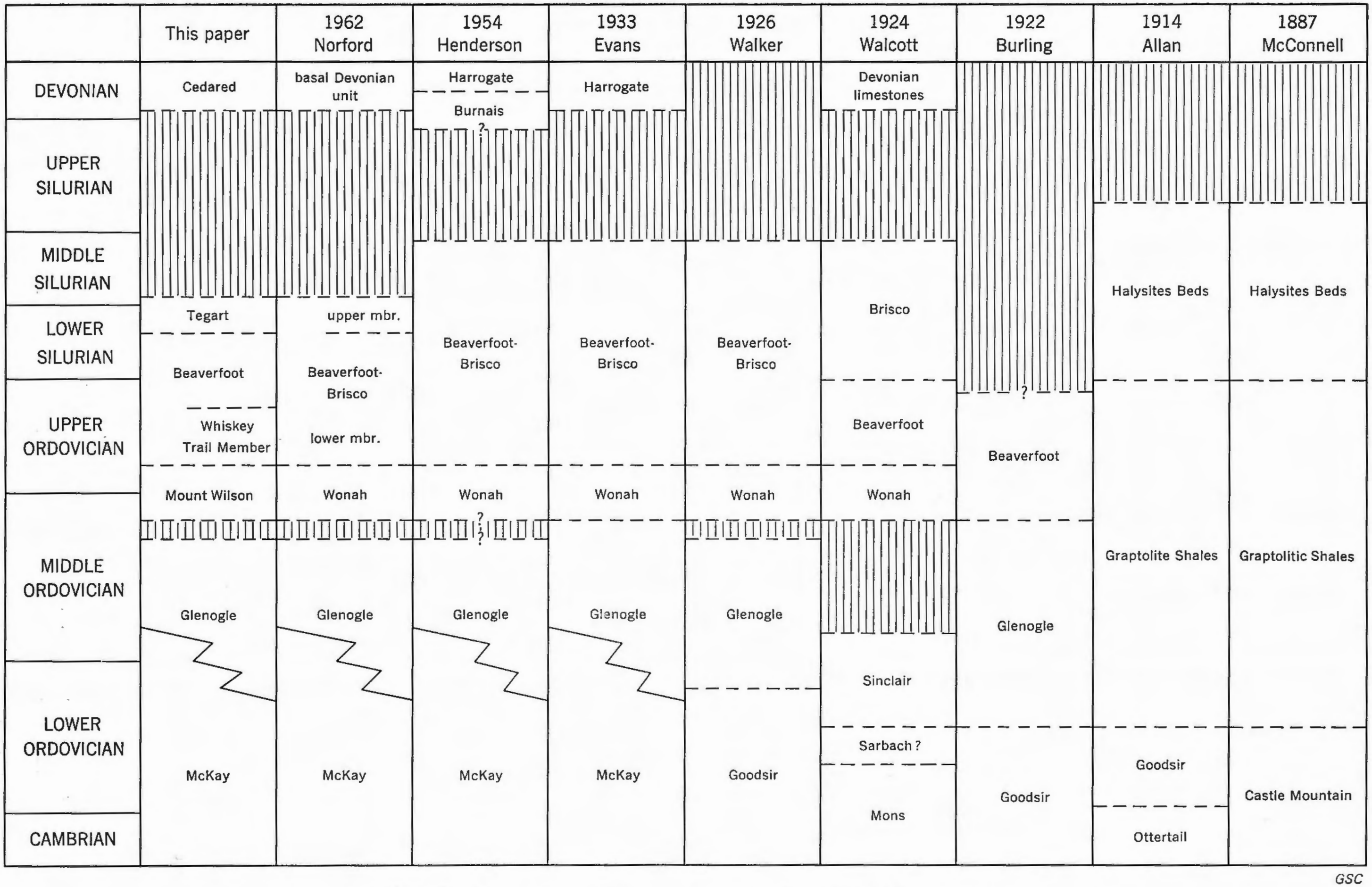


FIGURE 4. History of nomenclature, western part of southern Rocky Mountains.

Eastern Part of the Southern Rocky Mountains

The first reports of rocks of the Middle Ordovician to Silurian interval in the eastern part of the southern Rocky Mountains were by Walcott (1923 and 1928), who erected the Mount Wilson Quartzite and the Skoki Formation. The Mount Wilson was tentatively assigned to the Devonian, and a Chazy age was suggested for the Skoki (Fig. 5). The presence of pre-Devonian rocks stratigraphically above the Mount Wilson Quartzite was demonstrated by Severson (1950), who thought the rocks Silurian. Harker, Hutchinson, and McLaren (1954) showed these rocks to be Upper Ordovician and Norford (1961) assigned them to the Beaverfoot–Brisco Formation.

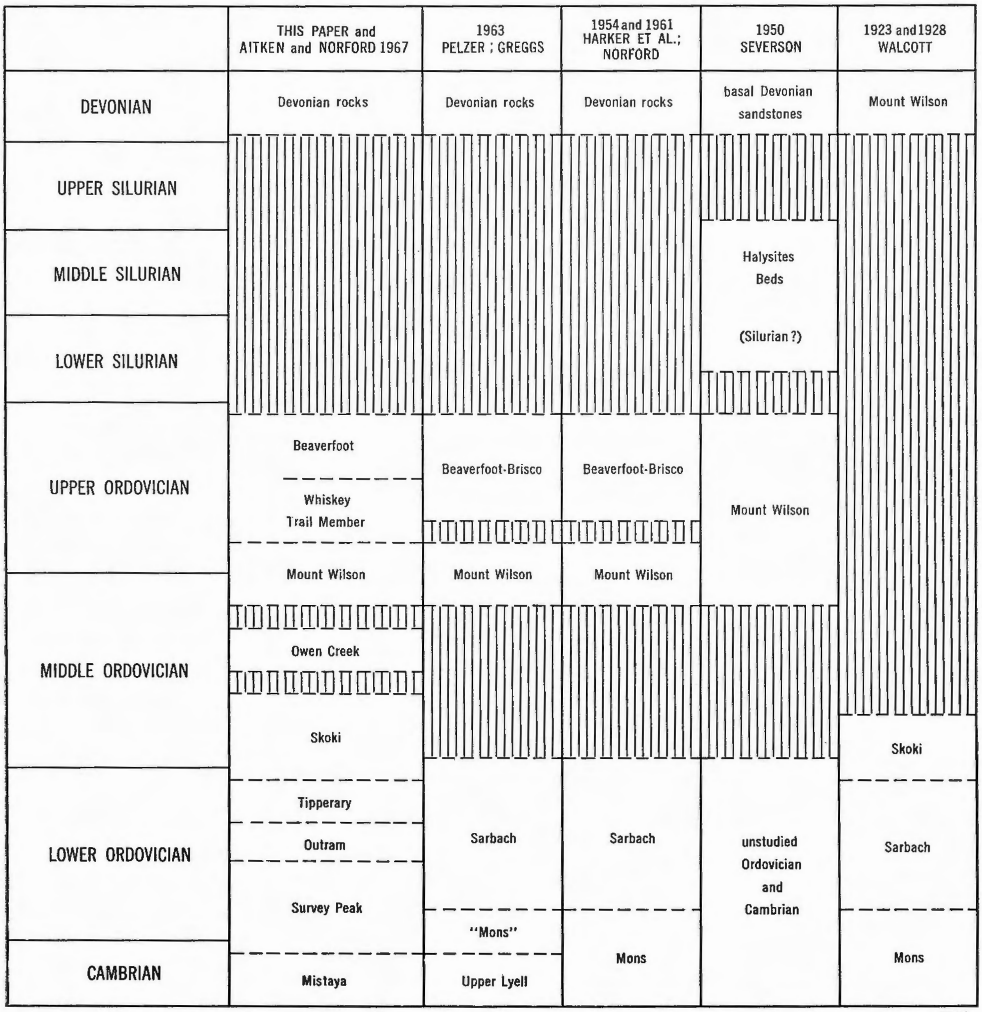


FIGURE 5. History of nomenclature, eastern part of southern Rocky Mountains.

Hughes (1955) described Ordovician rocks at Tangle Ridge, east of the Columbia Icefields, but the Ordovician section appears to be faulted. His Ordovician Formation A seems to include parts of the Survey Peak, Outram, and Skoki Formations. His Formation B ("Mount Wilson") may be basal Devonian.

Wilson described Ordovician fossils from the Rocky Mountains in 1924 and 1926. Her work revealed the presence of the Beaverfoot Formation near the Palliser River and studies by Cole (1928) indicated a development of the Mount Wilson Quartzite near Pipestone River. Recently, Rigby (1965) and Ethington and Clark (1965) have described sponges and conodonts respectively from the Survey Peak, Outram, and Skoki Formations from the west flank of Nigel Peak.

LITHOSTRATIGRAPHIC UNITS

Lower Ordovician Rocks

Little or no lithological change marks the boundary between the Cambrian and Ordovician Systems in the southern Rocky Mountains. The McKay Group (Evans, 1933) in the west and the Survey Peak Formation (Aitken and Norford, 1967) both span the boundary, and detailed faunal studies are required to establish the precise horizon of the base of the Ordovician within these units. Lower Ordovician rocks in the eastern part of the southern Rocky Mountains traditionally have been placed within the Mons and Sarbach Formations (Walcott, 1920), but a new terminology has recently been introduced and these names are now obsolete (Aitken and Norford, 1967).

The Survey Peak Formation consists of calcareous shales and mudstones, siltstones, microcrystalline limestones, calcisiltites, limestone–pebble conglomerates, biocalcarenites, and cryptalgal limestones. Four informal members can be distinguished. These are the basal silty, putty shale, middle, and upper massive members. All the members apparently accumulated on a shallow to very shallow sea bottom that was intermittently emergent. The Survey Peak rests with abrupt but concordant contact upon the uppermost Cambrian Mistaya Formation or its equivalent in the Lynx Group. The Survey Peak Formation can be recognized within the upper part of the McKay Group in the western part of the southern Rockies.

The Outram Formation (Aitken and Norford, 1967) includes dark shales, limy siltstones, calcisiltites, limestones (clotted, nodular, and laminated), biocalcarenites, and limestone-pebble conglomerates. Chert is present as nodules, tracery, and irregular masses. The Outram probably was deposited in a moderately shallow, poorly aerated sea. It has a conformable and gradational contact with the underlying Survey Peak Formation. The Outram is coeval with the lowest part of the Glenogle Shales of the western part of the southern Rocky Mountains.

The Survey Peak, Outram, and basal Skoki Formations appear to represent a complete sequence through Lower Ordovician (Canadian) time. Trilobites collected from the type sections of the Survey Peak and Outram at Mount Wilson indicate the presence of the A, B, D, E, F, G_1, G_2, and J zones of the standard Utah and Nevada sequence (Aitken and Norford, 1967). Barren intervals could correspond to the undocumented C, H, and I zones. Elsewhere *Trigonocerca entella* (Walcott) was described from the Outram Formation and may indicate the presence of zone H within the formation.

Species of *Phyllograptus* and *Didymograptus* were collected by Walcott (1928, p. 289, locality 21x; *see also* Ruedemann, 1947, pp. 105–106) from the Outram

Formation on the northeast shoulder of Fossil Mountain, directly opposite the type section of the Skoki Formation (Appendix, Section B). These graptolites were found 253–277 feet below the base of the Skoki (as picked by this author). Ruedemann's identifications suggest either the zone of *Didymograptus protobifidus* or that of *Isograptus caduceus* of the Glenogle sequence (Fig. 16). *Rossaspis* cf. *R. superciliosa* (Ross) has been identified by Ross (personal communication) with other trilobites in Walcott's collections from the latter's locality 69a in the Survey Peak Formation at the same section on Fossil Mountain, about 400 feet below the graptolites. Ross suggests that the 69a horizon can be correlated within the interval F to I of the Utah and Nevada sequence. Walcott's locality 69b of the same section is reported to be 30 to 40 feet above the graptolite collection (Walcott, 1928, p. 289). Ross (personal communication) has identified *Ptyocephalus* sp. and *Goniotelina* sp. in the 69b collection and suggests that the age is probably zone J. Thus the graptolite faunule of 21x must correlate within the interval F to J, probably within the upper part (H to J) of this interval, if one considers its stratigraphic position close to 69b.

Farther north, near Mount Robson, the poorly defined Lower Ordovician Chushina Formation (Walcott, 1923) can be interpreted as the lower part of the Survey Peak Formation (Aitken and Norford, 1967, pp. 157–158). Trilobites collected from the Chushina by E. W. Mountjoy and identified by Norford demonstrate the presence of the lower Canadian B and D zones, but no younger faunas are known from near the type area. The Chushina is directly overlain by Devonian rocks and is the only Ordovician unit preserved in the Rocky Mountains north of Jasper and south of Cecilia Lake (Slind and Perkins, 1967, Fig. 2). A variety of *Dictyonema flabelliforme* (Eichwald) has been described from the Mount Robson area (Ruedemann, 1930 and 1947, pp. 160–161) and indicates Tremadoc age. The material was collected from a glacier, but was thought to have originated within the Chushina Formation.

The McKay Group is a thick sequence of shaly limestones, limestones, and shales. The Ordovician part is about 1,300 feet thick in the Hughes Range and probably thickens to the southeast (Leech, 1958). Trilobites collected by G. B. Leech from the Ordovician part of the McKay Group of the Fernie and Kananaskis map-areas and identified by the author and by T. E. Bolton indicate the presence of the A, B, D, E, F, and G_1 zones. Fossils are rare in the uppermost beds of the group and younger Canadian trilobite zones may be present beneath the Glenogle Shales, but are as yet undocumented. In most stratigraphic sections, the basal part of the overlying Glenogle is Lower Ordovician (*Didymograptus protobifidus* zone), but the McKay Group at its type section in the southern Brisco Range extends up into the Middle Ordovician and is in part contemporaneous with the Glenogle Shales that now outcrop farther east (Evans, 1933, pp. 126–134). The Lower Ordovician (Canadian) part of the type section of the McKay Group is lithologically very similar to the Survey Peak and Outram Formations as developed at Mount Wilson.

The name Goodsir Formation has been used for an extremely thick sequence of shales, limestones, and slates in the ranges of the western part of the southern Rockies that lie immediately east of the Beaverfoot, Brisco, and Stanford Ranges. An exceptional use is that of North and Henderson (1954), who used the Goodsir Group as a

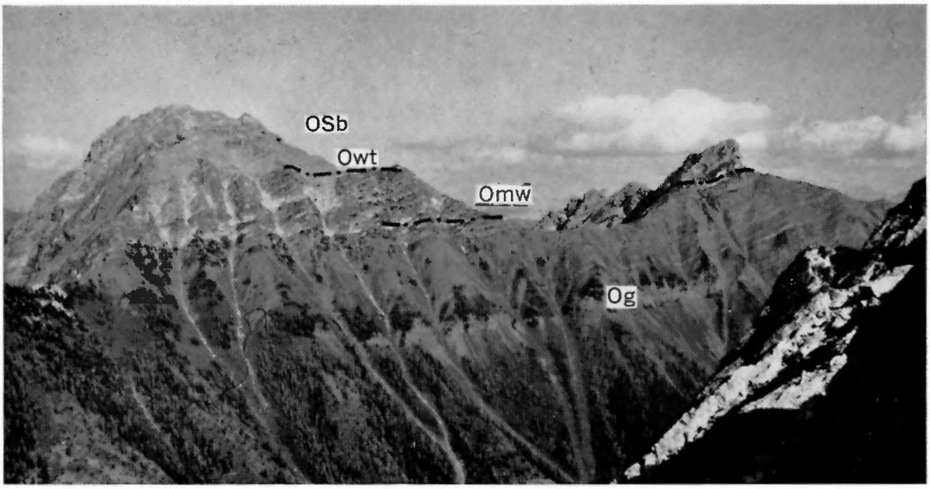


PLATE II. Ordovician rocks near Pinnacle Creek, Brisco Range. Northeast limb of anticline at head of creek. Og, Glenogle; Omw, Mount Wilson; Owt, Whiskey Trail Member; OSb, Beaverfoot.

supraformational term to encompass most of the high Upper Cambrian, Lower Ordovician, and Middle Ordovician formations in the southern Rocky Mountains. Most outcrops of the Goodsir Formation are slightly metamorphosed and the only reported fossils have been collected from near the base of the formation and are Franconian (Mogensen, 1960). The Goodsir is probably entirely equivalent to the McKay Group and the name is best discarded (Aitken and Norford, 1967, p. 159).

Glenogle Shales

The formation was erected by Burling (1921 and 1922) for rocks in the valley of the Kicking Horse River previously termed the "Graptolite Shales", and for similar rocks in the northern Beaverfoot Range. The type locality is at Glenogle (Fig. 2, locality H) where the rocks are structurally complex (Larson and Jackson, 1967). Allan (1914, p. 100) gave a thickness of about 1,700 feet for the formation in Glenogle Creek, just east of the type locality. The section at the head of Windermere Creek in the Stanford Range has been used as a reference section for the Glenogle Shales. Drag folds and small faults are present and therefore stratigraphic thicknesses are unreliable, but the sequence of faunas does not seem to be jumbled (Walker, 1926, Fig. II, pp. 26–27). The formation has been measured as 2,162 feet thick and can be divided into an upper part (535 feet) of sandy shales and argillaceous sandstones and a lower part (1,627 feet) of shales with interbedded mudstones and limestones (Walker, 1926, pp. 24–28). The younger graptolite faunas found at Glenogle have not been reported from the Windermere Creek section, but Walker found no graptolites in the sandy upper part of the formation.

The sandy upper part of the Glenogle is well developed in the eastern parts of the Beaverfoot, Brisco, and Stanford Ranges, and also northwest of White Swan

Lake and near Blackfoot Creek. It is not present in most of the western parts of the three ranges and is apparently missing in the outcrops near the Kicking Horse River described by Larson and Jackson (1967), but these outcrops are not structurally straightforward, and the beds could be faulted out, or, alternatively, covered. The sandy upper Glenogle is well developed in the headwaters of Horse Creek, about 6 miles south of the outcrops near the Kicking Horse River. These sandy beds probably represent a belt of deposition in which the sea shallowed in late Glenogle time. The shallowing may not have affected sedimentation in the western part of the area of Glenogle deposition, and normal graptolitic shales may have continued to the limit of the formation. A more likely alternative is that erosion prior to deposition of the Mount Wilson Quartzite locally removed these sandy beds from many of the western parts of the ranges.

The lower part of the Glenogle Shales consists of shales, limy shales, shaly limestones, and limestones. Limestones are common in the most easterly development of the Glenogle, near Bull River (Leech, 1958, p. 14) and near the North White River, towards the contemporaneous shelf deposits of the Owen Creek, Skoki, Tipperary, and Outram Formations (Figs. 7 and 8). The Glenogle appears to change eastward to an intermediate facies of limestones and shales of the Outram Formation. The upper part of this development of the Outram Formation itself changes facies eastward into the Owen Creek, Skoki, and Tipperary shelf formations. Tongues of Outram facies are present within the Skoki Formation at Mount Leman, Mount Byng, and Whiterose Mountain.

Graptolites collected from the Glenogle in the first half of the century were studied by Ruedemann (1947 and earlier papers). Recent revisions of Ordovician graptolite zonation in North America (Berry, 1960 and 1962; Ross and Berry, 1963; Jackson, 1964; Jackson and Lenz, 1962; and Larson and Jackson, 1967) require modification of Ruedemann's zonation of the Glenogle graptolite faunas. Jackson is currently engaged in such a study.

The existing literature allows recognition of five graptolite zones within the Glenogle Shales (Fig. 16):

Nemagraptus gracilis
Glyptograptus cf. *G. teretiusculus*
Paraglossograptus etheridgei
Isograptus caduceus
Didymograptus protobifidus

Jackson (1964, Fig. 2) suggested two Glenogle subzones within the *I. caduceus* zone and two within the *P. etheridgei* zone. Larson and Jackson (1967) considered that a zone of *Diplograptus decoratus* may be locally recognized within the upper part of the *P. etheridgei* zone. The zone of *N. gracilis* has only been detected in the outcrops near Glenogle. Brachiopods and trilobites are also present in the Glenogle faunas, but these are very rare.

The Glenogle–McKay contact is gradational in many outcrops (Walker, 1926, p. 24; Evans, 1933, p. 135; Leech, 1954, p. 14) and the major part of the Glenogle Shales in the southeast Brisco Range may be contemporaneous with the upper

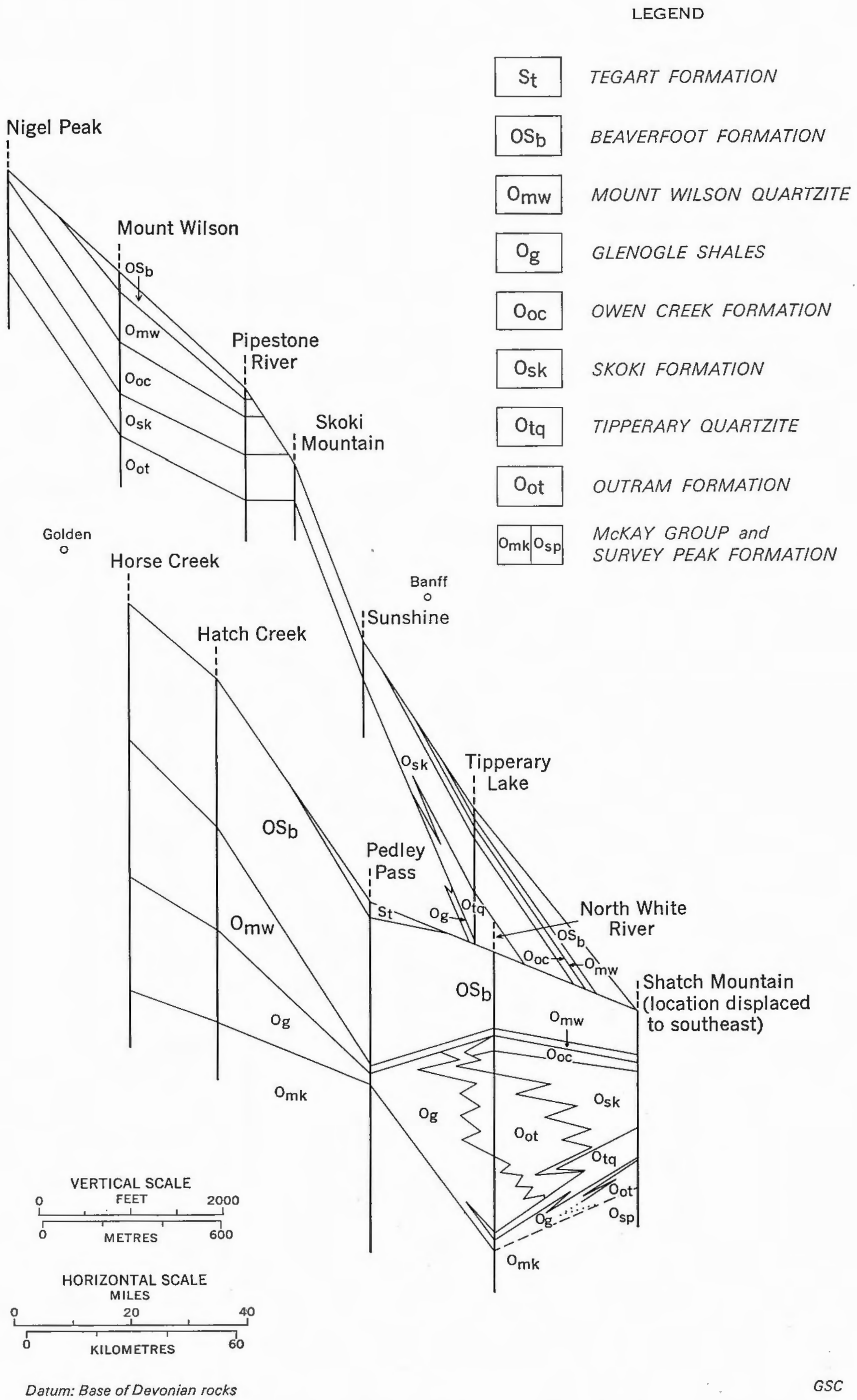
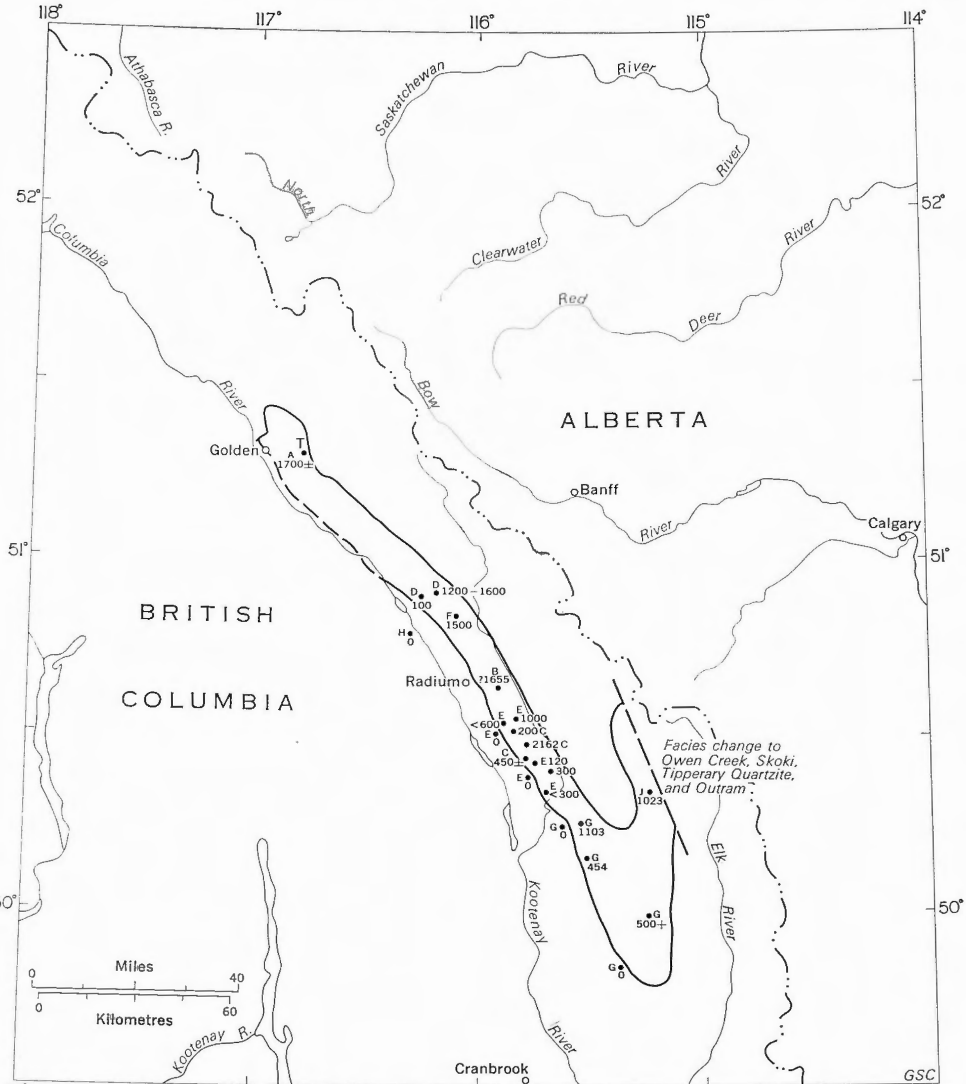


FIGURE 7. Fence-diagram, Middle Ordovician to Silurian formations, datum base of Devonian rocks.



Type section. . . . . . . T *Measured sections (thickness in feet). . . . . .* • 500

*Data by Allan, 1914. . . . .*A *Data by Evans, 1933. . . . .*D *Data by Leech, 1954, 1958, 1959 & MS. . . .* G
*Data by Walcott, 1924. . . .*B *Data by Henderson, 1954 . . . .*E *Data by McCammon, 1965. . . . .*H
Data by Walker, 1926 . . . . C *Data by North and Henderson, 1954 . . .* F *Additional data from Reesor, 1957*
*Upper part of formation changed facies to Outram. . . .*J

FIGURE 8. Distribution map for the Glenogle Shales.

part of the type McKay Group adjacent to the west (Evans, 1933, p. 130). The Glenogle–Mount Wilson contact is paraconformable in almost all outcrops. In much of the outcrop region the sandy upper part of the Glenogle is present, and a gradual change in sedimentary conditions between the typical shales and the Mount Wilson quartz sands could be postulated. Shallow erosion surfaces occur at this contact near

Blackfoot Creek and at Pinnacle Creek, and Walker reported evidence of erosion of the uppermost shales of the Glenogle on the first north fork of Windermere Creek. This last locality has a very thin Glenogle section (200 feet thick, Walker, 1926, p. 28) in which the sandy upper part of the formation does not appear to be present.

The sandy upper part of the Glenogle Shales is missing from the southwest part of the Glenogle outcrop belt. The formation thins abruptly to the southwest in the same region. The Glenogle is only about 450 feet thick east of Mount Tegart, and identifications of graptolites by Ruedemann, listed by Walker (1926, p. 29) as within 15 feet of the top of the formation, indicate the *Paraglossograptus etheridgei* zone. The two uppermost graptolite zones of the Glenogle Shales are missing at this outcrop. The base of the Mount Wilson is thus disconformable and the southwest thinning of the Glenogle is primarily erosional.

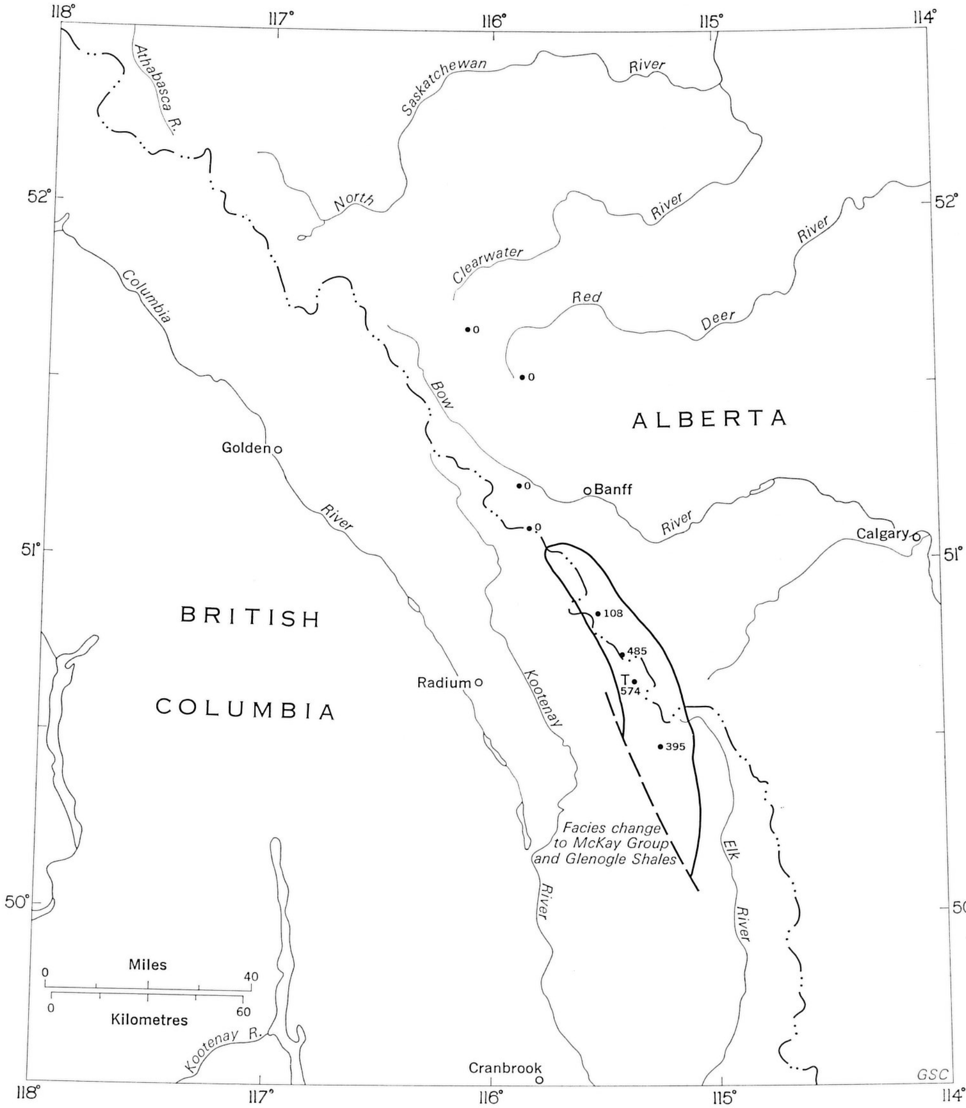
Tipperary Quartzite

The name Tipperary Quartzite is here proposed for a Lower Ordovician quartzite unit that is only developed in the southeast part of the southern Rocky Mountains (Fig. 9). The Skoki Formation overlies the Tipperary Quartzite, which itself overlies a thin tongue of Glenogle Shales extending eastward into the Outram Formation. The unit is 574 feet thick at the type section, a steep gully at 50°40′N, 115°21′W, just east of Tipperary Lake (Appendix, Section C).

The formation consists of thickly bedded quartzites with very minor dolomitic quartz sandstones, siliceous dolomites, and shaly mudstones. Coarse crosslamination is well developed in the lower half of the formation (Plate III). Measurements of current directions in this part of the formation at the type section suggest transport from the east. The Tipperary Quartzite is very similar lithologically to the Mount Wilson Quartzite, but is generally more thickly bedded and more commonly crosslaminated. The two formations are easily confused in mapping and study of the overlying formations is necessary to confirm their identification.

The contact with the underlying Glenogle Shales is covered in the type section, but is apparently concordant. Laterally, the Glenogle beds appear to thin drastically and the contact could be unconformable, or it could be the locus of slip of the competent quartzite unit over the subjacent shaly beds. The contact with the Skoki Formation is an erosion surface. No fossils are known from the Tipperary Quartzite, but it overlies trilobites suggesting the *Pseudocybele* (J) zone at the type section and it underlies brachiopods and trilobites of the *Hesperonomia* zone at Shatch Mountain. The formation is thus well dated as uppermost Canadian. Slind and Perkins (1967, p. 458) have recently proposed the name Monkman Quartzite for a similar formation in east-central British Columbia that is about the same age as the Tipperary Quartzite.

The Tipperary Quartzite is very restricted in its outcrop development and thins both to the north and south of the type section. To the west the formation is represented by the coeval part of the Glenogle Shales. Beds of quartzite within the



Type section . . . . . . .T *Measured sections (thickness in feet) . . . .*•485

FIGURE 9. Distribution map for the Tipperary Quartzite.

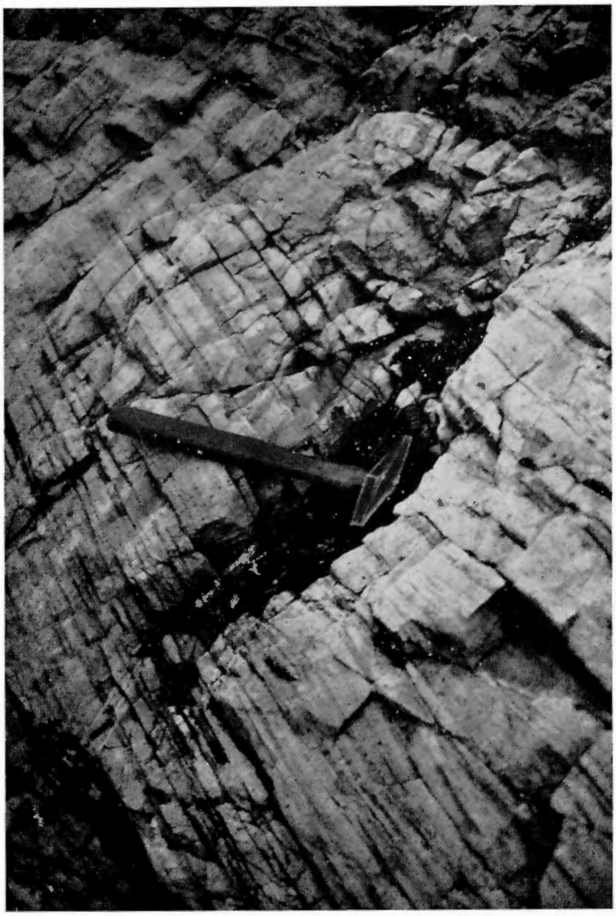


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PLATE III

Crossbedding in Unit 5 of type section of Tipperary Quartzite, Tipperary Lake section.

lower part of the Glenogle Shales of the North White River section represent a tongue of the Tipperary Quartzite extending westward into the region of shale deposition[1].

Skoki Formation

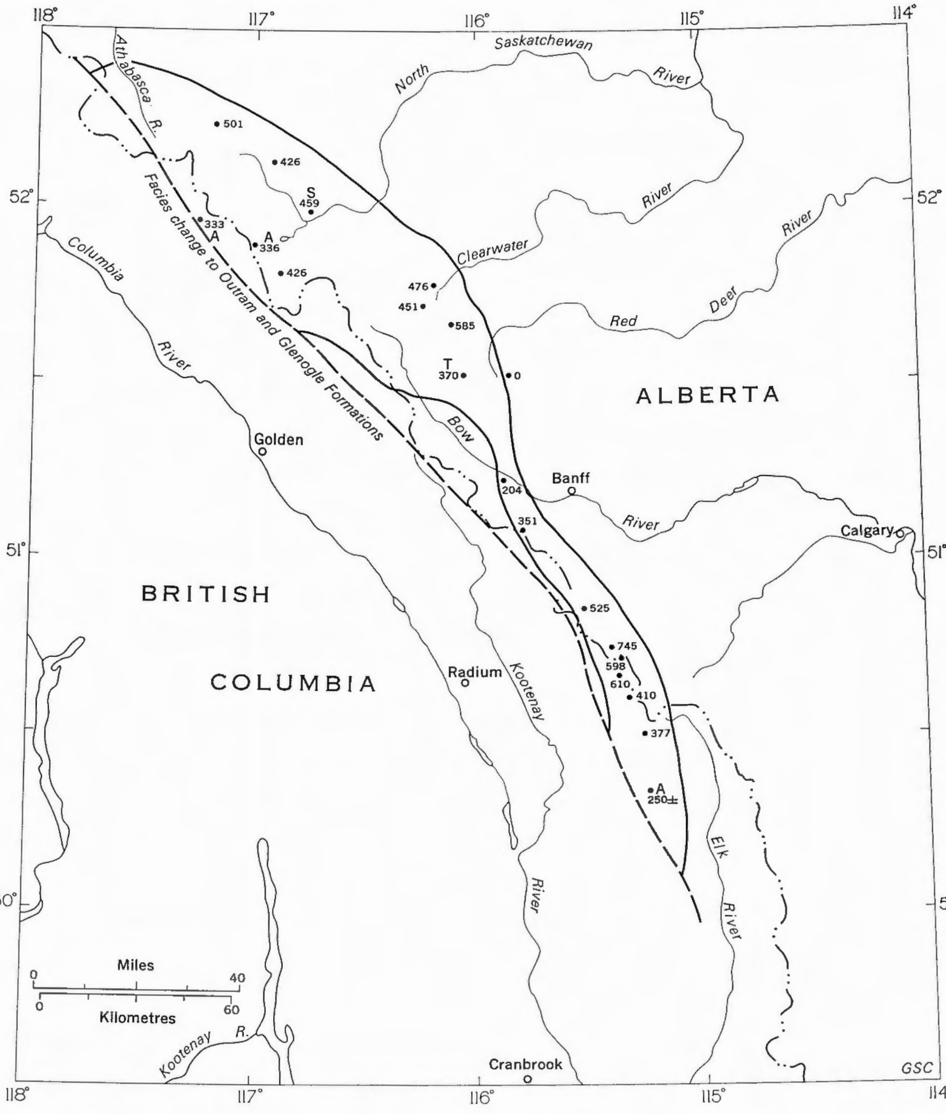
Towards the end of his field work in the southern Rocky Mountains, Walcott realized that the upper part of his Sarbach Formation in some sections was somewhat different from the rest of the unit. He proposed the Skoki Formation for these upper beds and noted the presence of gastropods and cephalopods that indicated Chazy age (Walcott, 1928, pp. 217–218). The formation was only positively identified from Skoki Mountain (Pl. XI) and the adjacent part of Fossil Mountain, but actually is widely distributed in the eastern part of the southern Rocky Mountains.

[1]Ketner (1968) has recently suggested that most of the quartz sand forming Ordovician quartzites in the Cordilleran miogeosyncline was derived from the Peace River–Athabasca arch of northern Alberta. This could be so, but the geometry of the distribution of the Tipperary Quartzite probably indicates deposition from the immediate east of the present outcrops.

Walcott's citation of the type locality refers to both the eastern side of Skoki Mountain and the northeast shoulder of Fossil Mountain, but his measured section was at the latter, a mile southeast of Skoki Mountain. This section is poorly exposed, with the uppermost 50 feet covered, and is very inferior to the complete exposure available at Skoki Mountain itself. The first locality given by Walcott is here taken to be the type locality, the citation of Skoki Mountain having precedence over that of Fossil Mountain. The type section is designated as a steep gully at the east end of the northeast face of Skoki Mountain at 51°32′N, 116°03′W, and shows 370 feet of the Skoki Formation exposed beneath a slightly irregular disconformable contact with quartz sandstones at the base of the Devonian Fairholme Group (Appendix, Section B, Pl. X). This thickness is less than the 500 feet cited by Walcott for his section on the adjacent northeast shoulder of Fossil Mountain. The lowermost 22 feet of Walcott's Skoki is now assigned to the Outram Formation, but the remaining 23 per cent discrepancy is primarily due to lack of accuracy in Walcott's measurements. No additional higher Skoki strata outcrop on Fossil Mountain and the Devonian actually rests on progressively lower horizons within the Skoki of Fossil Mountain southwards from Skoki Mountain. Thus the Skoki is about 350 feet thick in the central east face of Fossil Mountain and about 300 feet thick in the southeast face. In the type section, the base of the Skoki is picked at a disconformable undulatory contact with the Outram Formation. Nodular weathering rocks are common in the upper part of the Outram Formation.

At the section at Skoki Mountain, much of the Ordovician sequence was removed by erosion prior to the deposition of Devonian rocks, and a reference section at Mount Wilson (Appendix, Section A) is therefore selected to demonstrate better the uppermost beds of the Skoki Formation. At Mount Wilson Devonian rocks rest on an Upper Ordovician horizon within the Beaverfoot Formation. Excellent exposure shows 459 feet of Skoki concordantly underlying the Owen Creek Formation. Correlation via the Pipestone River section suggests that about 80 feet of strata that are present at the top of the Skoki Formation at Mount Wilson are missing at Skoki Mountain. The loss of these beds at the type section is due to erosion that also removed the Owen Creek Formation, the Mount Wilson Quartzite, the Beaverfoot Formation, and possibly younger rocks from Skoki Mountain prior to the deposition of the basal Devonian beds. The Skoki Formation is thickest in the southern part of its region of development and measures 745 feet at Mount Leman (Fig. 10). Much of the thickening is due to the presence of interbedded quartzites in the lower part of the formation. Part of the Glenogle Shales is the western correlate of the Skoki Formation.

The contact between the Skoki and Owen Creek Formations is concordant and apparently conformable in many stratigraphic sections, but at Mount Coleman deep channelling is developed and the contact is disconformable. Boulder conglomerates, breccias, sandstone dykes, and swallow holes are present at Division Mountain and Mount Whiterose. A swallow hole containing boulders of Owen Creek Formation cuts down 200 feet into the Skoki Formation at Division Mountain. The base of the Owen Creek Formation rests on the same part of the Skoki Formation in all studied stratigraphic sections and no regional truncation of the formation can be detected.



Type section . . . . T
Standard section . . . . S
Measured sections (thickness in feet) . . . . 250•
Lower part of Skoki Formation at North White River, Division Mtn. and Mt. Whiterose represented by Outram Formation . . . . . . A

FIGURE 10. Distribution map for the Skoki Formation.

The Skoki Formation overlies the Tipperary Quartzite in the Spray River and Palliser River region, but rests directly on the Outram Formation in the north. Minor disconformities are present at the contacts in some outcrops, but the Skoki–Outram boundary is difficult to detect in many stratigraphic sections and is diachronous in the extreme westerly development of the Skoki Formation. At North White

River, Mount Whiterose, and Division Mountain, the uppermost beds of the Outram Formation contain faunules of the *Orthidiella* zone which, in the Alberta sections to the east, is developed within the lower part of the Skoki but above the *Hesperonomia* zone at the base of the formation. In Alberta, faunules from the uppermost Outram beds indicate a similar age for the top of the formation both in the north in the Mount Wilson region and in the south near the Spray and Palliser Rivers. In the north, brachiopod faunules of the *Hesperonomia* zone are present in both the basal Skoki and the uppermost Outram. In the south, the barren Tipperary Quartzite separates the two formations. All three contacts, Tipperary–Skoki, Tipperary–Outram, and Skoki–Outram, fall within the *Hesperonomia* zone. The lower part of the Skoki Formation at Tipperary Lake contains quartzite beds interbedded with the typical dolomites and probably the Tipperary Quartzite is more closely related to the Skoki Formation than to the Glenogle Shales and the underlying Outram Formation. The sub-Tipperary Quartzite contact in the south is probably equivalent to the sub-Skoki contact in the north.

Dolomites that weather greyish orange, very pale orange, yellowish grey, and light grey, are the common rocks in the lower part of the Skoki Formation. Clastic quartz silt and sand are common in most beds and many beds contain sparse dark brown wispy argillaceous layers. Some beds have abundant chert layers and nodules. Dolomites composed of echinoderm debris are present. Rare limestones in the Mount Wilson section are basically lime muds with wispy layers containing argillaceous material. The lower Skoki changes facies westward into Outram beds.

The upper part of the Skoki Formation consists of thickly bedded resistant dolomites that weather light grey, very pale yellowish brown, yellowish grey, very pale orange, and very light grey (Pl. IV). Most beds contain minor clastic quartz sand and silt. Coarse pisoliths are common in many beds and are probably algal. A bed with abundant large gastropods (*Palliseria robusta* Wilson) is found near the top of the formation in most stratigraphic sections (Pl. V). The gastropod species ranges through almost 150 feet of the Mount Wilson section and banks of gastropod shells may have been common during deposition of the upper part of these beds. Thus the bed with abundant gastropods may not have been deposited simultaneously over the whole area of Skoki sedimentation, but no two such beds have been found in any studied section.

Three faunal assemblage zones can be recognized within the Skoki Formation (Fig. 16). The zones of *Hesperonomia* and *Orthidiella* contain orthid brachiopods, echinoderm fragments, and straight cephalopods. The higher zone of *Anomalorthis* is sparsely fossiliferous with large gastropods, *Receptaculites*, and rare brachiopods and conodonts, and roughly corresponds to the lithologically distinct upper part of the formation.

Owen Creek Formation

The Owen Creek Formation is here proposed for rocks that underlie the Mount Wilson Quartzite and overlie the Skoki Formation. Owen Creek drains the east flank of Mount Wilson. The formation is 614 feet thick at the type section, a gully at 52°00′N, 116°45′W, on the southern face of Mount Wilson (Appendix, Section A),

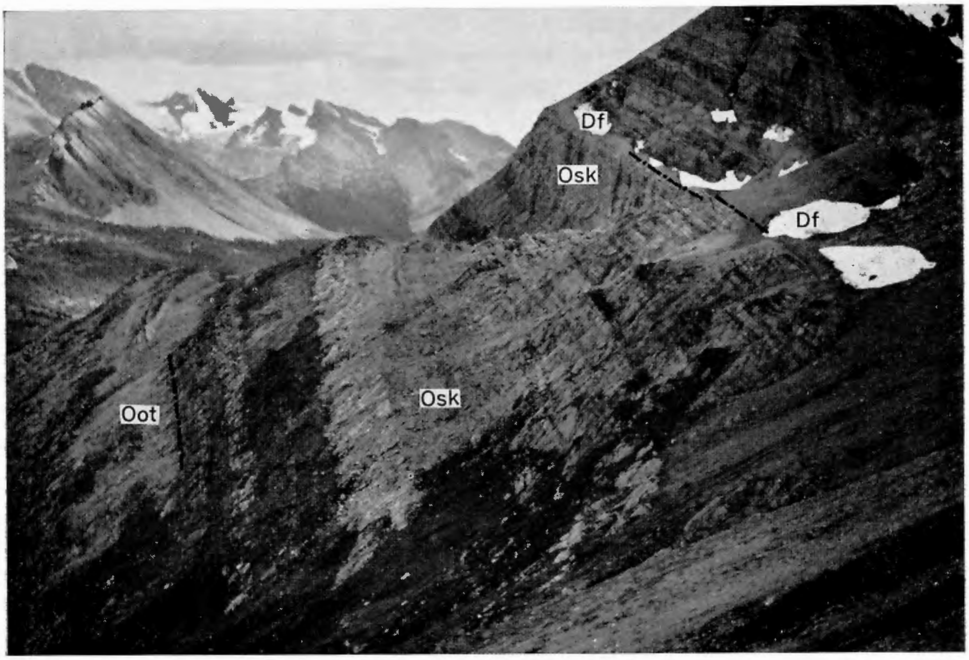


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PLATE IV. Skoki Formation on east face of Fossil Mountain, view from north; note that two members can be differentiated. Oot, Outram; Osk, Skoki; Df, Fairholme.

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PLATE V

Gastropod bed in uppermost Skoki Formation, *Palliseria robusta* Wilson in the Nigel Peak section.

where the contact with the Skoki Formation is apparently conformable (Pl. VI). Elsewhere channel fillings are present at the Skoki–Owen Creek contact and a disconformity can be recognized. The formation is consistent in thickness within the Mount Wilson–Nigel Peak–Mount Whiterose area, but thins to the southeast and is only 194 feet thick at Tipperary Lake, a hundred miles from the type section (Fig. 11). The contact between the Owen Creek Formation and the Mount Wilson Quartzite is apparently conformable at Mount Wilson and the thinning of the formation could be depositional in origin. However, erosion surfaces are developed at the contact at Tipperary Lake, at Devon Mountain, and at Nigel Peak, and an angular unconformity is present near the North White River. Thus the Owen Creek–Mount Wilson contact probably represents a significant hiatus throughout the eastern part of the southern Rocky Mountains.

The most common Owen Creek rocks are aphanitic dolomites that weather yellowish grey, light grey, very pale orange, light olive-grey, and very light grey. Bedding is well developed. Clastic quartz silt and very fine sand form 1 to 25 per cent of most beds and sparse, well-rounded, floating coarse quartz sand is present in some beds. Dolomitic mudstones that weather reddish brown, greyish red, and pale greenish yellow, are common as interbeds in the lower part of the formation. Rare mudcracks are present. The uppermost beds of the Owen Creek Formation include dolomitic quartz sandstones and siltstones.

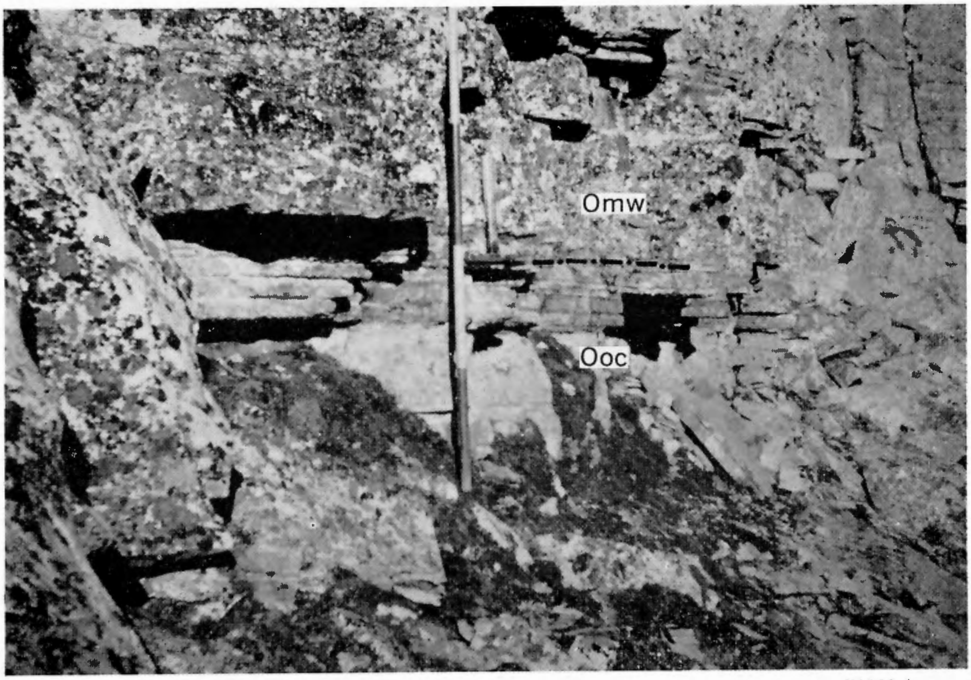

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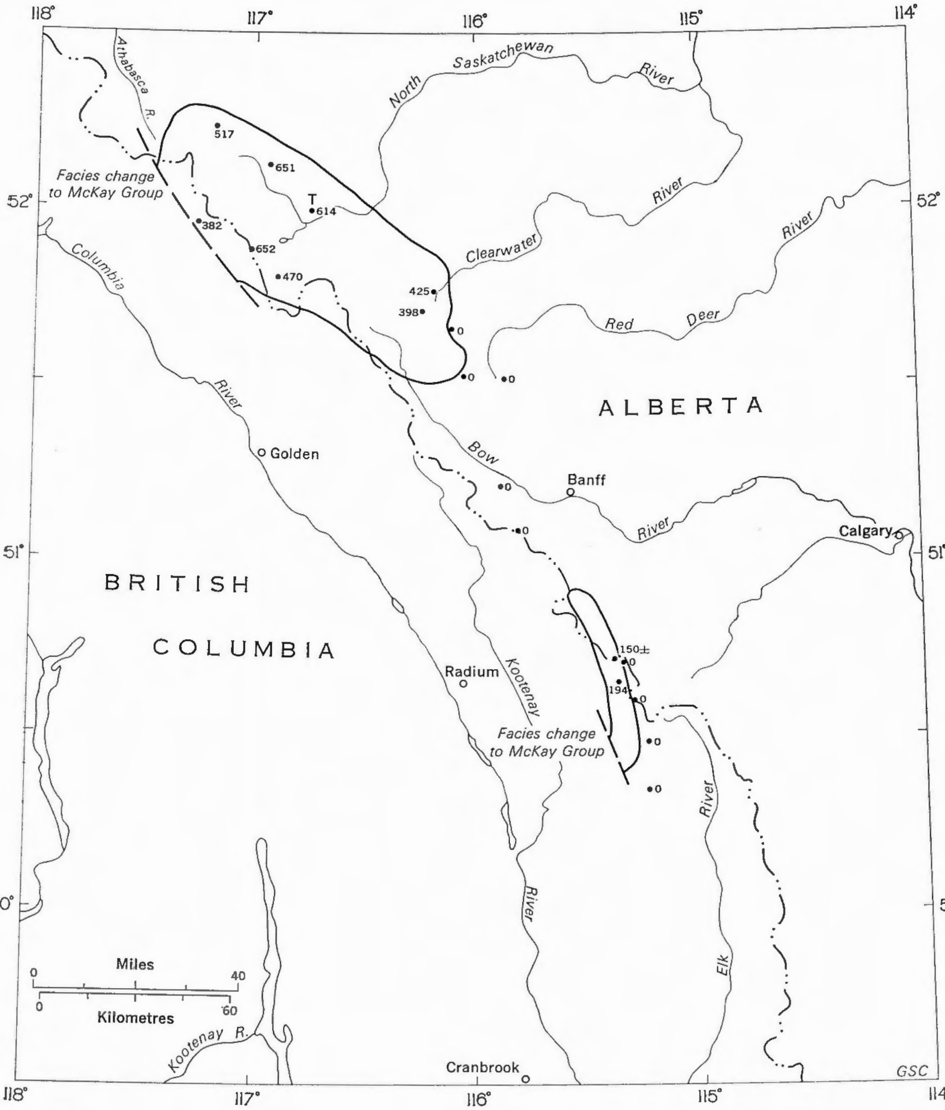
PLATE VI. Contact between Owen Creek Formation and Mount Wilson Quartzite, Mount Wilson section. Ooc, Owen Creek; Omw, Mount Wilson.



Type section . . . . T *Measured sections (thickness in feet)* . . . . . . •425

FIGURE 11. Distribution map for the Owen Creek Formation.

The Owen Creek Formation is essentially unfossiliferous. Rare fossils are present in the lower part of the formation, but were almost certainly deposited as clastic particles and were possibly derived from older rock units. Such fossils include *Maclurites*? sp., *Palliseria*? sp., and *Ceratopea unguis* Yochelson and Bridge. The last species was identified by Yochelson who considers that it indicates upper Lower Ordovician (Upper Canadian), but on stratigraphic grounds the Owen Creek is dated as Middle Ordovician. The specimens of *Ceratopea* are probably reworked and thus may indicate erosion of adjacently exposed upper Canadian rocks during early Owen Creek time. The formation disconformably overlies the Skoki Formation of Whiterock (early Middle Ordovician) age. The oldest fossils above the Owen Creek are those of the "conodont zone" of the basal Beaverfoot Formation and uppermost Mount Wilson Quartzite, which is either very high Middle Ordovician or low Upper Ordovician.

Mount Wilson Quartzite

Walcott erected the Mount Wilson Quartzite without examining the outcrop at the type locality, Mount Wilson. He was unable to give details of the upper and lower contacts, which he thought were against Devonian rocks and the Lower Ordovician Sarbach Formation (Walcott, 1923, pp. 464–465). The thickness was estimated as more than 250 feet and the age of the formation was later assumed to be Devonian (Walcott, 1928, p. 210).

The type locality actually gives excellent exposure of the formation (Pl. VII). The type section is here designated as the steep gully at 52°00′N, 116°45′W, on the southern face of the mountain (Appendix , Section A). The Mount Wilson Quartzite is 548 feet thick and monotonously uniform. The unit abruptly but, it seems, conformably overlies the Middle Ordovician Owen Creek Formation, and is concordantly overlain by the Beaverfoot Formation. The quartzites are pure and very resistant. The Mount Wilson weathers white and very light grey, with dark stains and light greyish orange stains on steep cliff faces.

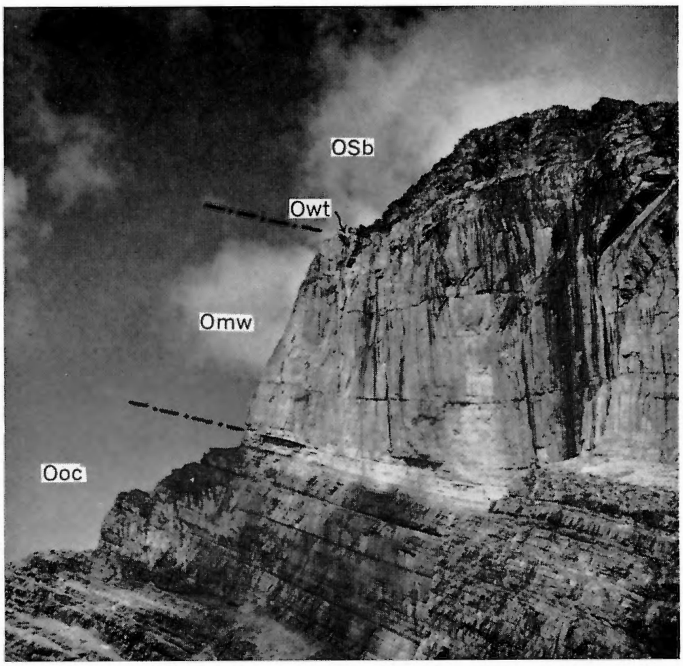


PLATE VII

Mount Wilson Quartzite at the type section at Mount Wilson. Ooc, Owen Creek; Omw, Mount Wilson; Owt, Whiskey Trail Member; OSb, Beaverfoot.

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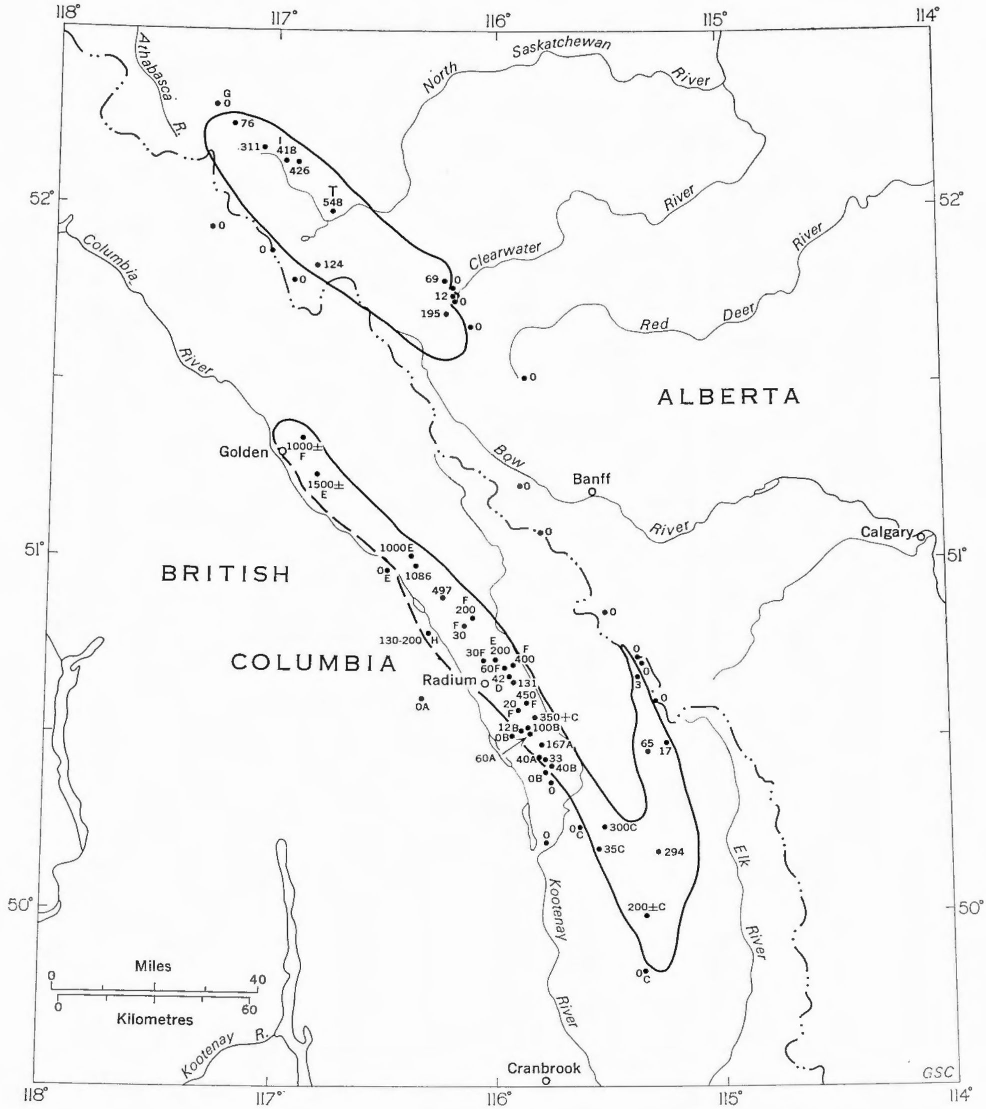
Walcott's mistakes at Mount Wilson resulted in further confusion a year later when he introduced the term Wonah Quartzite for sub-Beaverfoot quartzites in the Mount Sinclair Section (Walcott, 1924b, pp. 14, 32, 49, 50). The same quartzite unit in the Beaverfoot Range had been included in the original Beaverfoot Formation by Burling (1922, pp. 452–454). The two quartzite units are essentially similar lithologically, underlie the Beaverfoot Formation that carries the distinctive *Bighornia–Thaerodonta* fauna close to its base, and overlie two distinct sequences (Outram, Tipperary Quartzite, Skoki and Owen Creek; and Glenogle Shales) that are temporal equivalents but differ in facies. Furthermore, the two units can be correlated one with the other from the western part of the southern Rockies to the eastern part via Pedley Pass, the White River, and Tipperary Lake (Fig. 7). Walcott's erection of two names for the single rock unit concealed its widespread distribution (Fig. 12). The thickest development of the formation is in the Beaverfoot Range in the western part of its area of distribution.

Crosslaminated beds are not uncommon in the Mount Wilson Quartzite, but measurements of current directions are difficult in the typically cliff-forming outcrops. J. D. Aitken (personal communication, 1966) and R. D. Ferguson have sampled attitudes of crosslamination in the upper and lower parts of the Mount Wilson Quartzite at two localities, one at Mount Wilson just southeast of the type section, and the other at Cirrus Mountain. Each of the resultant four samples consists of at least 20 measurements. When corrected for dip and plotted on rose diagrams, the data display pronounced southwesterly directed maxima in the inferred current directions. The data strongly suggest transport from the northeast[1].

The lower contact of the Mount Wilson Quartzite is apparently conformable on the Owen Creek Formation or on the Glenogle Shales in most stratigraphic sections, but a few outcrops suggest unconformable contacts with both formations (*see* discussions of these units). The contact with the Whiskey Trail Member of the Beaverfoot Formation is apparently conformable in nearly all stratigraphic sections, but minor erosion surfaces are present at Pinnacle Creek and near Blackfoot Creek.

Fossils are extremely rare in the Mount Wilson Quartzite, as may be expected from the lithology. Evans (1933, p. 139) found some crinoid fragments and poorly preserved orthid brachiopods in atypical dark yellowish brown, platy dolomitic sandstones at the base of the formation northeast of Golden. Small gastropods and fragments of bryozoans occur as clastic grains in the top bed of the formation at Mount Sinclair and Tipperary Lake. These are similar to fossils in the immediately overlying Whiskey Trail Member of the Beaverfoot Formation. At Pinnacle Creek, a thin shale interbed is present well within the typical white quartzites, 33 feet from the top of the formation. This bed contains rare conodonts and fragments of clams and small gastropods. The conodonts include *Cordylodus* and a worn *Zygognathus* or *Trichonodella* and date the formation as Middle or Late Ordovician (W. C. Sweet, personal communication to T. T. Uyeno).

[1]Ketner (1968) has recently suggested that most of the quartz sand forming Ordovician quartzites in the Cordilleran miogeosyncline was derived from the Peace River–Athabasca arch of northern Alberta.



Type section . . . . T	*Measured sections (thickness in feet)* . . . 300•
Data by Walker, 1926 . . . . A	*Data by North and Henderson, 1954* . . . . . F
Data by Henderson, 1954 . . . . B	*Data by Aitken, unpublished* . . . . G
Data by Leech, 1954, 1959 C	*Data by McCammon, 1965* . . . . H
Data by Walcott, 1924 . . . . D	*Data by Belyea and McLaren, 1965* I
Data by Evans, 1933 . . . . E	

FIGURE 12. Distribution map for the Mount Wilson Quartzite.

Wonah Quartzite

Walcott selected a thin stratigraphic section (Appendix, Section F) on Mount Sinclair as the type locality for his Wonah Quartzite (1924b, pp. 14, 32, 49, 50). The thickness was estimated as 110 feet; the formation is actually 131 feet thick. No evidence of unconformity was described at its contacts and the lithology of the type section was given as thickly bedded, white to light grey quartzites. The present study confirms the suggestion of North and Henderson (1954, p. 68) that the term Wonah is obsolete, as it is a synonym of the Mount Wilson Quartzite.

Beaverfoot Formation

The Beaverfoot Formation was proposed by Burling (1922, pp. 452–454) for carbonates and underlying quartzites in the Beaverfoot Range. Later refinements adjusted the lower boundary by segregating the quartzites from the formation (Walcott, 1924b, Wonah Quartzite; *this paper*, Mount Wilson Quartzite). The type section of the Beaverfoot Formation is at Carbonate Creek and is 945 feet thick (Pl. XIX and Appendix, Section G). The contact with the Mount Wilson Quartzite is covered but apparently concordant. The section ends in the axial region of a faulted syncline. Walcott (1924b) proposed another unit, the Brisco Formation, for carbonates thought to be lithologically distinct from the Beaverfoot, but this unit is now discarded.

The Beaverfoot Formation is here used for the rocks overlying the Mount Wilson Quartzite in the type section, together with higher beds faulted out of Burling's section but thought to be part of the same lithological unit of resistant dolomites and limestones. All rocks in the type section of the Brisco Formation at Mount Sinclair are considered part of the Beaverfoot Formation. The Pedley Pass section is proposed as a standard section for the Beaverfoot Formation. This section gives excellent outcrop of 1,661 feet of the formation with the Tegart Formation and the Mount Wilson Quartzite exposed above and below (Pl. XIV and Appendix, Section D). The section has advantages over most other stratigraphic sections of the formation in that much of the Beaverfoot is present as limestone instead of dolomite. The upper contact is covered, but is conformable nearby at Mount Tegart. The lower contact is concordant but irregular, as it is in most exposures in the southern Rockies. Shallow erosion surfaces are present between the sandy basal beds of the Beaverfoot Formation and the subjacent Mount Wilson Quartzite at Pinnacle Creek and near Blackfoot Creek, but may not be significant as such channelling is not uncommon on bedding planes between sandstone beds.

Away from the standard section, the Tegart Formation is missing from much of the area of Beaverfoot outcrop, and Devonian rocks rest directly on the Beaverfoot, disconformably or paraconformably. Basal conglomerates are present above the contact at Bull River (Leech, 1962, pp. 399–402) and at Horse Creek (Belyea and Norford, 1967, p. 7), Tipperary Lake, and Mount Joffre.

In the south and southeast parts of its area of outcrop the Beaverfoot Formation overlaps the Mount Wilson Quartzite and rests on older rocks (Fig. 6). The Beaverfoot rests on the Owen Creek Formation at Palliser Pass; on the Skoki Formation at

Mount Onslow; on Lower Ordovician and Upper Cambrian horizons within the McKay Group in the southwest part and western margin of the Stanford Range; similarly in the Hughes Range and northeast of Cranbrook (Leech, 1960 and 1962); at Steamboat Mountain and Jubilee Mountain within the Rocky Mountain Trench; and at Mount Forster west of the Trench (Reesor, 1957). It rests on the Cambrian Jubilee Formation south of Horsethief Creek west of the Trench (Reesor, 1957) and in the western margin of the Stanford Range, northwest of Mount Tegart (Henderson, 1954). There is no well-documented occurrence of the Beaverfoot Formation resting directly on the Glenogle Shales.

Most of the Beaverfoot Formation consists of medium to thickly bedded resistant dolomites, which weather pale, very pale, and dull yellowish brown, light grey, light brownish grey, very light grey, light olive-grey, and grey. Some beds contain fine siliceous material; rare beds contain common clastic quartz silt. The rocks are now silt-size to finely crystalline mosaics, but a few samples show ghosts of coarse dolomite sand. Some beds contain sparse biogenic debris. Chert nodules are present at a few horizons. Some parts of the Beaverfoot Formation at Pedley Pass and near Blackfoot Creek are still preserved as limestones and dolomitic limestones. The limestones are aphanitic and weather light grey. Some limestones contain sparse biogenic debris. Clastic quartz silt is conspicuous in some beds.

A thin sequence of recessive rocks is present at the base of the Beaverfoot Formation in most sections. Where this sequence is absent the basal Beaverfoot consists of the typical, resistant, thickly bedded dolomites, of which the lowest bed commonly contains abundant quartz sand and may be conglomeratic. Rounded chert nodules that weather light brown are prevalent in the basal beds and include the common banana-shape described by Burling (1922, p. 453). The *Bighornia–Thaerodonta* fauna is common right at the base of this main part of the Beaverfoot Formation and extends into higher beds.

Whiskey Trail Member

The name Whiskey Trail Member is here proposed for the recessive beds that separate the two cliff-forming units, the Mount Wilson Quartzite and the main part of the Beaverfoot Formation (Pl. II). This thin rock-unit is retained within the Beaverfoot Formation for convenience in mapping, but its depositional history may have more affinity with that of the Mount Wilson than with that of the main part of the Beaverfoot. The type section of the member lies within the type section of the Beaverfoot Formation in the Carbonate Creek section (Pl. XVII and Appendix, Section G). Whiskey Trail follows the north branch of Carbonate Creek to the summit of the Beaverfoot Range. The member is 93 feet thick at the type section and thins to the southeast where it is 19 feet thick in the standard section of the Beaverfoot at Pedley Pass. It is thinly developed in the eastern part of the southern Rocky Mountains, measuring 17 feet at Cirrus Mountain, 14 feet at Mount Wilson (Pl. VII), and only 7 feet at Tipperary Lake (Fig. 13). The Whiskey Trail Member is not present where the Beaverfoot overlaps the Mount Wilson Quartzite to rest on older rocks. Thus it is absent at Mount Sabine, Mount Onslow, Palliser Pass, and 4 miles south-southeast of Indian Head Mountain. The member is difficult to detect at Shatch Mountain and near North White River where the subjacent

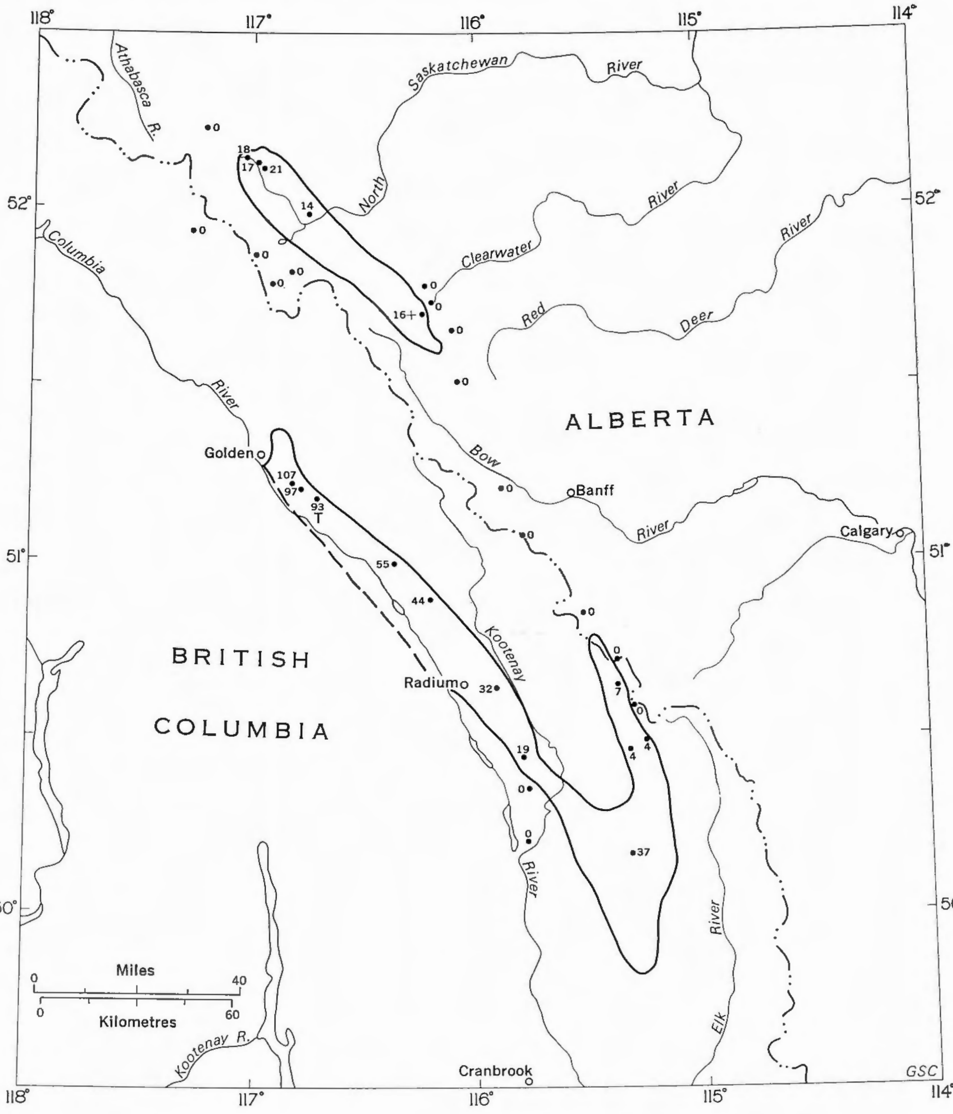


FIGURE 13. Distribution map for the Whiskey Trail Member of the Beaverfoot Formation.

Mount Wilson includes atypical impure quartz sandstones, conglomeratic and dolomitic rocks. An erosion surface can be detected between the Whiskey Trail Member and the main part of the Beaverfoot Formation at Pedley Pass and probably also at Carbonate Creek.

The Whiskey Trail Member consists of dolomitic quartz sandstones with very minor quartzite layers, typically thin bedded; coarsely arenitic dolomites, echinoderm-debris dolomites, and argillaceous dolomites; and olive-grey mudstones. Its fauna

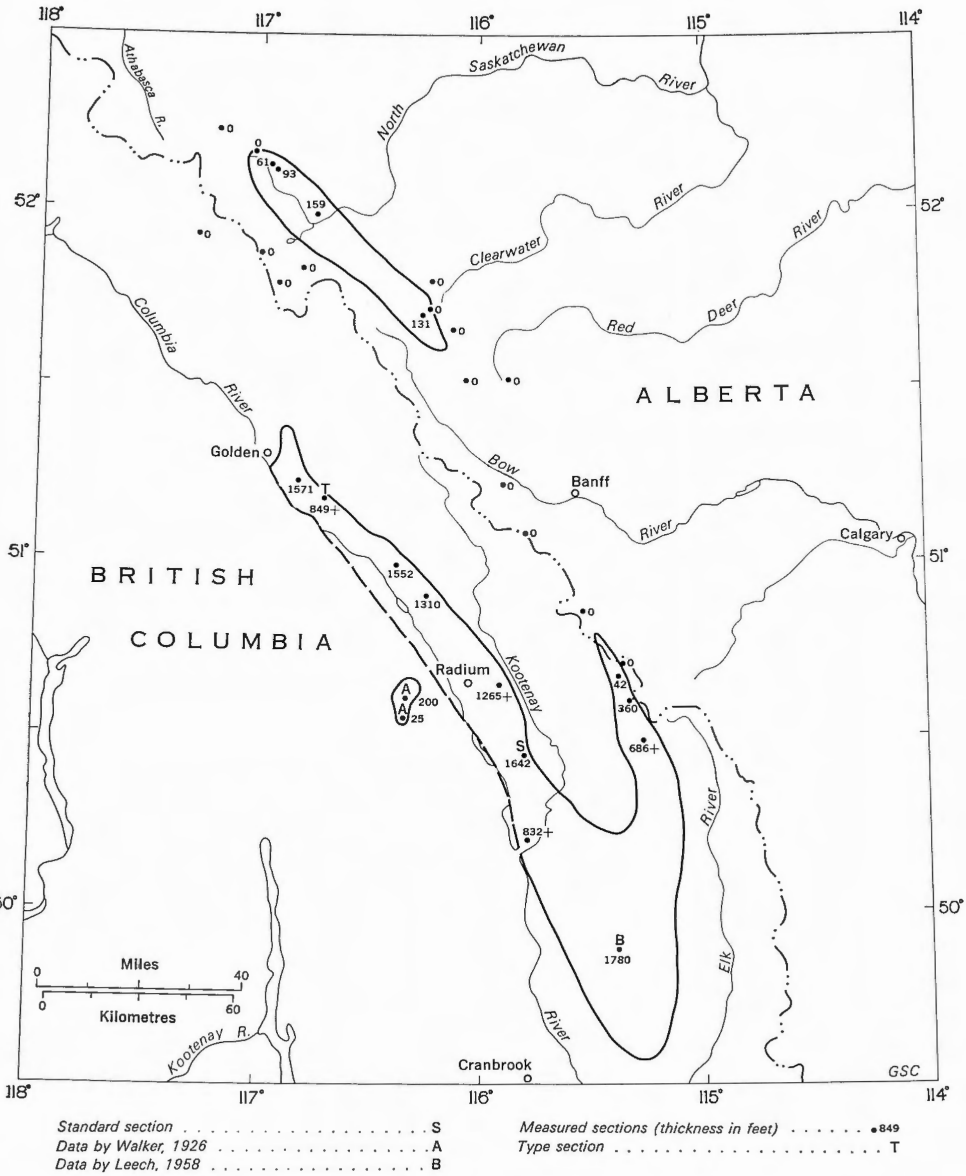


FIGURE 14. Distribution map for the Beaverfoot Formation, without the Whiskey Trail Member.

seems to be stratigraphically distinct from the *Bighornia–Thaerodonta* fauna and consists of bryozoans and minute gastropods, echinoderm and brachiopod fragments, solitary and colonial corals, conodonts, and extremely rare graptolite debris.

The uppermost bed of the Mount Wilson Quartzite locally contains rare clastic grains of mudstone among the quartz sand. At Mount Sinclair greyish black minute gastropods occur as clastic grains and bryozoans are found at Tipperary Lake.

The distribution pattern of the Whiskey Trail Member more closely resembles that of the Mount Wilson Quartzite rather than that of the main Beaverfoot Formation (Figs. 12, 13, and 14). Where the Beaverfoot overlaps the Mount Wilson Quartzite to rest on formations as old as Middle or Upper Cambrian, it also overlaps the Whiskey Trail Member. The horizon of widespread Beaverfoot transgression seems to be the top of the Whiskey Trail Member, not the Mount Wilson–Beaverfoot contact.

Five faunas can be differentiated within the Beaverfoot Formation (Fig. 16), but fossils are generally only abundant just above the Whiskey Trail Member. Corals, brachiopods, and echinoderm fragments are the most common fossils; cephalopods, stromatoporoids, bryozoans, gastropods, trilobites, clams, conodonts, and graptolites are also present.

Brisco Formation

Walcott (1924b, pp. 11–13, 32, 47, 48) proposed the term Brisco Formation for Silurian carbonates and argillaceous rocks thought to be lithologically distinct from the Beaverfoot Formation, and which contain fossils of younger age than the Richmond fossils found in the basal 139 feet of the Beaverfoot type section. Walcott did not attempt to position the base of the Brisco within the upper part of the Beaverfoot type section (945 feet thick, Appendix, Section G), which contains Silurian fossils (GSC loc. 64557). The Brisco type section was given as the upper southwest slope of Mount Sinclair (Appendix, Section F), but this section was evidently not studied by Walcott. The Mount Sinclair section lacks a stratigraphic top and does not contain the graptolitic argillaceous rocks mentioned by Walcott and now assigned to the Tegart Formation. Walcott's thicknesses are estimates, not measurements.

Studies subsequent to Walcott's work have not substantiated his lithological differentiation of the Brisco and Beaverfoot Formations. The Brisco Formation is therefore considered obsolete, and the entire Brisco type section is now placed in the Beaverfoot Formation. Rocks elsewhere called Brisco by Walcott belong to the Beaverfoot and Tegart Formations.

Beaverfoot–Brisco Formation

Geologists have found themselves unable to differentiate satisfactorily the Silurian Brisco Formation from the original Beaverfoot Formation and have treated the two as a lithostratigraphic unit, the Beaverfoot–Brisco Formation (Walker, 1926; Evans, 1933; Henderson, 1954; Leech, 1954, 1958, 1959, and 1960; Reesor, 1957; Norford, 1961 and 1962a). This unit is now replaced by the Beaverfoot (expanded from Burling's original usage) and Tegart Formations. The term Beaverfoot–Brisco is therefore abandoned.

Tegart Formation

The term Tegart Formation is here proposed for argillaceous limestones and shales that overlie the Beaverfoot Formation in the western part of the southern Rocky Mountains. The type locality is Mount Tegart, where the formation is 243 feet thick and conformably overlies the resistant Beaverfoot Formation (Pl. XVI and Appendix, Section E). The lower half of the type section is on the northeast face of the mountain, and the upper half is in a steep gully at the south end of the dip slope on the back of the mountain. The upper contact is paraconformable with the Cedared Formation of probable Middle Devonian age. The formation thins in all directions away from the type section (Fig. 15). Such thinning may be due to facies change into the upper beds of the Beaverfoot Formation, but a significant unconformity is present at the base of the Cedared Formation (Belyea and Norford, 1967, p. 8). A more likely explanation of the thinning is truncation of the Tegart Formation beneath the regional sub-Devonian unconformity.

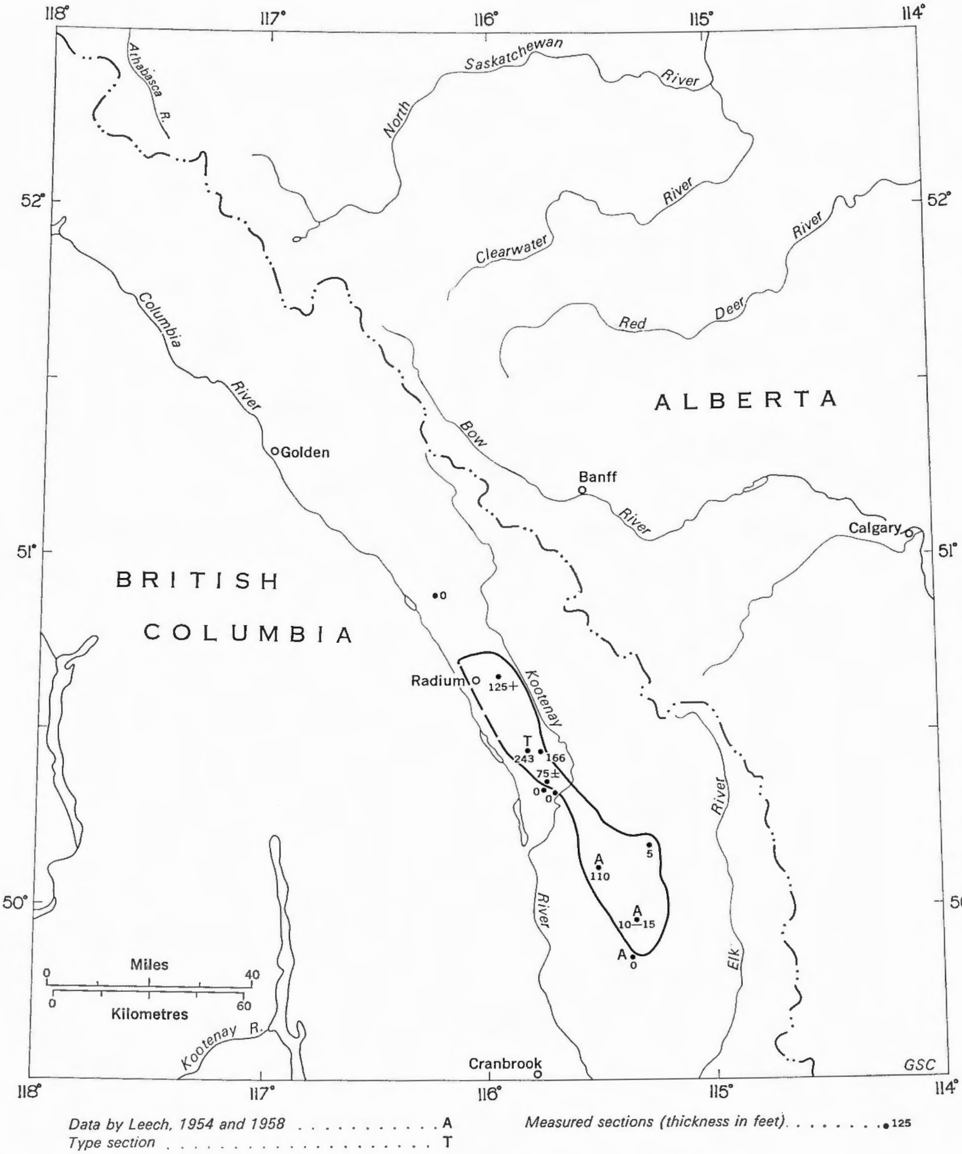


FIGURE 15. Distribution map for the Tegart Formation.

The common rocks are recessive, thinly bedded, dark grey and dark brownish grey, argillaceous limestones. These rocks are aphanitic with sparse silt-size grains and weather dull grey, dull brownish grey, and light olive-grey. Most beds are siliceous and etching in hydrochloric acid leaves residues of clastic quartz silt and clay-size material. Poorly fissile limy shales form the basal part of the formation and are present as interbeds in the rest of the unit. The shales are brownish grey, dark grey, and olive-grey. They weather yellowish brown, light olive-grey, light brown, brownish grey, and very pale yellowish brown.

Graptolites from faulted outcrops of the Tegart Formation attracted the attention of early workers (Walcott, 1924b; Ruedemann, 1947) and were one of the prime reasons for Walcott's erection of the Brisco Formation. Walcott thought that his collections of graptolites from an outcrop in Sinclair Creek were from a band of shales and argillaceous limestones within his Brisco Formation. Reliable stratigraphic sections show the Tegart Formation always overlying the Beaverfoot Formation, which includes the entire Brisco Formation as erected by Walcott. The graptolites are common in the shales of the Tegart Formation and rare in the limestones. Trilobites, brachiopods, straight cephalopods, and rare corals are present in the limestones. These fossils include species also found in the uppermost beds of the Beaverfoot Formation. The benthonic fauna of the Tegart Formation indicates the zone of *Eophacops–Cheirurus* and the graptolites show that this zone includes part of the *Monograptus spiralis* zone of the uppermost Lower Silurian (Thorsteinsson, 1958; Jackson and Lenz, 1962; Norford, 1962a).

Basal Devonian Rocks

An episode of uplift and erosion removed vast quantities of Lower Palaeozoic rocks from the southern Rocky Mountains within the interval Middle Silurian to Early Devonian. The basal Devonian sediments laid down above the resultant sub-Devonian unconformity were laterally discontinuous and very variable. Some deposits may have been marine, some fluviatile, others terrestrial. Abrupt facies changes were common.

Fossils are rare in these basal Devonian rocks. In the western part of the southern Rockies charophytes in the Cedared Formation indicate probable Middle Devonian age (Belyea and Norford, 1967). In the eastern part of the southern Rocky Mountains fish from rocks near Mount Joffre suggest an early Middle Devonian age (D. L. Dineley, personal communication). In the Ghost River region of southwest Alberta, fossil plants from the Yahatinda Formation of basal Devonian clastic rocks indicate a late Middle Devonian or early Late Devonian age, but fish fragments from an adjacent horizon suggest an Early Devonian age (Greggs, *et al.*, 1962; Aitken, 1963, p. 281, 1966, pp. 22–23; McGregor, 1963 and 1964). Aitken considers the Yahatinda to be Middle Devonian. A basal sandy unit in the Nigel Peak–Mount Whiterose–Coronation Mountain region grades upward into Upper Devonian rocks of the Fairholme Group (Norford, 1961).

BIOSTRATIGRAPHY

The Ordovician and Silurian sequences of the southern Rocky Mountains were deposited on the eastern margin of a geosyncline in which rocks of graptolitic facies accumulated. Graptolites are the standard fossils used for world-wide correlation of the two systems. The stratigraphic relations of formations of different facies and faunas in the southern Rockies allow some degree of correspondence to be established between the standard North American sequence of graptolite faunas and a succession of benthonic faunas in coeval rocks (Fig. 16). Such benthonic faunas are widely distributed in the carbonate rocks that were deposited on the western flank of the North American continent in Ordovician and Silurian times.

The Glenogle Shales contain an almost complete sequence of graptolite faunas for the late Arenig to early Caradoc interval. In the Blackfoot Creek–White River region, the basal Glenogle zone of *Didymograptus protobifidus* overlies McKay beds that are G_1 zone or younger. A rare occurrence of late Arenig graptolites in the Outram Formation on the northeast shoulder of Fossil Mountain suggests correlation of the *D. protobifidus* zone or the *Isograptus caduceus* zone with part of the H–J interval. The presence of ?*Trigonograptus* sp. within zone J of the Outram Formation at Mount Wilson indicates correlation of this part of zone J within the interval mid-*I. caduceus* zone to top-*Paraglossograptus etheridgei* zone (Jackson *in* Aitken and Norford, 1967, pp. 183–184). Interbedded graptolitic and trilobite–brachiopod faunas in the Glenogle Shales near the North White River show that the *Orthidiella* zone is coeval with the *I. caduceus* zone or the *P. etheridgei* zone. The stratigraphic position of the Mount Wilson Quartzite above the Glenogle Shales shows that the "conodont zone" is entirely younger than the *Nemagraptus gracilis* zone. Rare graptolite fragments collected from the "conodont zone" in the Whiskey Trail Member of the Beaverfoot Formation are too incomplete to allow biostratigraphically useful identifications. Shales in the basal part of the Tegart Formation contain graptolites and are both overlain and underlain by rocks with faunas of the *Eophacops–Cheirurus* zone. The graptolites allow correlation of part of this zone with part of the zone of *Monograptus spiralis.*

The faunas of the graptolite zones of the Glenogle Shales have been listed by Jackson (1964, and in manuscript) and by Larson and Jackson (1967). Graptolites of the *Monograptus spiralis* zone of the Tegart Formation have been identified by Thorsteinsson (*in* Norford, 1962a, p. 452) and include:

Monograptus columbianus Ruedemann
Monograptus 2 spp aff. *M. vomerinus* (Nicholson)
Monograptus walcottorum Ruedemann
Stomatograptus grandis (Suess)

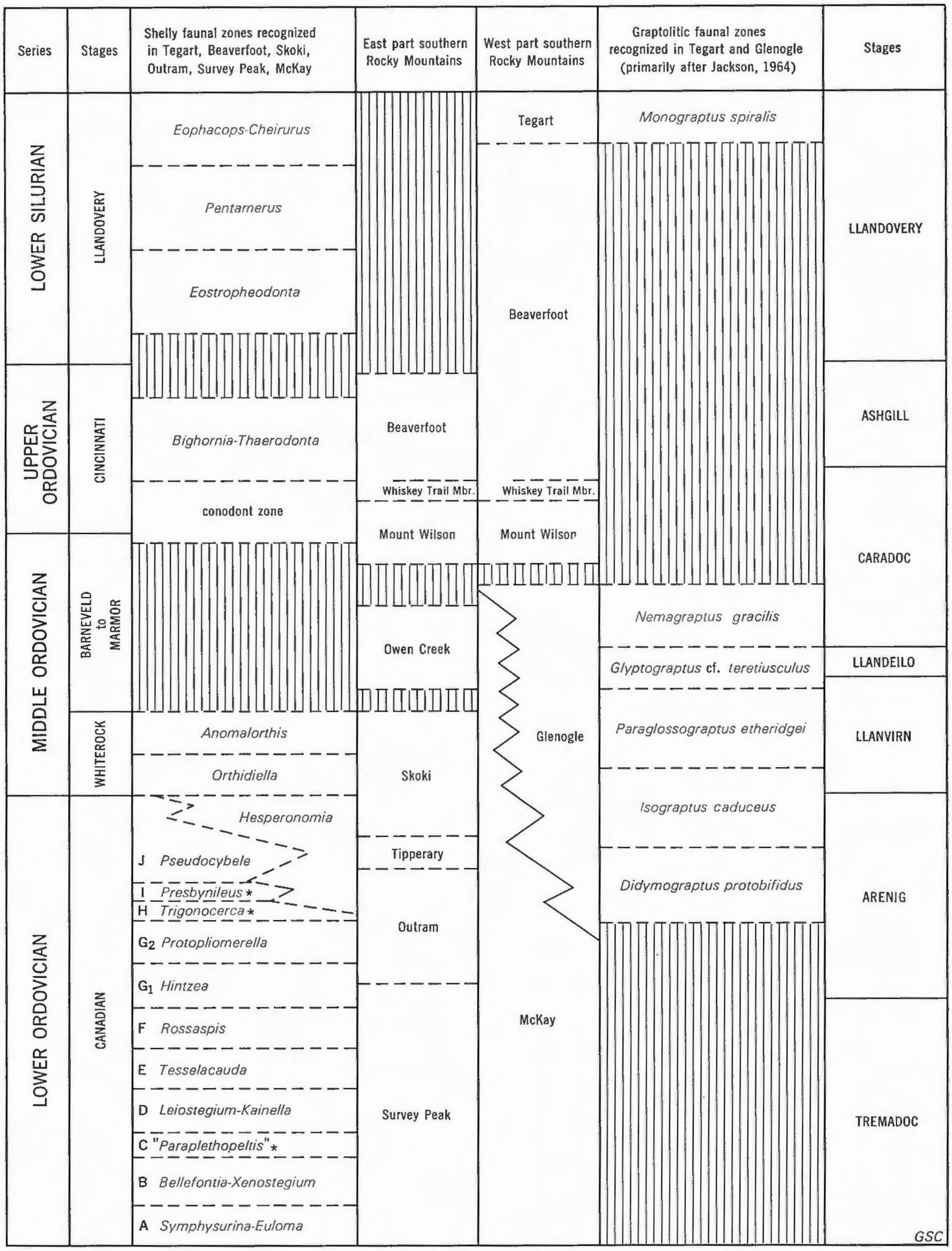


FIGURE 16. Geochronology of the Ordovician and Silurian rocks of the southern Rocky Mountains. The Canadian trilobite zones that are marked with an asterisk have not yet been documented from the Survey Peak Formation, Outram Formation, or the McKay Group.

In addition to some of these species, Ruedemann (1947, p. 115, and *in* Walcott, 1924b, pp. 12–13) has reported *Monograptus marri* Perner and *Retiolites* (*Gladiograptus*) *geinitzianus* Barrande.

The Ordovician benthonic faunas of the McKay, Survey Peak, and Outram units are poorly known, although species have been described from these rocks by Walcott (1924a, 1924c, and 1925), Kindle (1929), Ruedemann (1930 and 1947), Ulrich and Cooper (1938), Ulrich and others (1936, 1943, and 1944), Kobayashi (1953 and 1955), Rigby (1965), Ethington and Clark (1965), and Norford (*in press*). Recent studies (Aitken and Norford, 1967) and previous work have only locally sampled these units, but have established the presence of most of the Canadian zones recognized in Utah and Nevada (Ross, 1949 and 1951; Hintze, 1953). A few zones (C, H, and I) have not yet been documented, but these omissions may be due to the reconnaissance nature of the work in this stratigraphic interval in western Canada.

Three brachiopod assemblage zones can be differentiated within the Skoki Formation. The lowest, the *Hesperonomia* zone, is also present in the uppermost 300 feet of the Outram Formation at Mount Wilson, an interval that also contains trilobites of the *Pseudocybele* (J) zone. The *Hesperonomia* zone is based on brachiopods whereas the *Pseudocybele* zone is defined by trilobites and its brachiopod fauna is poorly known. The two zones are largely equivalent. The *Hesperonomia* zone has not been previously recognized and may correlate with parts of the *Pseudocybele* (J) and *Hesperonomiella minor* (K) zones of Utah and Nevada and possibly also with lower rocks. Its fauna includes species of *Hesperonomia, Diparelasma, Leptella, Syntrophopsis, Taffia,* and *Tritoechia,* together with gastropods, trilobites, straight cephalopods, sponges, conodonts, and abundant fragmentary echinoderms that include *Blastoidocrinus.*

The *Orthidiella* zone of the Skoki Formation contains *Orthidiella extensa* Ulrich and Cooper, *Orthambonites marshalli* (Wilson), *Petroria rugosa* Wilson, "*Plectorthis*?" *sinuatis* Wilson, species of *Diparelasma, Orthambonites,* and *Maclurites,* and straight cephalopods, trilobites, conodonts, receptaculitids, sponges, gastropods, and echinoderm fragments. Conodonts identified by T. T. Uyeno include:

Acontiodus spp.
?*Coelocerodontus* sp.
Drepanodus parallelus Branson and Mehl
Drepanodus spp.
Oistodus cf. *O. forceps* Lindström
Oistodus inclinatus Branson and Mehl
Oistodus lanceolatus Pander
Panderodus cf. *P. comptus* Branson and Mehl
Phragmodus undatus Branson and Mehl
Sagittodontus sp.
Scolopodus cf. *S. quadraplicatus* Branson and Mehl

The *Orthidiella* zone is also developed within the Outram Formation west of the Alberta–British Columbia boundary and in the North White River area; *Orthambonites, Orthidiella, Carolinites, Ectenonotus, Goniotelina, Kawina,* and *Nileus* are present. In this area, the *Orthidiella* zone can be demonstrated to be equivalent to part of the *Isograptus caduceus–Paraglossograptus etheridgei* interval. The brachiopods of the *Orthidiella* zone of the southern Rocky Mountains indicate direct correlation with the basal Whiterock *Orthidiella* zone of Nevada but Uyeno considers that the conodont fauna has elements in common with faunas from the Arenig of Sweden and the El Paso Formation of Texas. The El Paso is probably Canadian.

Brachiopods are not common the in *Anomalorthis* zone of the Skoki Formation. The fauna includes *Palliseria robusta* Wilson and species of *Anomalorthis*, *Syntrophopsis*, *Maclurites*, and *Receptaculites*, and clams and sponges, Correlation is with the Whiterock *Anomalorthis* zone of Nevada.

The Middle Ordovician rocks above the Skoki Formation in the eastern part of the southern Rocky Mountains are virtually barren of fossils, and thus no zonation of benthonic faunas is available between the *Anomalorthis* zone and the "conodont zone". The "conodont zone" is known from the Whiskey Trail Member of the Beaverfoot Formation and, at two localities, from the uppermost bed of the Mount Wilson Quartzite. The macrofauna is as yet unstudied. R. B. Sanders of the University of Iowa has studied conodonts from the lower part of the Beaverfoot Formation. From one sample collected from the Whiskey Trail Member at Pedley Pass he reports species of *Belodina*, *Cordylodus*, *Cyrtoniodus*, *Drepanodus*, *Euprioniodina*(?), *Ligonodina*, *Lonchodus*, *Panderodus*, *Prioniodina*, *Oistodus*, *Ozarkodina*, *Roundya*, *Spathognathodus*, and *Zygognathus* (*in* Norford, 1962a, p. 450). Conodont fragments collected by Norford from a shale interbed 33 feet from the top of the Mount Wilson Quartzite at Pinnacle Creek have been identified as *Cordylodus* sp. and *Zygognathus* or *Trichonodella* sp. by W. C. Sweet and may belong to this zone.

The main part of the Beaverfoot Formation can be divided into four coral–brachiopod assemblage zones and an almost barren interval (Norford, 1962a). As yet, the faunas have only been studied in a preliminary fashion. Significant hiatuses could be present within this barren interval of the formation, but none have yet been demonstrated by lithostratigraphic studies.

At Mount Sinclair, the Upper Ordovician *Bighornia–Thaerodonta* zone is documented from the 180 feet of Beaverfoot Formation directly overlying the Whiskey Trail Member. The fauna of the zone in the southern Rockies includes the following species (conodonts identified by Uyeno):

Bighornia cf. *B. parva* Duncan
Catenipora robustus (Wilson)
Catenipora delicatulus (Wilson)
Favistina alveolata stellaris (Wilson)
Favistina aff. *F. stellata* (Hall)
Grewingkia sp.
Lobocorallium prolongatum (Wilson)
Palaeofavosites sp.
Palaeophyllum halysitoides (Wilson)
Palaeophyllum primum (Wilson)
Palaeophyllum sp.
Sarcinula burlingi (Wilson)
Sarcinula sp.
Streptelasma sp.
Diceromyonia aff. *D. tersa* (Sardeson)
Dinorthis columbia Wilson
Dinorthis rockymontana Wilson
Rhynchotrema increbescens occidens Wilson

Rhynchotrema kananaskia Wilson
Rhynchotrema windermeris Wilson
Thaerodonta aff. *T. saxea* (Sardeson)
Acontiodus? sp.
Drepanodus? sp.
Panderodus cf. *P. feulneri* (Glenister)
Panderodus gracilis (Branson and Mehl)
Prioniodina cf. *P. oregonia* Branson, Mehl, and Branson

A thick stratigraphic interval of the Beaverfoot Formation separates the *Bighornia–Thaerodonta* zone from the *Eostropheodonta* zone and is very poorly fossiliferous. The interval is about 1,000 feet thick at Pedley Pass and about 800 feet thick at Mount Sinclair. Macrofossils from the interval include *Catenipora*, *Palaeofavosites*, and *Streptelasma*. Conodonts identified by Uyeno from this interval on Mount Sinclair include:

faunule B, from the interval 447 to 537 feet above the upper limit of the *Bighornia–Thaerodonta* zone:

Eoligonodina? sp.
Hindeodella sp.
Panderodus cf. *P. arcuatus* (Stauffer)
Panderodus gracilis (Branson and Mehl)
Prioniodina? sp.
Roundya? sp.
Spathognathodus? sp.

faunule A, from a horizon 127 feet above the upper limit of the *Bighornia–Thaerodonta* zone:

Cordylodus flexuosus (Branson and Mehl)
Drepanodus suberectus (Branson and Mehl)
Panderodus cf. *P. feulneri* (Glenister)
Panderodus gracilis (Branson and Mehl)

Uyeno considers faunule A to be Ordovician. Faunule B could be Ordovician or Silurian, but Uyeno suggests that *Hindeodella* and *Spathognathodus* are more typical of Silurian and younger faunas than of Ordovician faunas.

The *Eostropheodonta* zone of the Beaverfoot Formation is probably of Early or Middle Llandovery age and includes the following taxa:

Eostropheodonta sp.
Hesperorthis sp.
Alispira sp.
Catenipora sp.
Favosites sp.
Streptelasma fragile Wilson
Streptelasma sp.
"*Syringopora*" *columbiana* Wilson
Eophacops sp.
Encrinurus sp.

The *Pentamerus* zone of the Beaverfoot Formation includes species of *Pentamerus*, cf. *Spinatrypa*, *Cystihalysites*, *Favosites*, cf. *Plasmoporella*, *Ptychophyllum*?, *Streptelasma*, *Aparchites*, *Bythocypris*, *Tubulibairdia*, and a genus close to *Newsomites* (ostracods identified by Copeland). The stratigraphic position beneath the *Eophacops–Cheirurus* zone rules out a post-Llandovery age, and the presence of *Pentamerus* and *Cystihalysites* restricts the age assignment to Late Llandovery.

The *Eophacops–Cheirurus* zone includes the uppermost beds of the Beaverfoot Formation and the major part of the Tegart Formation. The upper part of the Tegart Formation is poorly fossiliferous, but probably also belongs within the zone. The zone brackets an incursion of the graptolite zone of *Monograptus spiralis*, which dates the zone as Upper Llandovery[1]. Trilobites and brachiopods are the common fossils and the fauna other than graptolites includes:

Eophacops aff. *E. marklandensis* (McLearn)
Cheirurus cf. *C. niagarensis* (Hall)
Aulacopleura? sp.
Encrinurus sp.
Favosites sp.
cf. *Glassia* sp.
Atrypa parva Hume

[1]Recent studies by Uyeno show that conodonts from the lower 115 feet of the type section of the Tegart Formation can be referred to the *Pterospathodus amorphognathoides* zone of the Carnic Alps. This interval of the Tegart Formation lies entirely within the Eophacops–Cheirurus zone.

PALAEOGEOGRAPHY AND DEPOSITIONAL HISTORY

The Ordovician and Silurian rocks of the southern Rocky Mountains can be discussed within the framework used by Robison (1964) for Cambrian rocks in Utah and Nevada, where the lithotopes suggest the presence of three, subparallel, gross depositional belts marginal to the craton. An inner detrital belt with orthoquartzites, shales, and mudstones lay offshore from the coast. The clean quartzites of the Tipperary and Mount Wilson quartzites and the aphanitic dolomites and mudstones of the Owen Creek Formation could be placed in this belt, and also the mudstones and siltstones in the lower part of the Survey Peak Formation.

A middle carbonate belt had broad transition zones with both the inner and outer detrital belts in Utah and Nevada. The thickly bedded dolomites and limestones of the Beaverfoot Formation and the similar dolomites and the pisolitic dolomites of the upper part of the Skoki Formation indicate deposition in water of moderate to shallow depth and correspond to such a carbonate belt. The more thinly bedded, somewhat more argillaceous limestones and dolomites of the lower part of the Skoki Formation probably accumulated in the outer margin of the carbonate belt.

An outer detrital belt of mudstones, shales, thinly bedded argillaceous limestones, and laminated siltstones lay seaward of the carbonate belt in Utah and Nevada. The Glenogle Shales and the rocks of the Active Formation in the Interior Ranges east of Trail suggest an outer detrital belt and were probably deposited in fairly deep water. The Tegart Formation was probably laid down in the shallower parts of the belt, transitional towards the carbonate belt.

The facies relations in the Ordovician and Silurian rocks of the southern Rocky Mountains can be interpreted in terms of transgressions and regressions of these belts and of the cratonic coastline. The carbonate belt was poorly developed in the southern Rockies during much of Canadian time, and the inner detrital belt of the Williston Basin from time to time merged directly with the margin of an outer detrital belt that occupied the eastern part of the Interior Ranges of British Columbia (Aitken and Norford, 1967, p. 173).

The inner detrital belt contracted in the final episode of the Canadian Epoch and the outer detrital belt covered the whole of the western part of the southern Rocky Mountains. A thin tongue of the Glenogle reached as far east as Shatch Mountain and Tipperary Lake. The basal Skoki Formation accumulated in the shallower waters of the carbonate belt that occupied most of the eastern part of the southern Rockies. The inner detrital belt with its Tipperary Quartzite was present in the south and probably also to the east. The coastline was probably fairly close to the east, for this episode falls within the unconformity between the Winnipeg and Deadwood formations described by Fuller and Porter (1962, pp. 464–469) in the Williston Basin. Most of southern Alberta and the Williston Basin were probably land at this time. A slight transgression at the close of the epoch shifted the inner detrital belt eastward, and the quartz sands of the Tipperary Quartzite gave way to carbonates of the lower part of the Skoki Formation.

A similar distribution pattern continued into the early Middle Ordovician, but with shallowing in late Whiterock time and deposition of the thickly bedded and pisolitic carbonates of the upper part of the Skoki Formation. A hiatus followed deposition of the Skoki Formation in the eastern part of the southern Rockies, reflected by a disconformity beneath the Owen Creek Formation. This hiatus may also have affected the outer detrital belt, for the base of the upper silty and sandy part of the Glenogle Shales in the eastern part of the Hughes, Stanford, and Brisco ranges may correlate as approximately the same horizon. The rocks of the Owen Creek Formation indicate very shallow deposition within the inner detrital belt.

A hiatus in the latter part of Ordovician time is revealed by the sub-Mount Wilson unconformity and was followed by a drastic change in regimen at the onset of sedimentation. A break is present at a similar horizon beneath the Bighorn Group in the Williston Basin (Fuller and Porter, 1962, pp. 476–477). The Mount Wilson Quartzite is a thick sheet of quartz sand deposited over most of the southern Rocky Mountains and its mode of deposition is difficult to explain. A possible model could be the reworking of slightly older shoreline deposits left by an earlier regressive phase and the incorporation of this material as a blanket deposit at the base of a widespread transgression. Dapples (1955) suggested a similar explanation for the St. Peter Sandstone of the north-central United States[1].

A broad belt of carbonate sedimentation probably covered the whole of the southern Rockies in Late Ordovician and most of Early Silurian time. The carbonates transgressed beyond the limits of the Mount Wilson Quartzite. The water deepened towards the close of the Early Silurian and the eastern part of the outer detrital belt moved into the western part of the southern Rockies. Erosion before deposition of Devonian rocks erased the records of this interval elsewhere in the southern Rocky Mountains and of later Silurian sedimentation in the whole region.

[1]Ketner (1968) has recently suggested that most of the quartz sand now forming the extensive Ordovician quartzites (such as the Mount Wilson) in the Cordilleran miogeosyncline of Canada and the United States was transported from sources in the Peace River–Athabasca arch of northern Alberta.

COMPARISON WITH THE WESTERN UNITED STATES

Ordovician and Silurian rocks in the western United States have been described as two assemblages (Roberts, *et al.*, 1958; Ross, 1961; Ross and Berry, 1963, pp. 7–9). A eugeosynclinal western facies of argillaceous and cherty rocks is developed in northeastern Washington, the western part of central Idaho, central Nevada, and California. The Active Formation of the Trail region of British Columbia and the Glenogle Shales and Tegart Formation of the western part of the southern Rocky Mountains of Canada have much in common with this western assemblage. A miogeosynclinal eastern facies of carbonates and quartzites is best known from southeast Idaho, Utah, and eastern Nevada. This eastern assemblage corresponds to the rocks of the eastern part of the southern Rocky Mountains of Canada and many of the individual formations of the two regions are strikingly similar.

Lower Ordovician rocks of the Fillmore and Wahwah Formations of the Ibex area of southwest Utah and of the Garden City Formation of northern Utah are lithologically and faunally very similar to the McKay Group and the Survey Peak and Outram Formations of the southern Rocky Mountains. The suite of lithologies is almost identical and consists of biogenic limestones, finely crystalline limestones and calcisiltites, flat pebble–limestone conglomerates, cherty dark aphanitic limestones, greyish green shaly mudstones, limy siltstones, and thrombolitic and stromatolitic limestones. No analogue of the Tipperary Quartzite is known from the eastern facies and this formation probably represents a local deposit.

The Antelope Valley Limestone of eastern Nevada has been divided into three lithological divisions (Merriam, 1963, pp. 23–25). The lowest division consists of medium to thinly bedded limestones and argillaceous limestones, and is very similar to the lower part of the Skoki Formation at Nigel Peak, one of the few localities in Canada where the lower part of the Skoki Formation is preserved as limestone not dolomite. The lowest division of the Antelope Valley in the type area belongs to the *Orthidiella* zone; in the Nevada Test Site, this division also includes part of the *Pseudocybele* (J) zone at its base (Ross, 1964, p. 1528). The lower Skoki represents the *Orthidiella* zone and much of the subjacent *Hesperonomia* zone that is in part equivalent to the *Pseudocybele* zone. The middle division of the Antelope Valley is thickly bedded and resistant. Pisolitic limestones are characteristic and the large gastropods *Palliseria* and *Maclurites* are common. The upper part of the Skoki Formation is preserved as dolomite, but otherwise is virtually identical to the middle division of the Antelope Valley. Both units correspond to the *Anomalorthis* zone. An upper division of the Antelope Valley Limestone is present in Nevada, but no equivalent strata are preserved in the eastern part of the southern Rocky Mountains where the Owen Creek Formation rests directly and disconformably on the upper part of the Skoki Formation. The Owen Creek rocks suggest local deposition in very shallow water. No comparable rocks are known from the eastern facies.

The upper part of the Eureka Quartzite is a thick unit of clean quartz sand. The unit is widespread in eastern Nevada and adjacent Utah and California and corresponds in lithology and stratigraphic position to the Mount Wilson Quartzite in Alberta. The uppermost Eureka in the Arrow Canyon Range is probably Wilderness to Maysville in age (Ross, 1964, p. 1531). The only internal dating available for the Mount Wilson Quartzite is Middle or Late Ordovician from conodonts near the top of the formation at Pinnacle Creek.

Resistant grey dolomites and limestones (Ely Springs, Hanson Creek, Fish Haven, Roberts Mountain, Lone Mountain, Hidden Valley, and Laketown formations) separate the Eureka from Devonian rocks in the eastern facies. Dolomites of the Beaverfoot Formation fill a similar stratigraphic position in the eastern part of the southern Rocky Mountains. Silurian carbonate formations are widespread in the eastern facies of the mountain states and faunas as young as Upper Silurian are present in the Laketown (Waite, 1956) and in the Lone Mountain (Merriam, 1963, p. 41) formations.

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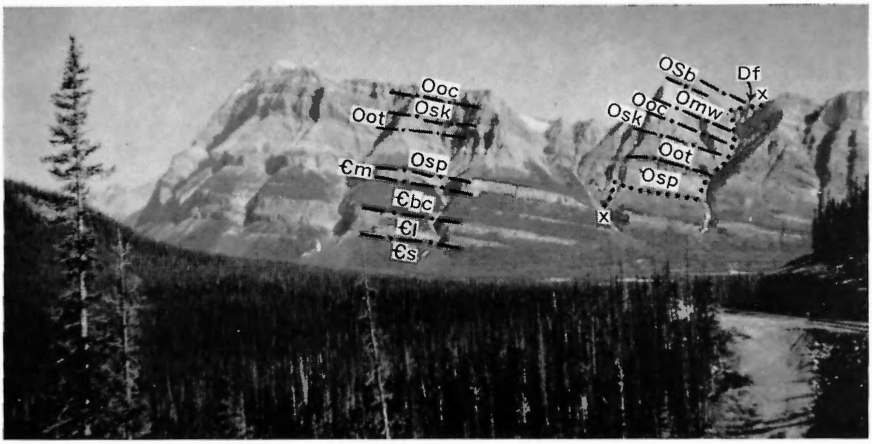
APPENDIX—STRATIGRAPHIC SECTIONS

The study is based on about forty measured sections, but only those that include type sections or standard sections of the various rock units are here presented. A good type section of the Glenogle Shales is not available at Glenogle (Fig. 2, section H) where the outcrops have been described by Larson and Jackson (1967, pp. 498–499). Measurements were by 5-foot staff, a method that can keep errors below five per cent for well-exposed stratigraphic sections. Materials left after etching of samples in hydrochloric acid are termed acid residues in the following rock descriptions.

A Mount Wilson Section

The southern face of Mount Wilson presents a well-exposed section that begins within the Upper Cambrian and ends at a dip-slope in the Upper Devonian at the back of the mountain. Dips are 20 to 30 degrees north-northeast. The interval Skoki to Beaverfoot was measured up a steep gully at 52°00′N, 116°45′W (Pls. VIII and IX). The section contains the type sections of the Mount Wilson Quartzite and the Owen Creek Formation and the standard section of the Skoki Formation. The type sections of the Outram and Survey Peak Formations are beneath the Skoki Formation (Aitken and Norford, 1967).



113398 B

PLATE VIII. Mount Wilson section, view from south. Cs, Sullivan; Cl, Lyell; Cbc, Bison Creek; Cm, Mistaya; Osp, Survey Peak; Oot, Outram; Osk, Skoki; Ooc, Owen Creek; Omw, Mount Wilson; OSb, Beaverfoot; Df, Fairholme; x....x, line of section.

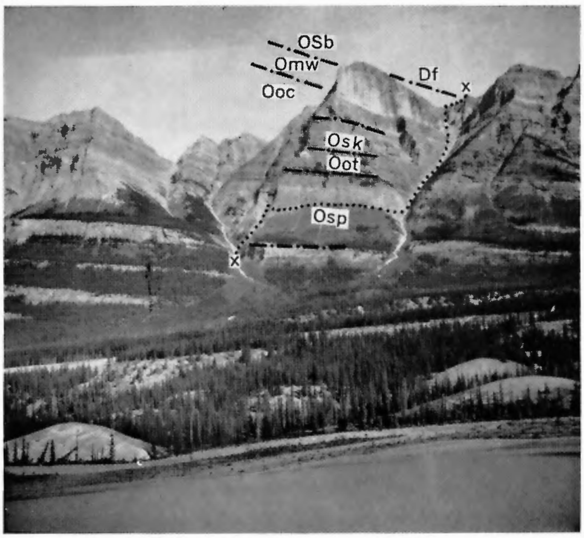


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PLATE IX

Mount Wilson section, closer view of Ordovician section.

Unit No.		Thickness in feet: Unit	Total from base
	FAIRHOLME GROUP (basal beds)		
	Dolomites, very finely crystalline, greyish brown and dark brownish grey, weather yellowish brown and dark yellowish brown, slightly recessive, bedding 2 to 12 inches, irregular; with thin dolomite stringers; acid residues of dark brown clay-size material and rounded very fine to coarse quartz sand that amounts to about 20 per cent of lowest beds. *Coenites* (?) sp. (GSC loc. 56108, 1,918′, identified by McLaren and Norris). Contact with Unit 16 abrupt, concordant.		
16	Quartzites, rounded fine to coarse quartz sand, off-white, weather off-white, pale greyish orange, and very pale yellowish brown, bedding 2 to 18 inches, some beds crosslaminated. Quartz sandstones, dolomitic with patches of siliceous cement, pale yellowish brown, weather pale greyish orange. At 1,857–1,858′, siliceous dolomites with quartz sandstone layers, weather greyish brown. Covered intervals at 1,871–1,876′, 1,821–1,824′, 1,808–1,814′. Barren. Unit is less resistant than Unit 15, contact concordant, not exposed.	71	1,879
	BEAVERFOOT FORMATION (187 feet)		
15	Dolomites, microcrystalline, grey, dark grey, and brownish grey, weather light grey, yellowish grey, light olive-grey, pale yellowish brown, pale greyish orange, and brownish grey, resistant, bedding 1 foot to 8 feet, but some beds weather somewhat platy and nodular; some beds with sparse biogenic debris, mostly echinoderm fragments; with rare stylolites; acid residues of light clay-size material. At 1,700′, very rare, light grey weathering chert nodules; at 1,638–1,645′, common dark grey rounded chert nodules that weather light brown. Solitary and colonial corals, brachiopods, bryozoans, and echinoderm fragments common in basal beds (GSC loc. 56107, 1,637–1,645′), very rare brachiopods and echinoderm debris higher in unit.	173	1,808
	WHISKEY TRAIL MEMBER (14 feet)		
14	Covered interval.	4	1,635
13	Quartz sandstones, dolomitic, matrix microcrystalline to aphanitic, with 70 to 80 per cent poorly sorted rounded fine to coarse quartz sand; light greyish orange-pink and yellowish brown, weather greyish orange, somewhat recessive, bedding 1 foot to 2 feet; with sparse light clay-size material in acid residues. Covered interval at 1,622–1,626′. Contact with Unit 12 concordant, without discernible erosion, but uppermost surface of Unit 12 is stained yellowish orange.	10	1,631

Unit No.		Thickness in feet: Unit	Total from base
	MOUNT WILSON QUARTZITE (548 feet)		
12	Quartzites, off-white, white, and very light grey, weather off-white, very light grey, and very pale orange, with lichen stains and light greyish orange stains, very resistant, bedding 2 feet to massive, some beds laminated and crosslaminated. Fine to medium quartz sand, well-rounded to subround, rare amethyst in many beds. Rare beds with patches with minor intergranular porosity. Uppermost bed has sparse very fine dolomite rhombs partly filling such intergranular porosity. Erosion surface at 1,351 about 8 inches deep. Barren. Contact with Unit 11 covered in gully but visible in adjacent cliffs as abrupt, concordant, and without discernible erosion.	548	1,621
	OWEN CREEK FORMATION (614 feet)		
11	Dolomites, weather yellowish grey, with floating quartz sand. Dolomitic quartz sandstones and siltstones, very fine rounded quartz sand and silt with about 25 per cent aphanitic dolomite matrix and about 1 per cent well-rounded floating coarse quartz sand; very light brownish grey and very light grey, weather yellowish grey, very pale yellowish brown, and very pale orange, bedding ½ inch to 6 inches; acid residues include light clay-size material. Unit poorly exposed in gully (covered intervals at 1,059–1,073′, 1,043–1,058′), but completely exposed in adjacent cliffs. Barren.	33	1,073
10	Dolomites, aphanitic with 1 to 15 per cent rounded quartz silt and very fine sand, dark grey and grey, weather yellowish grey, light grey, light olive-grey, very pale orange, and very light grey, bedding ¼ foot to 6 feet, well developed; some beds with pale reddish brown wispy markings; rare beds with stylolites; acid residues include common to abundant varicoloured clay-size material. Sparse fine cracks filled by sparry dolomite at 825′. In lower part of unit, greyish red and brownish grey dolomites, some with reddish brown flecks, weather orange-pink, pale red, greyish pink, and dark greyish orange-pink; acid residues of abundant light reddish brown clay-size material, and, in some beds, clastic quartz silt. Interbeds of dolomitic mudstone amount to ½ to 5 per cent of rocks, greenish grey, dark grey, and light olive-grey, weather reddish brown, greyish red, pale greenish yellow, yellowish grey, and greyish olive, recessive, bedding ¼ inch to 3 inches; some beds with minor clastic quartz silt and very fine sand. Arenaceous dolomites at 1,000′. At 983–988′, recessive dolomites, weather very pale yellowish brown and platy. Sparse irregular silicification at 1,000′; horizon with quartz rosettes at 860′. Covered interval at 999–1,000′. Barren.	239	1,040

Unit No.		Thickness in feet Unit	Total from base
9	Dolomites, aphanitic, dark grey, weather olive-grey, light olive-grey, and yellowish grey, recessive, bedding ¼ inch to 3 inches, platy; acid residues of common light clay-size material and clastic quartz silt and very fine sand. Dolomites, aphanitic to very finely crystalline, dark grey, many beds finely laminated, dark brownish grey and grey, weather yellowish grey, very pale yellowish brown, pale greyish orange, and light olive-grey, bedding ½ foot to 2 feet, well-developed; rare thin dolomite stringers; acid residues of clay-size material and common clastic quartz silt and very fine sand. Unit poorly exposed, covered intervals at 798–801′, 773–788′, 763–765′, 748–752′. Mud-cracks in talus at 773′. Barren.	54	801
8	Dolomites, aphanitic with 5 to 15 per cent rounded quartz silt and very fine sand; grey, dark grey, and light olive-grey, weather yellowish grey, light grey, very pale orange, and light olive-grey, bedding 1 inch to 3 feet, some beds indistinctly finely laminated with layers rich in quartz grains, many beds with 1 to 5 per cent floating, well-rounded, fine to very coarse quartz sand; with rare thin dolomite stringers and vugs; rare beds with stylolites; acid residues include varicoloured clay-size material. Minor recessive dolomites, weather dark brownish grey, and platy, bedding ¼ inch to 2 inches. Very minor well-laminated dolomites, dark brownish grey and grey laminae, weather yellowish brown and light olive-grey; some beds with greyish black weathering chert nodules. At 718′, coarsely arenaceous dolomite bed, 6 inches thick. At 650′, bed with rounded aggregates of crystalline silica. Argillaceous partings at 629′. Covered intervals at 692–694′, 681–682′, 661–662′, 625–627′, 608–610′. Small gastropods as clastic components of bed with chert pebbles at 581–581½′ (GSC loc. 56106); large gastropods in basal beds at 459–465′; unit otherwise barren. Contact with Unit 7 concordant.	288	747
	SKOKI FORMATION (459 feet)		
7	Dolomites, very finely to finely crystalline, dark grey and dark brownish grey, weather light grey and yellowish grey, resistant, bedding 1 foot to massive; dark ghosts of fine to medium sand common in lower beds; acid residues of dark brown clay-size material and clastic quartz silt, sparse rounded very fine quartz sand in some of the lower beds. Abundant large gastropods in a single bed at 455–458′. Rare stylolites at 450′. Sparse large gastropods and rare brachiopods and stromatoporoids (GSC locs. 56105, 455–458′; 56104, 453–455′; 56103, 425–430′). Contact with Unit 6 gradational, picked above abundance of pisoliths.	74	459
6	Dolomites, finely to very finely crystalline mosaics with dark ghosts of medium to coarse sand and coarse pisoliths; dark grey, dark brownish grey, and grey, weather light grey, light olive-grey, pale yellowish brown, greyish orange, and yellowish grey, resistant, bedding 1 foot to 15 feet; many beds contain 30 to 60 per cent pisoliths, some with traces of concentric structure; thin dolomite	192	385

Unit No.		Thickness in feet Unit	Total from base
6 (cont.)	stringers in some beds; acid residues of dark brown clay-size material, rounded quartz silt and very fine sand. At 291–293′, recessive thinly bedded dolomites. Covered intervals at 250–252′, 248–249′. Rare large gastropods at 323–385′.		
5	Dolomites, very finely to finely crystalline, grey, dark grey, and brownish grey, weather greyish orange, light grey, yellowish grey, and very pale yellowish brown, bedding 1 foot to 10 feet; with rare chert nodules in some beds; some beds with dark brown wispy argillaceous layers; with rare thin dolomite stringers; acid residues of light brown clay-size material and common rounded quartz silt and very fine sand. Echinoderm fragments and brachiopods (GSC locs. 56102, 152–160′; 56101, 121–135′).	78	193
4	Limestones, aphanitic with irregular weathered pebbles of similar limestone, with abundant patches and layers with 10 to 40 per cent biogenic debris, with about 30 per cent dark brown wispy layers of very argillaceous limestone with sparse pyrite crystals; dark grey, weather grey, light grey, and pale greyish orange, bedding 1 foot to 6 feet; acid residues include quartz silt and very fine sand. Echinoderm and brachiopod debris.	23	115
3	Dolomites, very finely to coarsely crystalline, light brownish grey, weather greyish orange and dull light grey, bedding 2 feet to massive; acid residues of common rounded quartz silt and very fine sand; with rare layers of dark insoluble material segregated between the crystals of the dolomite mosaic. At 79–85′, brachiopods and echinoderm fragments (GSC loc. 56100).	20	92
2	Dolomites, very finely to finely crystalline, dark grey and brownish grey, weather greyish orange, pale yellowish brown, yellowish grey, and pale orange, bedding ½ foot to 12 feet; with dark brown wispy argillaceous layers; with sparse chert nodules in upper beds; acid residues of light brown clay-size material and common rounded quartz silt and very fine sand. Echinoderm fragments locally common.	57	72
1	Dolomites, medium to very coarsely crystalline, light pinkish orange-grey, weather dull yellowish brown, very light grey, pale orange, and pale yellowish brown, bedding ½ foot to 6 feet; rare pisoliths present; acid residues of clastic quartz silt and rare very fine sand, rare pyrite; some beds with about 1 per cent intergranular porosity. Echinoderm fragments (GSC loc. 70037, 0–11′). Contact with subjacent rocks concordant.	15	15

Outram Formation

Limestones, some argillaceous, aphanitic, dark grey and dark brownish grey, weather grey, pale yellowish brown, and greyish orange, somewhat recessive, bedding 1 inch to 6 feet, some beds weather nodular; with bluish black chert as thin layers and rarer

Unit No.		Thickness in feet: Unit	Total from base
	nodules; acid residues of abundant light clay-size material and clastic quartz silt. Dark brownish grey limy mudstone as irregular layers within beds and as minor interbeds. These beds are dolomitized on west side of gully. Trilobites, including *Pseudocybele* sp. (GSC loc. 56098, 20–30 feet below zero; 56099, talus from same interval). Only top 30 feet described (*see* Aitken and Norford, 1967, for description of rest of Outram Formation and underlying Survey Peak Formation).		

B Skoki Mountain Section

Skoki Mountain is formed by Ordovician and Devonian rocks that dip southwest at about 45 degrees (Pl. XI). The section was measured up a steep gully at the east end of the northeast face of the mountain at 51°32′N, 116°03′W (Pl. X). The upper part of the Ordovician sequence found at Mount Wilson is missing owing to erosion prior to the deposition of Upper Devonian rocks and only the Skoki Formation separates the Fairholme Group from the Outram Formation.

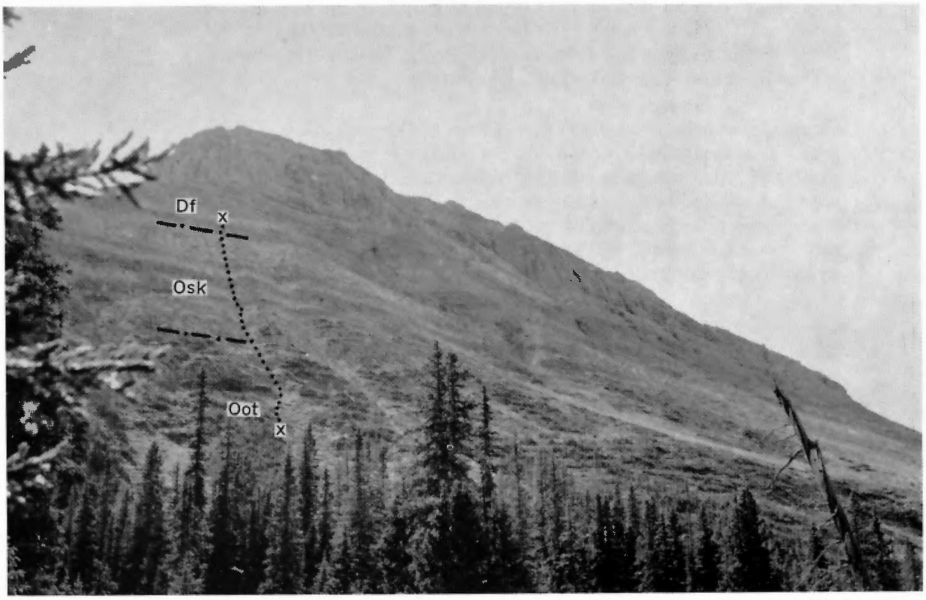

PLATE X. Skoki Mountain section, view from foot of northeast side of east end of Skoki Mountain. Oot, Outram; Osk, Skoki; Df, Fairholme; x....x, line of section.

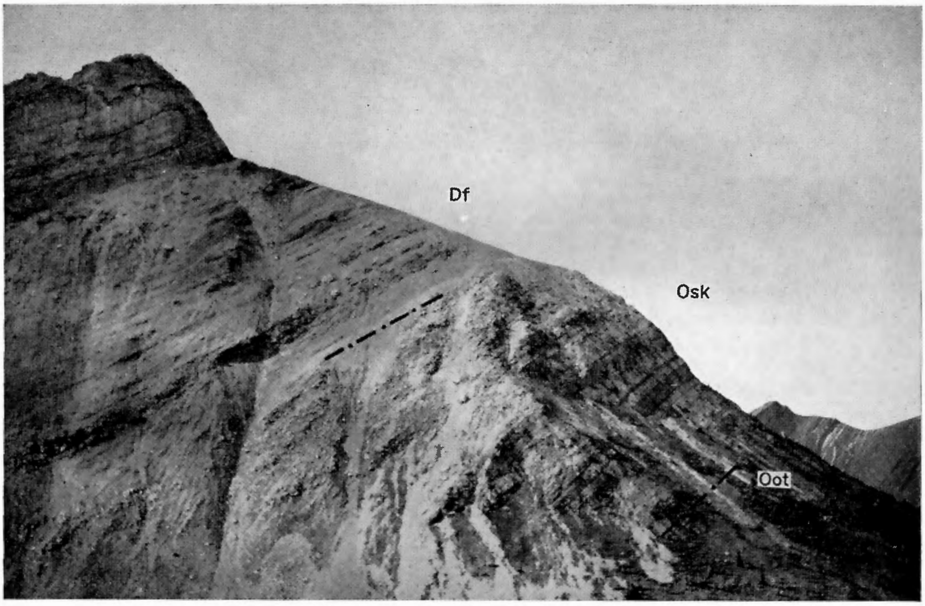

PLATE XI. Skoki Mountain, view from southeast.

Walcott gave Skoki Mountain as the type locality for his Skoki Formation (1928, p. 217) but studied a section on the northeast shoulder of Fossil Mountain, a mile southeast of the present section. Precise comparison is difficult with the poorly exposed section described by Walcott (1928, pp. 217–218, 287–291), but Unit 2 (39 feet) undoubtedly corresponds to Walcott's Skoki Unit 1c (42 feet), and Unit 1 combined with Units B and C (totalling 67 feet) is probably equivalent to his Unit 1d (66 feet). The base of the Skoki Formation is now drawn within the Unit 1d, between Units 1 and C, about 22 feet higher than originally picked by Walcott.

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
	FAIRHOLME GROUP (basal beds)		
	Limestones, aphanitic to microcrystalline with common flaky angular pebbles and sand of dark argillaceous limestones; dark brownish grey and pale yellowish brown, some rocks mottled, weather dark grey, somewhat recessive, some beds weather rubbly, bedding ½ foot to 2 feet; stylolites in some beds; acid residues of sparse dark brown clay-size material, pyrite(?), and rare rounded quartz sand and silt. At 387′, breccia layer, 2 inches thick. Brachiopods (GSC loc. 57228, 408–418′, *Atrypa* cf. *A. clarkei* Warren, *Atrypa* cf. *A. gregeri* Rowley (identified by McLaren and Norris)). Contact with Unit 10 hidden by 2 feet of covered interval.		

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
11	Quartz sandstones, microcrystalline limy cement, some patches with dolomitic and siliceous cements, with as much as 70 per cent fine to very coarse quartz sand, well-rounded; pinkish light grey, yellowish grey, and very pale orange, weather pale yellowish brown and greyish orange, bedding 2 to 6 inches, minor cross-lamination; rare pyrite(?) in acid residues. Minor quartz siltstones, somewhat argillaceous, with sparse well-rounded quartz sand. Very minor mudstones, non-limy, olive-grey, weather light olive-grey, very poorly fissile; as laminae and irregular pebbles within sandstone and siltstone beds. Barren. Contact with Unit 9 concordant, slightly irregular with about 1 inch of relief, interpreted as disconformable.	12	382
	SKOKI FORMATION (370 feet)		
10	Dolomites, microcrystalline to very finely crystalline, light olive-grey and yellowish grey, weather yellowish grey, very pale orange, and pale greyish orange, bedding 1 inch to 24 inches, some beds poorly laminated; with wispy argillaceous layers in some beds; with rare dolomite stringers; acid residues of rounded clastic very fine quartz sand and silt, amounting to 5 per cent of most rocks, and common light clay-size material. *Receptaculites*, gastropods, and brachiopods (GSC loc. 57227, 354–359′).	16	370
9	Dolomites, very finely to coarsely crystalline, pale yellowish brown, brownish grey, and light brownish grey, weather very pale yellowish brown, yellowish grey, very pale orange, and pale pinkish grey, resistant, bedding 1 foot to 15 feet; some beds with coarse pisoliths (up to $\frac{3}{4}$ inch in diameter), some with ghost concentric structure, amounting to as much as 40 per cent of rock; acid residues of rounded clastic quartz silt and very fine sand and sparse light brown clay-size material. At 324′, rare stylolites. At 318′, rounded quartz sand amounts to 2 per cent of rock. Echinoderm fragments, rare brachiopods, straight cephalopods (GSC loc. 57226, 222–226′), and at 343′, fragments of large gastropods.	133	354
8	Dolomites, microcrystalline to aphanitic with about 15 per cent dark very fine to medium sand; dark brownish grey, weather pale greyish orange and yellowish grey, bedding 2 to 3 feet, most beds weather flaggy $\frac{1}{2}$ inch to 2 inches; dark brownish grey elongate rounded chert nodules amount to as much as 8 per cent of most beds, weather greyish orange and dark yellowish orange; acid residues of abundant light brown clay-size material and abundant rounded clastic quartz silt and very fine sand, latter amounting to 5 per cent of some beds. Barren. At 212–217′, more resistant dolomite bed with echinoderm fragments, without chert nodules, resembles Unit 7.	16	221
7	Dolomites, microcrystalline to very finely crystalline, light brownish grey and yellowish brown, weather greyish orange and pale greyish orange, resistant, bedding 2 to 3 feet; with thin wispy laminae of dark brown argillaceous dolomite; with rare irregular chert nodules, but these amount to 8 per cent of a bed at	18	205

Unit No.		Thickness in feet: Unit	Total from base
7 (cont.)	187′; acid residues of abundant light clay-size material and rounded clastic quartz silt and very fine sand. Echinoderm fragments and brachiopods (GSC loc. 57225, 193–198′).		
6	Dolomites, similar to Unit 4. At 180–184′, very dolomitic mudstones, microcrystalline to aphanitic with about 5 per cent fine dolomite grains; brownish grey and dark yellowish brown, weather very pale yellowish brown and yellowish grey, recessive, poorly fissile; with common rounded elongate chert nodules; acid residues of abundant light brown clay-size material and clastic quartz silt; with fragments of inarticulate brachiopods. At 179–180′, dolomite bed with abundant echinoderm debris, similar to Unit 5.	15	187
5	Dolomite, microcrystalline to finely crystalline with about 40 per cent coarse echinoderm debris, pale yellowish brown, weathers greyish orange, resistant, a single 8-foot bed; acid residues of common light brown clay-size material and common rounded clastic quartz silt and very fine sand.	8	172
4	Dolomites, aphanitic to microcrystalline, yellowish brown and brownish grey, weather greyish orange, very pale orange, and yellowish grey, commonly striped, bedding 1 foot to 6 feet, weathering flaggy ½ inch to 2 inches; with common chert layers and nodules; acid residues with light clay-size material and common rounded clastic quartz silt and very fine sand, latter amounting to 10 per cent of some beds. Rare shaly layers and argillaceous partings. At 149–151′, dolomite bed with abundant echinoderm debris, similar to Unit 3. Contact with Unit 3 slightly undulatory.	29	164
3	Dolomites, very finely crystalline with about 30 per cent coarse echinoderm debris, light brownish grey and yellowish grey, weather very pale orange, pale greyish orange, and pale yellowish brown, bedding 2 feet to massive; some beds with rare wispy brown argillaceous layers; acid residues of rounded clastic quartz silt and very fine sand, and light clay-size material. Echinoderm debris and brachiopods (GSC loc. 57224, 87–89′).	51	135
2	Dolomites, microcrystalline, dark brownish grey and light brownish grey, weather greyish orange and yellowish grey, resistant, bedding 1 foot to 6 feet; with abundant (20 to 60 per cent of rocks) dark brownish grey chert as discontinuous thin layers and rarer rounded nodules; some beds with rare thin dark brown wispy argillaceous layers; acid residues with common light clay-size material and rounded clastic quartz silt that is abundant in some beds. Fragments of echinoderms and brachiopods.	39	84
1	Dolomites, very finely to very coarsely crystalline, pale yellowish brown, light brownish grey and light olive-grey, weather very pale orange, greyish orange, and light grey, bedding 2 to 8 feet; without chert nodules except at 19–21′; with very rare wispy dark brown argillaceous layers that weather yellowish brown; acid residues with rounded clastic quartz silt and sand, common in some beds, and in some beds light clay-size material. At 19–21′, dolomitic mudstones, aphanitic to microcrystalline, olive-grey, weather yellowish brown and olive-grey, nodular; with about 25 per cent	45	45

		Thickness in feet	
Unit No.		Unit	Total from base
1 (cont.)	rounded elongate chert nodules; with clastic quartz silt and very fine sand; with very elongate dolomite-filled vugs. Debris of echinoderms and brachiopods (GSC locs. 57223, 43′; 57222, 0–1′). Contact with subjacent rocks drawn above less resistant nodular limestones and dolomites, both with chert nodules; contact disconformable, undulatory (1½ inches relief) with very fine channelling. Basal Skoki is a dolomite conglomerate, matrix microcrystalline to very finely crystalline, rounded pebbles of very finely crystalline dolomite, biogenic debris amounts to about 50 per cent of rock, rounded clastic quartz silt to medium sand about 5 per cent, but about 30 per cent of basal ¼ inch; layers of irregular silicification common in lowest Skoki bed.		
	OUTRAM FORMATION (upper beds)		
C	Dolomites, somewhat argillaceous, aphanitic to finely crystalline, brownish grey and yellowish brown, weather yellowish grey and very pale orange, recessive, bedding 2 to 6 inches; with brownish grey weathering argillaceous layers; with 5 to 10 per cent chert layers and nodules. Echinoderm and trilobite fragments.	14	
B	Limestones, somewhat argillaceous, with sparse biogenic debris, aphanitic with sparse very fine dolomite rhombs; dark brownish grey and olive-grey, weather light grey and dull yellowish brown, nodular, bedding 1 foot to 3 feet; with yellowish orange weathering wispy argillaceous layers common in many beds; with about 3 per cent discontinuous chert layers and nodules; acid residues with light brown clay-size material and abundant rounded clastic quartz silt to fine sand. Trilobites.	8	
A	Limestones, aphanitic, with layers and patches of biogenic fragmental limestone, dark grey and dark brownish grey, weather light grey, slightly recessive, bedding 2 to 20 feet; with minor dark brown wispy argillaceous layers, weather pale yellowish brown; acid residues of abundant clay-size material and sparse clastic quartz silt to fine sand. Interbedded argillaceous limestones, weather light olive-grey, nodular, recessive, with common wispy argillaceous layers. Covered intervals at 95–97′ and 99–103′ below zero. Limestone bed with 8 per cent rounded quartz sand at 137–139′ below zero. Echinoderm fragments, trilobites, and gastropods (GSC locs. 57221, 37–42′; 57220, 84′; 57219, 103–109′ below zero). Outcrops of the Outram and Survey Peak Formations extend to about 1,000 feet below zero (GSC locs. 57218, 169–170′; 57217, 374′ below zero).	118	

C Tipperary Lake Section

Ordovician cliffs overlook the Palliser River east of Tipperary Lake and form the western limb of an anticline breached by the river (Pl. XII). Dips are 12 to 33 degrees southwest. The section commences near the core of a minor flexure and was measured up a steep gully at 50°40′N, 115°21′W (Pl. XIII) and on the dip slope of the south shoulder of Mount Cradock. The section contains the type section of the Tipperary Quartzite.

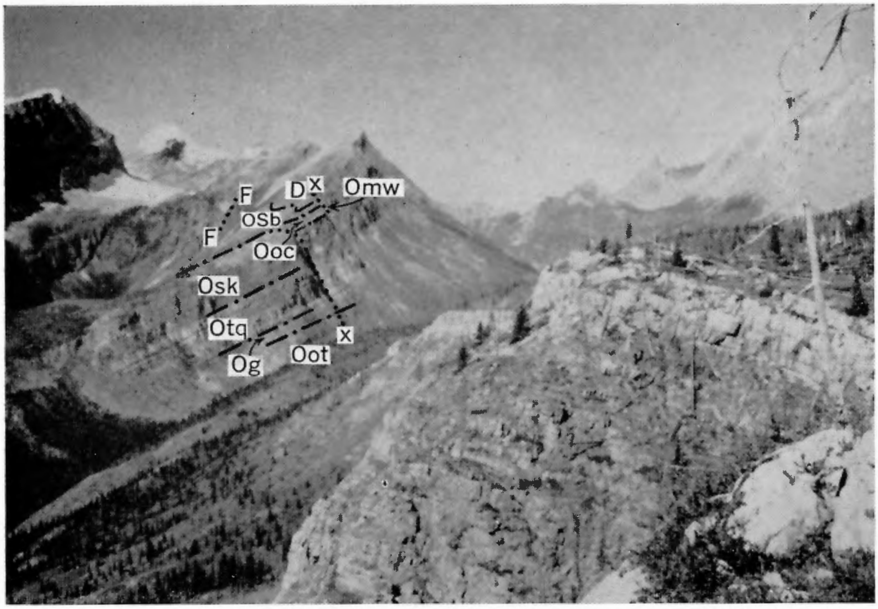

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PLATE XII. Tipperary Lake section, view from southeast. Oot, Outram; Og, Glenogle; Otq, Tipperary; Osk, Skoki; Ooc, Owen Creek; Omw, Mount Wilson; OSb, Beaverfoot; D, Devonian; x....x, line of section; F....F, fault. Basal Devonian rocks in foreground, Palliser River in valley, Mount Cradock in the peak to the right of the section.

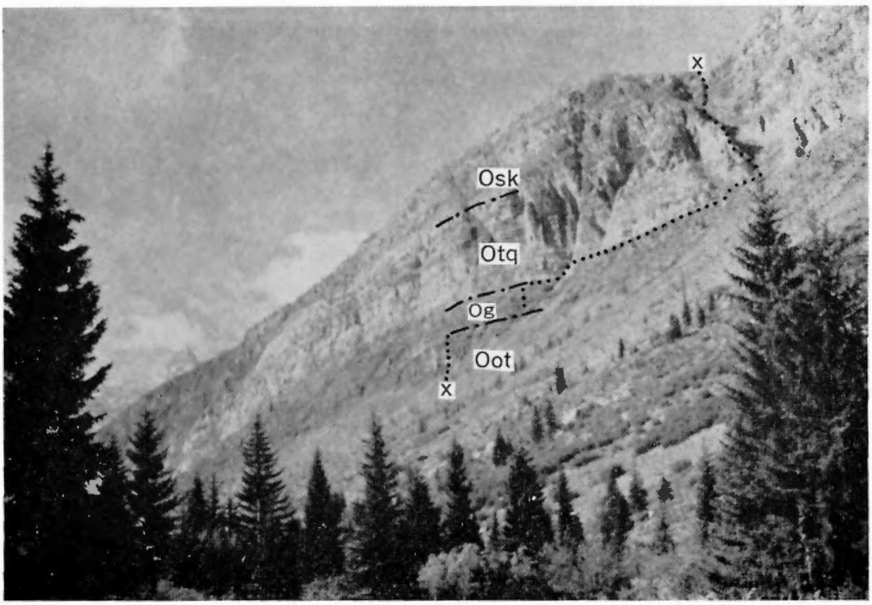

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PLATE XIII. Tipperary Lake section, view from foot.

Unit No.		Thickness in feet: Unit	Total from base
	DEVONIAN ROCKS (lowermost 30 feet)		
23	Quartz sandstones, dolomitic with layers of white quartzite, weather greyish orange, bedding ½ foot to 2 feet. Barren. Contact gradational with Unit 22, stratigraphically higher beds are exposed elsewhere on Mount Cradock.	8	1,467
22	Conglomerates, bedding 2 to 5 feet. Matrix dolomitic quartz sandstone, microcrystalline dolomite and quartz with rounded fine to coarse quartz sand; weathers greyish orange and rubbly; with lenses of off-white and pale yellowish brown weathering quartzite; acid residues include light clay-size material. Roundstones subangular to round, small pebbles to medium boulders, polymict with lithologies of blocks suggesting derivation from the Tipperary and/or Mount Wilson Quartzites, and the Beaverfoot and Owen Creek Formations. Lithologies include quartzites, weathering off-white; dolomites, weathering light grey, with *Streptelasma* and *Bighornia*; dolomites, weathering very pale orange; dolomites, weathering very light grey and containing about 5 per cent rounded quartz sand; and chert, weathering bluish black. Contact with Unit 21 disconformable, cutting out 22 feet of Unit 21 within 100 yards, and with a local relief of 6 inches on the erosion surface.	22	1,459
	BEAVERFOOT FORMATION (56 feet)		
21	Dolomites, microcrystalline, grey and dark grey, weather light grey and light olive-grey, resistant, bedding 1 foot to 10 feet; with thin dolomite stringers; some beds with stylolites; acid residues with sparse light clay-size material. Rare corals. Unit 21 thickens towards Tipperary Lake to the southwest, beneath the sub-Devonian unconformity.	33	1,437
20	Dolomites, microcrystalline, grey, weather yellowish grey, light grey, and very pale orange, resistant, bedding 1 foot to 3 feet; with about 10 per cent rounded chert nodules, weather greyish brown and off-white; some beds with thin dolomite stringers; acid residues with light clay-size material and sparse clastic quartz silt. Solitary and colonial corals, brachiopods, and bryozoans (GSC locs. 47410, 1,389–1,403′; 57209, 1,388–1,397′).	16	1,404
	WHISKEY TRAIL MEMBER (7 feet)		
19	Dolomites, very finely crystalline with about 40 per cent ghosts of coarser biogenic debris, mostly echinoderm; light brownish grey, weather very pale yellowish brown and light brownish grey, recessive, bedding ½ foot to 2 feet; acid residues of light brown clay-size material and common clastic quartz silt to medium sand. Limestones, aphanitic with sparse biogenic debris, and rare layers of argillaceous limestone, dark grey and grey, weather grey and light grey; with irregular silicification; acid residues include common light clay-size material and common clastic quartz silt and sand. Covered interval at 1,381–1,382′. Echinoderm and brachiopod fragments, small gastropods, and colonial corals (GSC loc. 57208, 1,385′ 0–2″). Contact with Unit 18 covered, concordant.	7	1,388

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
	MOUNT WILSON QUARTZITE (3 feet)		
18	Quartzite, fine to coarse rounded quartz sand, off-white, weather off-white and lichen-stained, resistant, bedding ½ foot to 2 feet, some beds crosslaminated; with very rare amethyst grains; with very rare sand grains and pebbles of mudstone. Very rare bryozoans as clastic grains. Contact with Unit 17 concordant, with erosion surface locally 3 inches deep.	3	1,381
	OWEN CREEK FORMATION (194 feet)		
17	Dolomites, many beds slightly argillaceous, aphanitic with 10 to 30 per cent rounded quartz silt and very fine sand; grey, light grey, brownish grey and light brownish grey, weather yellowish grey, very light grey, very pale orange, pale greyish orange, light pink, and yellowish orange, bedding 2 to 18 inches, well developed; some beds with sparse floating well-rounded medium to coarse quartz sand; some beds poorly laminated with layers rich in quartz silt and very fine sand; these layers weather light brown; acid residues include abundant light clay-size material and rare pyrite; rare stylolites; rare argillaceous interbeds in lower part of unit. At 1,375′, dolomite with 15 to 40 per cent very fine to fine rounded quartz sand and 3 to 10 per cent well-rounded coarse quartz sand; sand grains poorly concentrated in indistinct laminae. Rare quartz rosettes and irregular silicified masses at 1,303′. Covered intervals at 1,331–1,348′ and 1,305–1,309′. Barren. Contact with Unit 16 gradational.	130	1,378
16	Dolomites, very finely to finely crystalline, brownish grey, dark grey, and light grey, weather light grey, pale yellowish brown, and yellowish grey, bedding 2 to 24 inches; some beds with thin dolomite stringers; acid residues of clastic quartz silt and very fine sand, rare clay-size material, and rare pyrite; rare beds with floating rounded medium to coarse quartz sand; with irregular chert nodules at 1,242–1,248′, 1,235′, and 1,207–1,209′. Dolomites, aphanitic with 10 to 30 per cent rounded quartz silt and very fine sand, dark grey and grey, weather greyish orange, yellowish grey, and light grey, bedding 3 inches to 4 feet; some beds poorly laminated with layers rich in quartz grains; acid residues include common light clay-size material and rare pyrite. Very minor argillaceous interbeds, weather light brown, bedding ¼ to ½ inch. Covered interval at 1,195–1,202′. Barren except for brachiopod fragments in basal beds. Contact with Unit 15 apparently conformable.	64	1,248
	SKOKI FORMATION (610 feet)		
15	Dolomites, microcrystalline to aphanitic with 10 to 20 per cent quartz grains, grey, light brownish grey, and light grey, weather light grey and very pale yellowish brown, resistant, but less so than Unit 14, bedding 2 feet to massive; with rare dolomite vugs; acid residues of rounded very fine quartz sand and silt and rare light clay-size material. Brachiopod fragments and rare large gastropods.	24	1,184

Unit No.		Thickness in feet: Unit	Total from base
14	Dolomites, microcrystalline to very finely crystalline, grey and dark grey, weather light grey, yellowish grey, and very light grey, resistant, bedding 2 feet to massive; some beds with coarse pisoliths; some beds with thin dolomite stringers and vugs; acid residues of rounded quartz silt and very fine sand and light clay-size material. Rare stylolites at 1,000′. Echinoderm fragments. Large gastropods at 1,135–1,160′, abundant at 1,155–1,160′ (GSC loc. 47408). Contact with Unit 13 gradational.	170	1,160
13	Dolomites, microcrystalline to very finely crystalline, but some beds with ghosts of coarse sand and pebbles, grey and dark grey, weather yellowish grey, pale greyish orange, and greyish orange, less resistant than Unit 14, bedding ½ foot to 4 feet; some beds with irregular wispy argillaceous layers that weather light brown; many beds with thin dolomite stringers; acid residues of abundant rounded quartz silt and very fine sand and common light clay-size material; bed with 1 per cent well-rounded fine to medium quartz sand at 940′. Limestones and dolomitic limestones, weather light grey and light bluish grey with light brown weathering wispy argillaceous layers, bedding 3 to 18 inches (at 950′; limestone, aphanitic with biogenic fragments, ooliths, minor very fine rhombs of dolomite, and about 25 per cent pisoliths, showing concentric structure, with about 1 per cent sparry calcite filling irregular vugs; with thin calcite stringers; acid residues of brown clay-size material and common rounded quartz silt and very fine sand). Brachiopods and gastropods (GSC loc. 47412, 945–954′).	76	990
12	Dolomites, most beds argillaceous, microcrystalline to very finely crystalline, some beds with ghosts of arenitic grains, fine to very coarse; pinkish grey, light grey, light brownish grey, greyish red, grey, light olive-grey, and greyish orange-pink, weather light grey, greyish orange, yellowish grey, grey, and pale greyish orange, bedding 1 foot to 5 feet; some beds with dolomite-filled vugs and stringers; most beds with abundant irregular wispy layers of dolomitic mudstone with common quartz grains, reddish brown, pale red, dark grey, and light grey, weather moderate brown, reddish brown, pale red, and greyish orange; acid residues with clastic quartz silt and very fine sand and common light and light reddish brown clay-size material. Brachiopods, echinoderm fragments (GSC loc. 47411, 856–861′).	64	914
11	Dolomites, medium to coarsely crystalline, very light grey, pinkish grey, and dark grey, weather grey, yellowish grey, and very pale orange, bedding 1 foot to 6 feet; acid residues of sparse clastic quartz silt and very fine sand, and in lower beds, 1 to 5 per cent rounded fine to medium quartz sand. Rare chert nodules at 813′, weather off-white. Vuggy porosity at 807′. Echinoderm fragments common in some beds in lower part of unit; brachiopods above 818′ (GSC locs. 47407, 844′; 57207, 818–820′).	49	850
10	Quartzites, fine, and rarer medium rounded quartz sand, sparse patches with dolomite cement; off-white and very pale pinkish	72	801

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
10 (cont.)	orange, weather very light grey, off-white, pale greyish orange, resistant, bedding 2 feet to massive, many beds crosslaminated. At 746–752′ and 737–742′, dolomites and dolomitic quartz sandstones, with 5 to 50 per cent fine and medium rounded quartz sand, and quartz silt, some beds with about 20 per cent ghosts of coarse and very coarse dolomite sand; light grey, light brownish grey, and very light grey, weather grey, very pale yellowish brown, greyish orange, and very pale orange, bedding 1 foot to 3 feet; acid residues include rare light clay-size material. Barren.		
9	Dolomites, very finely to coarsely crystalline with common to abundant echinoderm debris in many beds; light grey and very pale orange, weather greyish orange, dull light grey, and yellowish grey, bedding 1 foot to 10 feet; many beds with 15 to 20 per cent rounded fine quartz sand and silt; many beds with layers and patches of dolomitic quartz sandstone; acid residues include rare light clay-size material. Chert as nodules and discontinuous thin beds, weathers light grey, pale greyish orange, and very light grey, amounts to 5 to 40 per cent of many beds. Echinoderm debris, rare brachiopod fragments (GSC loc. 57206, 683–684′).	50	729
8	Dolomites, very finely to medium crystalline, echinoderm debris an important constituent of some rocks, some beds with ghosts of very coarse sand and small pebbles of dolomite; light grey and grey, weather light brownish grey, greyish orange, and dull grey, bedding 3 to 12 feet, some beds crosslaminated; acid residues with clastic quartz silt and very fine sand, clay-size material in some beds, and in lower 30 feet of unit, rounded fine to medium quartz sand amounts to 15 to 25 per cent of most rocks. At 674–677′, lenticular quartzite bed. Echinoderm debris.	94	679
7	Quartzite, rounded fine sand, pinkish white, weathers off-white, bedding 7 feet, crosslaminated; with patches and laminae with dolomitic cement; rare amethyst grains. Bed thickens laterally. Barren.	7	585
6	Dolomite quartz sandstones, about 50 per cent well-rounded fine to medium quartz sand, minor quartz silt, about 5 per cent ghost coarse sand and pebbles of dolomite, some patches with siliceous cement; light grey, weather light brownish grey, bedding 2 feet; with thin dolomite stringers. Barren. Concordant contact with Unit 5, with erosion surface.	4	578
	TIPPERARY QUARTZITE (574 feet)		
5	Quartzites, rounded fine quartz sand, off-white, pale greyish orange, pale yellowish grey, very pale orange, and very light grey, weather off-white, pale greyish orange, greyish orange-pink, greyish pink, pale yellowish orange, yellowish grey, and moderate orange-pink, with lichen stains, resistant, bedding 3 feet to massive, coarse crosslamination common in lower half of unit, rare in upper half; rare beds with patches of dolomitic cement; most beds with rare amethyst grains. Most beds with patches of intergranular and drusy cavity porosity. At 353–357′, dolomitic quartz sandstone bed with quartzite laminae, weathers greyish orange. Barren.	496	574

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
4	Quartzites, rounded fine quartz sand, white, weather white and greyish pink, resistant, bedding 5 to 8 feet, lacking crosslamination; most beds with sparse amethyst grains. Barren.	47	78
3	Quartzites, weather light brown and light red, bedding 2 to 24 inches. Shaly mudstones with shaly partings, weather bluish grey, amount to about 30 per cent of unit. Barren.	8	31
2	Quartzite, off-white, weathers off-white and white, very resistant, a single 10-foot bed, lacking crosslamination. Barren.	10	23
1	Quartzites, rounded fine to medium quartz sand, with sparse dolomite rhombs in the siliceous cement; off-white and pale greyish orange, weather moderate orange-pink, pale greyish orange, off-white, and pale red, resistant, bedding 2 to 3 feet, lacking crosslamination; some beds with sparse intergranular porosity. Barren. Contact with the Glenogle Shales covered, concordant, but the immediately subjacent rocks appear to thin laterally beneath Unit 1.	13	13
	GLENOGLE SHALES (about 120 feet)		
	Shales, some siliceous, and argillaceous limestones, weather dark grey, recessive, mostly covered; with interbedded nodular limestones and dolomites at 30 to 50 feet below zero. Trilobites, including *Lachnostoma* sp., and fragments of echinoderms and graptolites (GSC locs. 47406, about 50–60′; 57205, 120–125′; 57204, talus from 120–220′; all footages below zero).	about 120	
	OUTRAM FORMATION (uppermost beds)		
	Limestones, some argillaceous, and dolomites, with irregular siliceous laminae and thin chert beds. Brachiopod fragments.	Not measured	

D Pedley Pass Section

The Mount Wilson, Beaverfoot, and Tegart Formations have excellent exposures beneath the Devonian Burnais and Cedared Formations (Pls. XIV and XV) on the northwest side of a northeast trending ridge at Pedley Pass (50°27′N, 115°46′W). Dips are 45 to 55 degrees to the northeast. The Devonian section has recently been described by Belyea and Norford (1967, pp. 61–63). Outcrop of the Beaverfoot Formation is complete and has been previously studied by Henderson (1954) and Norford (1962a). The section is now designated as the standard section for the Beaverfoot Formation.

BSN 10-2-64

PLATE XIV

Pedley Pass section, view from north. COmk, McKay; Og, Glenogle; Omw, Mount Wilson; Owt, Whiskey Trail Member; OSb, Beaverfoot; x....x, line of section. Tegart and Devonian outcrop just left of view (see Pl. XV).

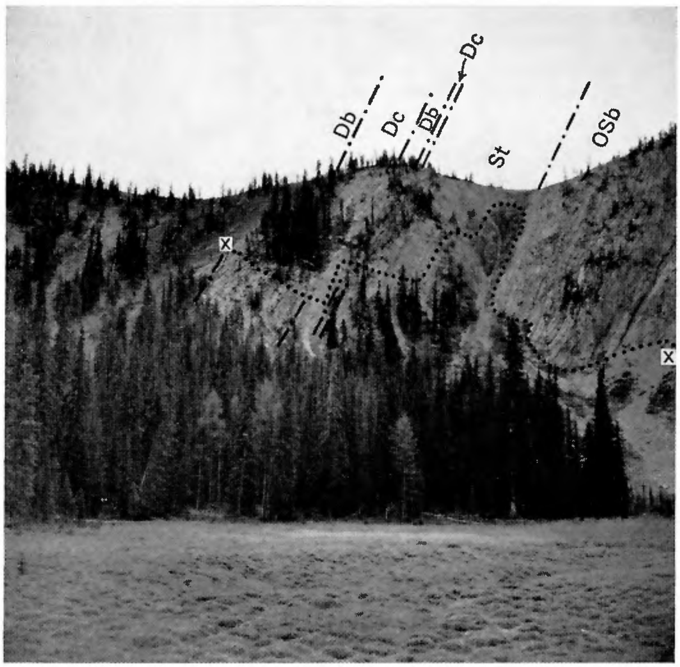

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PLATE XV

Pedley Pass section, upper part (continuation from Pl. XIV), St, Tegart; Dc, Cedared; Db, Burnais. Foreground is sink-hole topography underlain by Burnais Formation.

Norford previously published 1,593 feet as the Beaverfoot thickness; later remeasurement of the section gave the present figure of 1,661 feet. The difference between the two figures is within the five per cent accuracy hoped for in measurement of stratigraphic sections; the latter figure is chosen for it closely compares with Henderson's 1,659 feet for the same section.

Henderson reported Silurian fossils from Unit 28 and Norford (1962a) therefore picked the top of the Beaverfoot–Brisco Formation above these fossils. Subsequent field work by Norford has been unable to duplicate the collection and the top of the Tegart Formation is now picked at a horizon 16 feet lower, at the sharp lithological break below Unit 27.

Unit No.		Thickness in feet: Unit	Total from base
	BURNAIS FORMATION (lower tongue) (34 feet)		
29	Limestone breccias, rubbly weathering; bedding thick, indistinct, strongly contorted locally. Matrix amounts to about 50 per cent of rock; limestone, very finely to finely crystalline, grey, weathers light bluish grey and bluish grey. Sharpstones irregularly shaped: pebbles, cobbles, and boulders; with rare patches of bedded rocks with stratifications at any angle to that of the unit (an aspect of one such block measures 1 foot by 8 feet); about 40 per cent of sharpstones are limestones, weather light bluish grey and bluish grey; about 60 per cent are dolomites, many with siliceous content, weather pale yellowish orange, orange-pink, pale pinkish orange, and pinkish brown; rare sharpstones are silty mudstones, weather greyish yellowish green and pale reddish brown. Barren. Contact gradational with Unit 28.	24	1,900
28	Limestones, aphanitic to very finely crystalline, dark grey, weather light bluish grey and yellowish grey, rubbly, bedding 1 foot to 4 feet; calcite veins present. Barren. Contact with Unit 27 conformable.	10	1,876
	CEDARED FORMATION (lower tongue) (6 feet)		
27	Dolomites, very finely crystalline to aphanitic, brownish grey and brown, weather light grey and greyish orange, bedding $\frac{1}{2}$ foot to 3 feet, well-developed; with very recessive dolomite in lowest foot of unit. Barren. Contact with Unit 26 poorly exposed, paraconformable.	6	1,866
	TEGART FORMATION (166 feet)		
26	Argillaceous limestones, aphanitic to very finely crystalline, dark grey and brownish black, weather light brownish grey, light grey and grey, recessive, bedding $\frac{1}{2}$ inch to 3 inches, some beds laminated, a few nodular. Limy shales amount to 40 to 70 per cent of unit, weather brown and yellowish grey, recessive. Brachiopods and trilobites in limestones, graptolites in shales (GSC locs. C480, 1,843–1,852′; C479, 1,825–1,826′; 47397, 1,765–1,825′; C478, 1,795–1,796′; C477, 1,777–1,786′).	112	1,860

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
25	Limy shales, dark brown, weather brownish black and light brown, very recessive, unit poorly exposed, covered intervals at 1,731–1,735′, 1,708–1,729′, and 1,694–1,704′. Graptolites (GSC locs. 52175, 1,740′ 0–1″; 52174, 1,739′, 9–11″; 42021, 1729′; 42022, float 1,714–1,729′; 42023, 1,704–1,714′). Contact with Unit 24 covered, concordant.	54	1,748
	BEAVERFOOT FORMATION (1,661 feet)		
24	Limestones, aphanitic to microcrystalline, dark grey, olive-grey, grey, and brownish grey, weather light grey, bedding ½ foot to 4 feet, some beds weather slightly platy and rubbly; calcite stringers common, some beds with stylolites; acid residues of clay-size material and quartz silt, latter mostly clastic but some may be authigenic; biogenic fragments amount to 5 per cent of uppermost beds; lowermost beds slightly dolomitic. At 1,619–1,627′ thin discontinuous layers of greyish black chert; at 1,582′ prominent bedding plane. Echinoderm fragments, brachiopods, cephalopods, and trilobites (GSC locs. 52173, 1,692–1,693′; 42019 and 52172, 1,675–1,685′; 42020, 1,545–1,555′). Transitional contact with Unit 23.	151	1,694
23	Dolomites, very finely to finely crystalline, brownish grey and grey, weather very pale yellowish brown and yellowish brown, bedding ½ foot to 8 feet; rare dolomite stringers and vugs, some beds weather slightly vuggy; acid residues of light clay-size material and clastic quartz silt. Interbedded dark grey aphanitic limestones at 1,535–1,543′, some beds change laterally to dolomite. At 1,517′ prominent recessive bedding plane. Barren.	66	1,543
22	Dolomites with as much as 20 per cent rounded clastic quartz silt, very finely crystalline, brownish grey, weather very pale orange and very pale yellowish brown, bedding 3 to 12 inches, many beds finely laminated. Corals (GSC locs. 42024, 1,456–1,461′; 42025, 1,446–1,461′).	38	1,477
21	Limestones, aphanitic with 5 to 20 per cent silt-size dolomite rhombs, most beds with 2 to 20 per cent biogenic fragments, dark grey and grey, weather light grey, resistant, bedding 1 foot to massive; some beds with calcite stringers, veins, and vugs; most beds with 2 to 20 per cent wisps and mottles of limy dolomite, microcrystalline to very finely crystalline, brownish olive-grey and olive-grey, weather pale yellowish brown and yellowish brown; acid residues of fine clastic quartz silt and light clay-size material. Rare chert nodules at 1,423′ and 1,206′. Prominent bedding planes at 1,386′ and 1,284′. Tabulate and solitary corals, brachiopods, gastropods, cephalopods, and echinoderm fragments (GSC locs. 65721, 1,437′; 47401, 1,407–1,413′; 47400, 1,297–1,307′; 47399, 1,207–1,237′).	280	1,439
20	Limestones, microcrystalline with sparse microcrystalline dolomite rhombs, with about 15 per cent rounded quartz silt, with about 5 per cent biogenic fragments, dark grey, weather light grey, recessive, bedding ½ to 1 inch, undulatory and irregular with yellowish grey argillaceous partings. Prominent bedding plane at 1,156′. Tabulate corals, brachiopods, echinoderm debris, and bryozoans.	3	1,159

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
19	Limestones, aphanitic with sparse microcrystalline dolomite rhombs, with 10 to 20 per cent biogenic fragments, dark grey, weather light grey, resistant, bedding massive; with calcite stringers; with rare wispy patches of limy dolomite, microcrystalline to very finely crystalline, brownish olive and brownish olive-grey, weather yellowish brown; acid residues of light clay-size material, and rare fine clastic and authigenic quartz silt. Prominent bedding plane at 1,025′. Echinoderm fragments, tabulate and solitary corals, brachiopods, and bryozoans.	131	1,156
18	Limestones, microcrystalline to aphanitic, with 25 to 35 per cent biogenic fragments, some beds with common microcrystalline dolomite rhombs, dark grey, weather light grey and light bluish grey, resistant, bedding massive; with calcite stringers; with 20 to 30 per cent hackly weathering resistant mottles of limy dolomite, very finely crystalline to microcrystalline, pale yellowish brown, weather yellowish brown; acid residues of very sparse clastic quartz silt, rare authigenic quartz silt, and very rare light clay-size material. Tabulate and solitary corals, gastropods, stromatoporoids, and echinoderm fragments (GSC loc. 47405, 912–917′). Transitional contact with Unit 17.	110	1,025
17	Dolomites, very finely crystalline to microcrystalline, dark brownish grey and brownish grey, weather dull yellowish brown, pale yellowish brown, and pale greyish orange, bedding 8 feet to massive; with calcite stringers; upper beds with mottles of light grey weathering aphanitic dolomitic limestone with 40 to 70 per cent very fine to microcrystalline dolomite rhombs; acid residues of sparse light clay-size material and quartz silt. Tabulate and solitary corals, brachiopods, gastropods, stromatoporoids, and echinoderm fragments (GSC loc. 47402, 887′).	70	915
16	Dolomites, slightly limy, microcrystalline to very finely crystalline, dark brownish grey and dark grey, weather pale yellowish brown and dull light brownish grey, some beds mottled, bedding massive but weathering to partings ½ inch to 3 inches thick; with calcite stringers and vugs, and stylolites, but lacking chert nodules; acid residues of brown clay-size material and very fine quartz silt. Ghost brachiopods and gastropods.	30	845
15	Dolomites, silt-size, brownish grey and dark brownish grey, weather pale yellowish brown, light grey, light brownish grey, and light olive-grey, resistant, bedding ½ foot to 5 feet, some planes undulatory, most beds finely but irregularly laminated; with sparse chert layers and elongate nodules, weather brown; acid residues of light clay-size material and quartz silt. Prominent bedding plane at 747′. Barren.	68	815
14	Dolomites, very finely crystalline mosaics with dark ghosts of coarse sand grains, dark grey, weather pale yellowish brown, somewhat recessive, bedding 2 to 4 inches; lacking chert; acid residues of sparse authigenic quartz. Prominent bedding plane at 730′. Barren.	17	747

Unit No.		Thickness in feet: Unit	Total from base
13	Dolomites, microcrystalline, dark grey with brownish grey irregular layers and patches, weather light brownish grey and very pale yellowish brown, bedding 2 to 6 feet; with rare chert nodules; acid residues of authigenic quartz. Barren.	30	730
12	Dolomites, microcrystalline to very finely crystalline, some beds with irregular layers, patches, and ghost sand grains, dark grey and brownish grey, weather very pale yellowish brown, light brownish grey, and very light grey, resistant, bedding 1 foot to massive; some beds with dolomite-filled fine vugs; with rare dark grey weathering chert nodules in upper quarter of unit; acid residues of light clay-size material, and in some beds fine authigenic quartz, but at 537′ rounded very fine quartz sand and silt, clastic. Prominent bedding plane at 522′. Barren except for solitary corals, brachiopods, and stromatoporoids at 602–675′ (GSC loc. 47404, 602–606′).	178	700
11	Dolomites, microcrystalline, brownish grey and brownish olive-grey, weather very light grey and very light pinkish grey, blocky, bedding 4 inches to 4 feet, some beds laminated; with rare dark grey weathering chert layers; acid residues almost nil, but some beds have rare light clay-size material and rare authigenic quartz. Band of solution holes at 470–475′. Barren.	52	522
10	Dolomites, microcrystalline to very finely crystalline, brownish grey, weather pale yellowish brown and very pale yellowish brown, somewhat recessive, bedding 2 to 24 inches; with sparse dolomite and quartz filled vugs and fine drusy cavities; acid residues of rare light clay-size material and sparse authigenic quartz. Prominent bedding plane at 461′. Barren.	9	470
9	Dolomites, very finely crystalline to microcrystalline mosaics with ghosts of coarse sand grains in many beds, dark grey and brownish grey, weather very pale yellowish brown, pale yellowish brown, and very light grey, resistant, bedding 2 feet to massive, some planes undulatory; dolomite and quartz-filled vugs and stringers in some beds; acid residues of light clay-size material only. Rare chert nodules at 387′. Barren.	139	461
8	Dolomites, microcrystalline to aphanitic mosaics with ghosts of irregular patches and lumps, dark grey, weather very pale yellowish brown and very light grey, resistant, bedding 1 foot to massive; with dolomite and quartz-filled vugs and stringers; with rare chert nodules; acid residues of light clay-size material only. Solitary and tabulate corals, cephalopods, and echinoderm fragments.	84	322
7	Dolomites, very finely crystalline, some beds with ghosts of fine to very coarse sand grains, dark grey and brownish grey, weather very pale yellowish brown, resistant, bedding 1 foot to massive, some beds weather slightly rubbly, 2 to 24 inches; some beds with dolomite, calcite, and quartz stringers; acid residues of light clay-size material and sparse authigenic quartz, but at 86′ rounded clastic very fine to medium quartz sand. Sparse greyish black	176	238

Unit No.		Thickness in feet: Unit	Total from base
7 (cont.)	chert nodules at 182–197′, weather light brown. Prominent bedding planes at 238′ and 216′. Colonial and solitary corals, brachiopods, echinoderm fragments, and cephalopods (GSC loc. 47398, 182–197′). At 72–84′ rounded quartz sand amounts to about 10 per cent of a bed that is roughly laminated and crosslaminated.		
6	Dolomites, very finely crystalline to microcrystalline, dark grey, weather very pale orange, resistant, bedding 1 foot to 6 feet; with rare brown weathering chert nodules in upper beds; dolomite stringers; acid residues of light brown clay-size material and vein quartz. Echinoderm fragments, brachiopods, and gastropods. Contact with Unit 5 an erosion surface with as much as 6 inches relief.	10	62
	WHISKEY TRAIL MEMBER (19 feet)		
5	Dolomitic quartz sandstones, pale orange with brownish black speckles, weather very pale orange and greyish orange, bedding 2 feet, laminated; with about 50 per cent well rounded fine to very coarse quartz sand, sparse chert grains, and about 1 per cent grains and small pebbles of mudstone. Interbedded dolomites and very minor mudstones. Bryozoans, solitary corals, and small gastropods as clastic grains; conodonts.	10	52
4	Mudstones, slightly dolomitic, light olive-grey, weather olive-grey, recessive, poorly fissile, bedding 2 to 3 inches; with rare pyrite. Barren.	2	42
3	Dolomites, limy, arenaceous, pale yellowish brown with dark particles, weather greyish orange and very pale yellowish brown, recessive, bedding 2 to 6 inches, lenticular; about 40 per cent fine pebbles and sand of dolomite and mudstone, rare quartz sand; matrix microcrystalline to finely crystalline dolomite; calcite-filled vugs; with layers of mudstone within beds. Interbedded mudstones amount to 30 per cent of unit, dolomitic, light olive-grey, weather olive-grey, poorly fissile, recessive. Bryozoans and small gastropods as clastic grains in arenaceous dolomites. Contact with Unit 2 a shallow erosion surface 2 inches deep.	3	40
2	Dolomitic quartz sandstones, very pale orange and off-white, weather greyish orange, bedding 3 to 6 inches; with about 90 per cent subround to round, fine to medium quartz sand, very rare pyrite grains, very rare mudstone grains; cement commonly dolomite, rarely silica. Contact with Unit 1 concordant but irregular.	4	37
	MOUNT WILSON QUARTZITE (33 feet)		
1	Quartzites, white and off-white, weather off-white, and yellowish white, with brown stains, resistant, bedding 3 inches to massive, some beds laminated, rare beds crosslaminated; quartz sand medium to coarse, slightly angular to round. Basal 5 feet less resistant, weathers light brown.	33	33

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
	GLENOGLE SHALES		
	Shales, dark grey, weather dark grey and greyish black, recessive; with about 60 per cent paper shales, greyish black, weather greyish black, very recessive. Graptolites (GSC loc. 47396 from uppermost 30 feet of formation).		

E Mount Tegart Section

The Tegart Formation is well exposed on the northeast face and the southwest dip-slope (Pls. XVI and XVII) of Mount Tegart (50°27′N, 115°51′W). Dips are 10 to 30 degrees in the southwest limb of an anticlinal structure. Units 1 to 4 were measured on the northeast side of the crest of the mountain and Unit 5 at the summit and in a steep gully in the south part of the dip-slope. Measurement of the upper part of the formation is difficult and the thickness of Unit 5 may be inaccurate. Mount Tegart provides the thickest known development of the Tegart Formation and is the type section. The Tegart is overlain by a tongue of the Cedared Formation (Unit 6), which is itself overlain by breccias of the Burnais Formation. The lower part of the section has been previously studied by Walker (1926, p. 33).

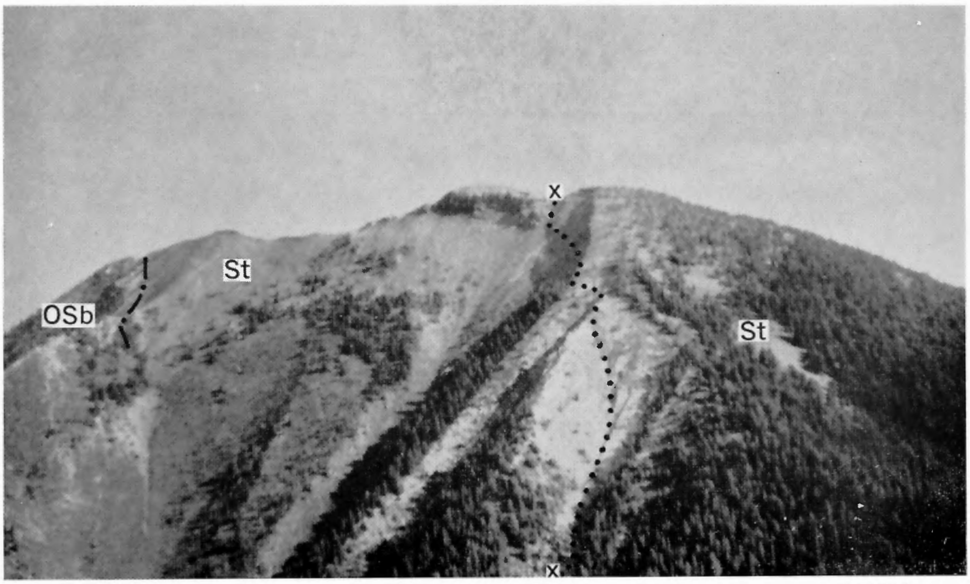

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PLATE XVI. Mount Tegart section, view from southwest. Osb, Beaverfoot; St, Tegart; x....x, line of section, which climbs northeast face of Mount Tegart from just below top of Beaverfoot Formation, and descends from crest of mountain into steep gully in central part of photograph. Contact with Cedared Formation exposed within lower part of gully, which is not visible in this photograph.

113398 C

PLATE XVII. Mount Tegart section, lower beds of Unit 5 of type section of Tegart Formation, view from west.

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
	CEDARED FORMATION (25 feet)		
6	Dolomites, microcrystalline to aphanitic, dark brownish grey, olive-grey, and light brownish grey, weather pale orange and yellowish grey, some beds poorly laminated, slightly recessive, bedding ½ foot to 2 feet; with common calcite stringers and veins; acid residues of light clay-size material and clastic quartz silt and very fine sand. Barren. Contact with Unit 5 concordant, undulatory, but without distinct evidence of erosion.	25	268
	TEGART FORMATION (243 feet)		
5	Limestones, most are argillaceous, aphanitic to microcrystalline, some beds with sparse dark pellets; dark grey and dark brownish grey, weather dull grey and light olive-grey, some beds mottled, recessive, bedding ½ inch to 3 inches; with calcite stringers and sparse vugs; acid residues of clay-size material, clastic quartz silt, and rare pyrite. Interbedded very limy shales amount to less than 5 per cent of unit, brownish grey, weather yellowish brown, light olive-grey, and very pale yellowish brown, poorly fissile. Upper 33 feet slightly more resistant than rest of Unit 5. Summit of Mount Tegart at 134′. Trilobites, brachiopods, echinoderm fragments, and straight cephalopods (GSC locs. C468, 173′; C467, 163′; C466, 144′; 64558, 118–132′).	135	243

Unit No.		Thickness in feet: Unit	Total from base
4	Limestones, argillaceous, aphanitic to very finely crystalline, dark grey, weather grey, rubbly, less recessive than Units 3 and 5, bedding 1 inch to 18 inches. Trilobites and echinoderm fragments.	6	108
3	Limestones, argillaceous, aphanitic with some silt-size grains, dark grey, weather dull grey, dull brownish grey, and bluish grey, recessive, bedding 1 inch to 6 inches; acid residues of abundant light brown clay-size material and common quartz silt. Interbedded very limy shales amount to 15 to 30 per cent of rocks, olive-grey, weather light olive-grey, yellowish brown, and light brown, with pink stains locally, poorly fissile. More resistant limestones at 98–100′. Trilobites, brachiopods, straight cephalopods, tabulate corals, and graptolites, the last mostly in shales (GSC locs. 52181, 83–102′; C473, 86–87′; 64559, 78–85′; C472, 78½–78¾′; C471, 68–68¼′; 7918, about 53–98′; 7919, 53′; C470, 40½–41′) Contact gradational with Unit 2.	67	102
2	Shales, very limy, dark grey and dark brownish grey, weather brownish grey and greyish brown, very recessive, poorly fissile; with 10 to 40 per cent interbedded argillaceous limestones, aphanitic with some silt-size grains, dark grey, weather grey and bluish grey, bedding 1 inch to 12 inches; both rocks give acid residues of abundant dark brown clay-size material and common fine quartz silt. Unit poorly exposed. Graptolites (GSC locs. 52180, 34–35′; 7920, 33′; 7921, 25′; 52179, 23½–24′; 7922, 15′).	28	35
1	Covered interval with outcrop at 2–3′ and 5–6′ of very limy shales, dark brownish grey, weather dark yellowish brown, very recessive, poorly fissile; with interbedded dark grey argillaceous limestones, microcrystalline to aphanitic; both rocks give acid residues of abundant dark brown clay-sized material and common fine quartz silt. Graptolites (GSC loc. 52178, 2–3′). Contact with subjacent rocks conformable.	7	7
	Beaverfoot Formation (uppermost 50 feet studied)		
	Limestones, somewhat argillaceous, with biogenic debris, microcrystalline to aphanitic, dark grey, weather light grey, slightly recessive, platy, bedding ¼ inch to 3 inches; acid residues of abundant brown clay-size material and sparse silt-size pyrite(?). Trilobites and brachiopods (GSC loc. 52177, 1–3′ below zero).	5	
	Limestones, aphanitic, light grey and grey, weather light grey and yellowish grey, resistant, bedding 1 inch to 24 inches. Most beds with shell fragments, straight cephalopods common at 28–39′ below zero.		

F Mount Sinclair Section

A tight syncline trends northwest through Mount Sinclair and is faulted in its axial region. The main mass of the mountain is composed of steeply dipping rocks of the Beaverfoot Formation. The section was measured in the west limb of the syncline, on the upper southwest slope of the mountain and on its west ridge (Pl. XVIII, the Wonah Ridge of Walcott). Dips are about 50 degrees to the northeast. Exposure is good, but faults are common in the section and the upper beds of the Beaverfoot Formation are faulted out. The section includes the type sections of the Wonah Quartzite and the Brisco Formation (Walcott, 1924, pp. 9–15, 32, 47, 49–50). The horizon picked by Walcott as his Beaverfoot–Brisco contact is probably the one between Units 21 and 22.

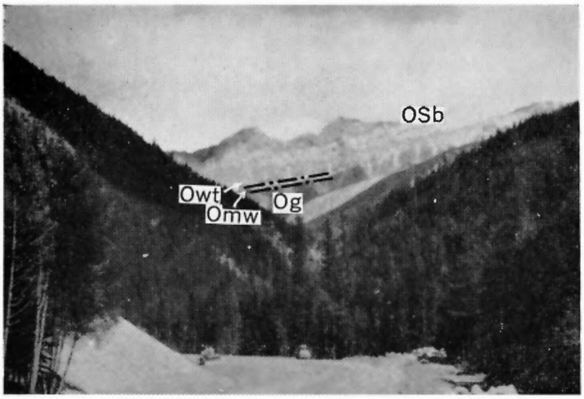

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PLATE XVIII

Mount Sinclair section, view from west. Og, Glenogle; Omw, Mount Wilson; Owt, Whiskey Trail Member; OSb, Beaverfoot. Line of section climbs front of ridge at its left end, here hidden by the shoulder of a low ridge, next follows crest of the ridge, then descends back of ridge into faulted outcrops of the Beaverfoot Formation. Peak of Mount Sinclair is at extreme right of ridge.

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
	Beaverfoot Formation (minimum thickness 1,298 feet)		
28	Dolomites, very finely crystalline to microcrystalline, brownish grey and grey, weather pale yellowish brown and yellowish grey, bedding 2 to 24 inches; without chert nodules; acid residues of brown clay-size material and clastic quartz silt. Sparse vuggy porosity at 1,413′. Rare solitary corals in lowest beds. Top of unit a strong fault beyond which similar rocks continue, but may belong to opposing limb of syncline. Additional beds of Unit 28 may be laterally preserved beneath the fault.	66	1,429
27	Dolomites, microcrystalline to finely crystalline, brownish grey, dark brownish grey, dark grey, and grey, weather pale yellowish brown, very pale yellowish brown, dull yellowish brown, and greyish	229	1,363

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
27 (cont.)	orange, resistant, bedding ½ foot to 6 feet; most beds with very light grey irregular chert nodules that weather off-white, amounting to 5 per cent of some beds; a few beds with irregular layers of silicification; acid residues of sparse clay-size material and common clastic quartz silt, latter amounting to 10 per cent of some beds. Brachiopods, solitary and tabulate corals, echinoderm fragments, gastropods, straight cephalopods, bryozoans, trilobites, and clams (GSC locs. 65726, 1,293–1303′; 45541, 1,277–1,279′; 65725, 1,253–1,273′; 65724, 1,213–1,233′; 45539, 1,138–1,168′).		
26	Dolomites, with 1 to 3 per cent visible biogenic debris, very finely to finely crystalline, dark brownish grey, weather dull brownish grey, pale yellowish brown, and dull yellowish brown, resistant, bedding 2 to 8 feet; with dolomite stringers and vugs; with rare stylolites; acid residues of brown clay-size material, quartz silt, and rare magnetite(?). At 1,131–1,134′, dolomite bed, slightly argillaceous, weathers dark yellowish brown. At 1,098–1,131′, patches of medium to coarsely crystalline mosaics and vuggy porosity. Echinoderm fragments.	66	1,134
25	Covered interval.	10	1,068
24	Dolomites, finely to very finely crystalline, dark grey and dark brownish grey, weather pale yellowish brown and dull yellowish brown, resistant, bedding 1 foot to 5 feet; with dolomite and calcite stringers and rare vugs; acid residues of sparse clay-size material and abundant quartz silt, certainly clastic in some beds, in some beds rare magnetite(?). Debris of echinoderms and other fossils.	40	1,058
23	Dolomites, biogenic debris a significant constituent in many beds, finely crystalline to microcrystalline, dark brownish grey and dark grey, weather yellowish brown, brownish olive-grey, dark yellowish brown, and pale yellowish brown, bedding 2 inches to 6 feet, some beds weather rubbly; with fine dolomite stringers and vugs in many beds; very rare stylolites; acid residues of sparse clay-size material and sparse quartz silt, rare magnetite(?) and pyrite(?) in a few beds. Sparse drusy cavity porosity at 863–873′. Irregular mottled layering at 833′. Abundant clastic quartz silt at 803′. Fault at 880′. Echinoderm debris common, rare brachiopods, solitary and colonial corals, gastropods, and stromatoporoids (GSC loc. 45543, 928′).	259	1,018
22	Dolomites, slightly argillaceous, finely to medium crystalline, brownish black and dark brownish grey, weather dark brownish grey, recessive, bedding thin and nodular; with abundant dolomite and calcite veins and stringers; acid residues of common dark brown clay-size material, sparse pyrite(?), and sparse quartz silt. Barren.	5	759
21	Dolomites, microcrystalline to aphanitic, brownish grey, dark brownish grey, and light brownish grey, weather light grey, light brownish grey and pale yellowish brown, bedding ½ foot to 3 feet; with dolomite and calcite stringers; rare beds with stylolites; acid	116	754

Unit No.		Thickness in feet: Unit	Total from base
21 (cont.)	residues of sparse light clay-size material, fine magnetite(?), and in some beds sparse quartz silt. Sparse vuggy porosity at 753′. At 683′, dolomite with common rounded clastic quartz silt. Barren.		
20	Dolomites, microcrystalline, dark grey, grey, and brownish grey, weather light olive-grey, light grey, very pale yellowish brown, and light brownish olive-grey, slightly recessive, bedding 1 foot to 20 feet; with common to abundant fine dolomite stringers, veins and vugs; acid residues of light clay-size material and in some beds fine quartz silt and rare magnetite(?). Barren.	60	638
19	Dolomites, microcrystalline, brownish grey, weather pale greyish orange and yellowish grey, bedding 8 to 14 inches, finely laminated; acid residues of light clay-size material and very fine quartz silt that amounts to about 10 per cent of rock. Barren.	13	578
18	Dolomites, microcrystalline, dark grey and dark brownish grey, weather very pale yellowish brown and light olive-grey; with dolomite stringers; with about 5 per cent irregular off-white chert nodules, weather brownish white; acid residues of sparse clay-size material and rare pyrite(?). Barren.	20	565
17	Dolomites, very finely to finely crystalline, dark grey and dark brownish grey, weather dark yellowish brown, bedding 1½ to 4 feet; with dolomite stringers and vugs; acid residues of sparse brown clay-size material and very rare fine authigenic quartz silt. Rare solitary corals.	17	545
16	Covered interval, possibly concealing faulting.	15	528
15	Dolomites, microcrystalline to very finely crystalline, dark grey and dark brownish grey, weather yellowish brown and pale yellowish brown, bedding 2 to 16 feet; with dolomite stringers and vugs; with irregular silicification in some beds; acid residues of sparse light clay-size material and quartz silt, with rare pyrite(?) in some beds. Rare tabulate corals.	45	513
14	Dolomites, microcrystalline, grey and dark grey, weather light olive-grey, pale yellowish brown, light grey, and light brownish olive-grey, bedding 5 to 8 feet; with dolomite stringers and vugs; acid residues of light clay-size material, rare authigenic quartz, and at 423′, sparse fine clastic quartz silt, and at 438–468′, common magnetite(?). Rare solitary corals.	70	468
13	Dolomites, very finely crystalline to microcrystalline, dark grey, weather pale yellowish brown and light brownish olive-grey, bedding 4 to 8 feet; some beds with sparse fine dolomite vugs; acid residues of clay-size material; quartz silt, and at 383′, very rare rounded quartz sand. Ghost gastropods and corals at 393′.	32	398

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
12	Dolomitic quartz sandstones, brownish grey, weather greyish orange, bedding 1 foot to 2 feet, finely laminated and crosslaminated, very fine rounded quartz sand, very finely crystalline dolomite cement amounts to about 70 per cent of most laminae, but many laminae have siliceous cement. Barren.	3	366
11	Dolomites, microcrystalline to very finely crystalline, dark brownish grey, dark grey, and grey, weather yellowish brown, pale yellowish brown, pale orange, and very light grey, bedding ½ foot to 6 feet; with dolomite stringers and vugs in some beds; with impure chert nodules at 358′ and 303′; acid residues of light clay-size material and rare quartz silt, quartz silt common at 343′ and amounts to 10 per cent of rock at 358′. At 353′, argillaceous dolomite with about 15 per cent biogenic debris. At 273′, ghosts of coarse sand and fine pebbles of dolomite, siliceous dolomite, and argillaceous dolomite, including rocks very similar to that at 263′; with coarsely crystalline dolomite vugs and stringers, with 1 per cent vuggy porosity. Small faults at 295′ and 293′. Covered interval at 295–301′. Brachiopods, solitary and colonial corals, gastropods, and echinoderm fragments (GSC loc. 45612, 333–343′).	95	363
10	Dolomites, very finely to finely crystalline, dark brownish grey and dark grey, weather pale yellowish brown, greyish orange, light grey, light brownish grey, and very pale orange, bedding ½ foot to 6 feet; many beds with dolomite stringers and vugs; acid residues of light clay-size material, and in some beds rare clastic quartz silt and very fine to fine quartz sand. At 263′, bed with 20 per cent very fine rounded quartz sand. Brachiopods, solitary and colonial corals, and echinoderm debris (GSC loc. 45542, 228–233′).	74	268
9	Quartzites, subround to subangular, very fine quartz sand, rare very fine dolomite rhombs, and 20 per cent rounded fine to medium quartz sand; light grey, weather off-white and light grey, bedding 3 to 6 inches. Barren.	1	194
8	Dolomites, very finely crystalline to microcrystalline, dark grey and dark brownish grey, weather dark yellowish brown, pale yellowish brown, and light grey, bedding ½ foot to 4 feet; dolomite and quartz stringers in most beds; some beds with biogenic debris; acid residues of light clay-size material. At 179–181′, basal 2 feet of a dolomite bed is dolomite breccia. Brachiopods, solitary and tabulate corals, echinoderm fragments, and bryozoans (GSC loc. 45548, 163–173′).	30	193
	WHISKEY TRAIL MEMBER (32 feet)		
7	Dolomites, very finely to coarsely crystalline, with ghosts of coarse sand and 5 per cent rounded quartz sand.	2	163

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
6	Mudstones, slightly limy and dolomitic, olive-grey, weather yellowish brown and brownish grey, very recessive; with rare fine quartz silt. Covered interval at 143–155′. Barren.	18	161
5	Dolomites, arenaceous, finely to very finely crystalline with medium and coarsely crystalline patches, with ghosts of coarse sand and fine pebbles, sparse quartz silt, and rare rounded quartz sand; grey, weather greyish orange, bedding ½ foot to 2 feet; with laminae and pockets of mudstone. Barren.	5	143
4	Mudstones, dolomitic, light olive-grey, weather yellowish brown and brownish grey, very poorly fissile, recessive; with minor thin beds of dolomitic quartz sandstone. Barren.	4	138
3	Dolomitic quartz sandstones, well-rounded fine to medium quartz sand, about 10 per cent dolomite cement, some patches and laminae with siliceous cement; yellowish brown, weather yellowish brown, bedding 3 to 12 inches with very rare sand grains of mudstone; with rare dolomite vugs. Very rare small gastropods as clastic grains.	3	134
	MOUNT WILSON QUARTZITE (131 feet)		
2	Quartzite, fine to coarse, round to subround quartz sand, siliceous cement with less than 1 per cent very fine dolomite rhombs; very pale yellowish brown, weathers off-white and brownish grey, resistant, bedding 4 feet; with very rare amethyst grains; with very rare sand grains of mudstone. Very rare small gastropods as clastic grains.	4	131
1	Quartzites, fine to coarse, round to subround quartz sand, off-white, very pale orange, pinkish white, and light brownish grey, weather off-white, light grey, greyish pink, and pale orange, resistant, bedding 2 to 10 feet, some beds laminated; most beds with rare amethyst grains. At 98′, sparse layers with very minor intergranular dark mud. Barren. Contact with subjacent rocks concordant, covered.	127	127
	GLENOGLE SHALES		
	Quartz siltstones, some with dolomite cement, some with siliceous cement; light olive-grey, dark brownish grey, grey, and pale yellowish brown, weather dark yellowish brown, greyish brown, and greyish red, bedding ½ inch to 2 inches, most beds with streaky laminae; insoluble residues of quartz silt and sparse light brown clay-size material. Top 4 feet covered, only uppermost 17 feet studied. Barren.		

G Carbonate Creek Section

Before the establishment of modern communications, the Whiskey Trail was used as a route over the crest of the Beaverfoot Range from McMurdo on the Columbia River to Leanchoil on the Kicking Horse River. On the southwest side of the range the trail follows the north branch of Carbonate Creek, but is now thoroughly overgrown for most of its length. The lower part of the Beaverfoot Formation outcrops in the core of a syncline on a southwest-trending ridge at 51°10½′N, 116°44′W, immediately northwest of the upper reaches of the creek. The southeast side of this ridge (Pl. XIX) is doubtless the section studied by Burling (1922, pp. 452–454).

The section lies in the overturned northeast limb of a tight syncline within which faulting is developed, both in the axial region of the fold and within the outcrop of the Mount Wilson Quartzite. Dips are about 145 degrees. The top of the section is picked at the stratigraphically highest trustworthy outcrop in the northeast limb. This section is the type section of the Beaverfoot Formation, which, as proposed by Burling, included quartzites now assigned to the Mount Wilson Quartzite. The section includes the type section of the Whiskey Trail Member of the formation. Burling gave a thickness of about 924 feet for the carbonate rocks; the present measurement is 945 feet.

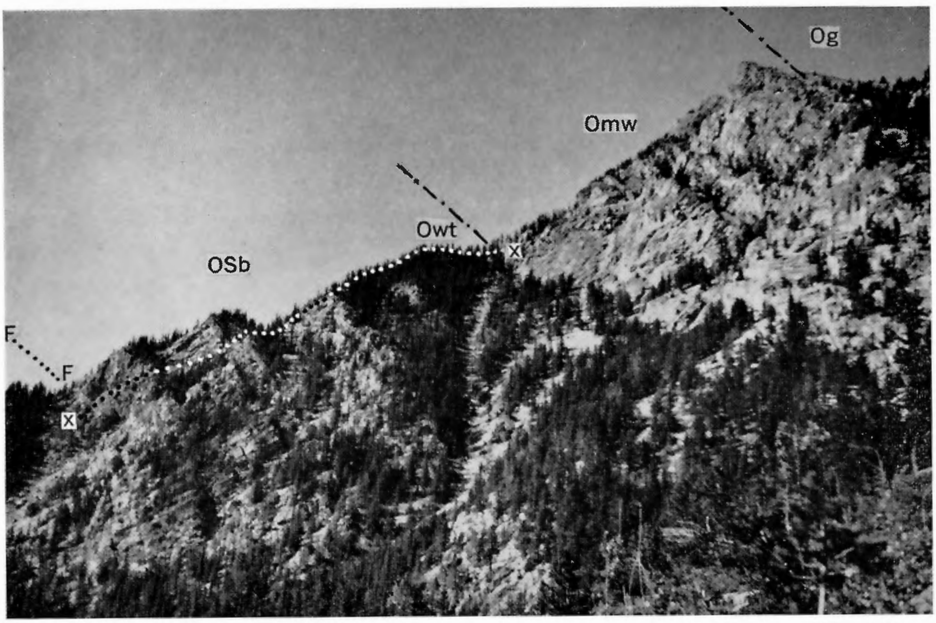

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PLATE XIX. Carbonate Creek section, view from southeast of overturned northeast limb of syncline. Og, Glenogle; Omw, Mount Wilson; Owt, Whiskey Trail Member; OSb, Beaverfoot; x....x, line of section; F....F, fault.

Unit No.		Thickness in feet Unit	Total from base
	BEAVERFOOT FORMATION (945 feet minimum)		
17	Dolomites, slightly limy, very finely crystalline, grey, weather light grey, light brownish grey, and dull olive-grey, some beds mottled, bedding 1 inch to 24 inches, most beds weather platy and slightly recessive; with minor dolomite and silica-filled stringers and small vugs; acid residues of subround clastic quartz silt and minor clay-sized material. At 937–938′, rare irregular chert nodules weather very light grey. Dolomitized gastropods.	26	945
16	Dolomites, most beds slightly limy, microcrystalline to finely crystalline, dark grey and grey, weather light grey, light brownish grey, and dull olive-grey, some beds mottled, resistant, bedding 2 feet to massive; with minor dolomite and silica-filled stringers, small vugs, and small drusy cavities; with rare chert nodules at some horizons; with sparse layers of irregular silicification in lower beds; acid residues of clastic quartz silt and minor clay-sized material in most beds, and also rare authigenic quartz. Colonial and solitary corals, mostly worn, fragments of echinoderms and brachiopods (GSC loc. 64557, 831–843′).	182	919
15	Dolomites, slightly limy, microcrystalline, light grey and light olive-grey, weather light brownish grey, slightly recessive, bedding 2 to 36 inches; with 5 to 10 per cent content of dark grey chert as elongate nodules and discontinuous layers, weathers yellowish olive-brown; acid residues of sparse dark clay-sized material. Rare gastropods.	22	737
14	Dolomites, slightly limy, very finely to finely crystalline, grey, weather dull light grey, grey, and brownish light grey, resistant, bedding 1 foot to massive; with rare dolomite-filled stringers and small vugs; acid residues of sparse authigenic quartz, and in some beds clastic quartz as silt and very fine sand and light clay-sized material. At 685′ and 680–683′, chert nodules. At 656–661′, 35 per cent content coarsely crystalline dolomite in lenticular layers paralleling bedding. At 599–617′, beds platy when well weathered. Colonial and solitary corals.	125	715
13	Dolomites, limy, aphanitic to microcrystalline, grey and dark grey, weather light grey, very light grey, and yellowish grey, most beds laminated, with microcrystalline and aphanitic laminae, bedding 2 to 18 inches; with rare thin dolomite stringers; acid residues of light clay-sized material and, in some beds, clastic quartz silt and well-rounded very fine quartz sand. Barren.	68	590
12	Covered interval	19	522
11	Dolomites, slightly limy, microcrystalline, dark grey, grey, and light grey, weather light grey, bedding 2 inches to 6 feet; with thin dolomite stringers; acid residues of replacements of authigenic feldspar(?), light clay-sized material, and in some beds, fine quartz silt. Barren.	70	503

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
10	Dolomites, limy, aphanitic to microcrystalline, grey and light grey weather light grey and very light grey, bedding 3 to 10 feet; acid residues of light clay-sized material and rare authigenic quartz. Rare brachiopods.	22	433
9	Dolomites, microcrystalline to very finely crystalline, dark grey and grey, some beds mottled, weather light grey and very light grey, bedding 1 foot to 6 feet; with sparse chert nodules; weather greyish brown; with rare thin dolomite stringers; acid residues of rounded quartz silt, rare replacements of authigenic feldspar(?), and light clay-sized material. At 347–351′, slightly recessive dolomites, weather platy and brownish grey. Barren.	82	411
8	Dolomites, slightly limy, microcrystalline, dark grey and brownish grey, weather light brownish grey, bedding 1 foot to 2 feet; with about 15 per cent content irregular chert nodules and layers, weather creamy brownish grey; acid residues of sparse rounded quartz silt and light clay-sized material. Barren.	7	329
7	Dolomites, very finely to finely crystalline, dark grey, weather dull dark grey and dark brownish grey, slightly recessive, bedding 1 foot to 5 feet indistinct and rubbly; with dolomite stringers common and sparse small vugs, mostly dolomite-filled; with sparse chert nodules; acid residues of dark brown clay-sized material and very rare authigenic quartz. Rare solitary and colonial corals.	43	322
6	Dolomites, slightly limy, microcrystalline but with ghosts of small pebbles in some beds, dark grey and grey, weather dull light grey, grey, and light yellowish brown-grey, some beds mottled, bedding 1 foot to 4 feet; with thin dolomite stringers; acid residues of dark brown clay-sized material, pyrite(?) crystals, sparse clastic quartz silt, and light clay-sized material. Colonial and solitary corals, echinoderm debris.	78	279
5	Dolomites, microcrystalline with rare fine crystals, dark grey, weather dull light grey, rubbly and recessive, bedding 3 to 24 inches; with thin dolomite stringers; acid residues of fine quartz silt and brown clay-sized material. At 155–169′ less recessive dolomites. Covered interval at 186–201′. Barren.	46	201
4	Dolomites, limy, microcrystalline, some beds with rare fine and medium crystals, grey, brownish grey, and olive-grey, weather light brownish grey and light yellowish brown-grey, relatively resistant, bedding $\frac{1}{2}$ foot to 3 feet; with well-rounded chert nodules in many beds, weather light brown, some banana-shaped, amounting to 5 per cent of rock at 97–105′; with thin dolomite stringers; acid residues of light clay-sized material and, in some beds, rounded quartz silt and very fine to medium sand. At 145′, dark grey coarse irregular patches of microcrystalline dolomite separated by light grey, very finely crystalline dolomite matrix. Quartz	62	155

Unit No.		Thickness in feet: Unit	Thickness in feet: Total from base
4 (cont.)	sand common in basal 3 inches of dolomite bed at base of unit. Solitary and colonial corals, stromatoporoids, echinoderm debris (GSC locs. 5062, 139′; 5063 and 5612, 129′).		
	WHISKEY TRAIL MEMBER (93 feet)		
3	Dolomites, argillaceous, slightly limy, aphanitic to microcrystalline, dark grey and olive-grey, weather yellowish grey, platy, and recessive, bedding $\frac{1}{4}$ to 1 inch; acid residues of abundant dark brown clay-sized material and pyrite crystals. Interbedded dolomites amount to about 20 per cent of unit, slightly limy, very finely to finely crystalline with ghosts of coarse crystals, light grey and light brownish grey, weather pale greyish orange and light grey, bedding 1 inch to 12 inches; acid residues of abundant rounded quartz sand and light clay-sized material. Covered intervals at 89–93′, 67–75′, 51–58′, and 39–45′, probably underlain by argillaceous dolomites. Solitary and colonial corals, articulate and inarticulate brachiopods, clams, gastropods, bryozoans, echinoderm fragments, conodonts, and diplograptid graptolites (GSC locs. 5064, 82–83′; 5066, 65′; 5065, 48–68′).	54	93
2	Dolomites, slightly limy, finely to coarsely crystalline, grey, weather pale yellowish brown and pale greyish orange, bedding 2 to 12 inches; with dolomite stringers and dolomite and quartz-filled vugs; acid residues of rounded quartz silt and sand, light clay-sized material, rare authigenic quartz. At 12–14′, mudstone. Barren.	29	39
1	Mudstones, slightly limy, dark olive-grey, weather olive-grey and yellowish brown, recessive, poorly fissile when well weathered; with very minor content of fine quartz silt. Covered interval at 0–2′, contact with Mount Wilson Quartzite concordant, taken as highest quartzite outcrop. Unit barren.	10	10
	MOUNT WILSON QUARTZITE		
	Quartzites, finely to coarsely crystalline, subround sand grains, off-white, weather off-white with abundant lichen stains, very resistant, bedding 6 to 12 inches in uppermost 7 feet, massive below. Barren. Only uppermost beds examined.		

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