GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 67-65

TRIASSIC STRATIGRAPHY BETWEEN THE ATHABASCA AND SMOKY RIVERS OF ALBERTA

(Report, 8 plates and 10 figures)

D. W. Gibson

rice, $2.00

1968

CANADA

GEOLOGICAL SURVEY
OF CANADA

PAPER 67-65

TRIASSIC STRATIGRAPHY BETWEEN THE ATHABASCA AND SMOKY RIVERS OF ALBERTA

D. W. Gibson

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Available by mail from the Queen's Printer, Ottawa,

from Geological Survey of Canada,
601 Booth St., Ottawa,

and at the following Canadian Government bookshops:

HALIFAX
1735 Barrington Street

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

OTTAWA
Daly Building, Corner Mackenzie and Rideau

TORONTO
221 Yonge Street

WINNIPEG
Mall Center Bldg., 499 Portage Avenue

VANCOUVER
657 Granville Street

or through your bookseller

Price $2.00 Catalogue No. M44-67-65

Price subject to change without notice

ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1968

CONTENTS

Illustrations

ABSTRACT

The Triassic Spray River Group, between Athabasca and Smoky Rivers of Alberta, comprises two main and contrasting lithofacies; the Sulphur Mountain and Whitehorse Formations. The former, defined near Banff, contains dark grey, brown to rusty-brown weathering, siltstones, silty dolomites, shales, and fine-grained sandstones; the latter, named after Whitehorse Creek near Cadomin, consists of a light grey- to buff-weathering assemblage of limestones, sandy limestones, dolostones, and intraformational breccias. The type section of the Sulphur Mountain Formation is re-defined to include some additional younger beds.

The Sulphur Mountain Formation can be subdivided into four new members which, in ascending order, are: the Phroso Siltstone Member, the Vega Siltstone Member, the Whistler Member, and the Llama Member. The formation and members have been correlated throughout the area, and have homotaxial affinities with the Sulphur Mountain Formation at Banff and the Daiber Group of northeastern British Columbia. The formation varies in thickness from 200 feet near Athabasca River to 1,000 feet northwestward in the vicinity of Smoky River.

The Whitehorse Formation, which forms the upper part of the Triassic sequence, has been divided into three distinct lithologic members for which the names, Starlight Evaporite Member, Brewster Limestone Member, and Winnifred Member, are proposed. The section at Dinosaur Pass is designated as a reference section to supplement the original type section where the Brewster Limestone Member is not exposed. The formation is characterized by rapid lithofacies changes and thickens in a northwesterly direction.

The presence of Claraia stachei Bittner and Euflemingites sp. suggests an Early Triassic age for the Phroso and Vega Siltstone Members, while the occurrence of Gymnotoceras helle McLearn, Daonella cf. dubia Gabb and Spiriferina cf. stracheyi Salter, suggests a Middle Triassic Anisian age for the Whistler Member. Mysidioptera poyana McLearn suggests an Upper Triassic Karnian age for the Brewster Limestone Member.

Detailed insoluble residue and mineralogical analyses of the Sulphur Mountain Formation indicate an increase in carbonate concentration to the northwest. A notable increase in maximal grain size above the Whistler Member coincides with the beginning of a pronounced marine regression. Analysis of sedimentary directional structures in the form of micro-cross-laminations, crossbedding, ripple-marks, flute casts, groove casts, and bounce casts, is consistent with the east to northeast sediment source area indicated by the mineralogical composition of the sediments.

Sediments of the Sulphur Mountain Formation were deposited during minor marine transgressions and regressions in a deltaic-type of environment analogous in some ways to those off the mouths of the present Mississippi and Niger Rivers. In contrast, sediments of the Whitehorse Formation were probably deposited in a more restricted, shallow-water, marine environment comparable in some ways to the Texas Gulf Coast area of the United States. The occurrence of gypsum, collapse breccias, and red beds indicate that deposition took place at times in a highly saline, shallow-water, evaporitic environment.

TRIASSIC STRATIGRAPHY BETWEEN THE ATHABASCA AND SMOKY RIVERS OF ALBERTA

INTRODUCTION

GENERAL STATEMENT

The Triassic stratigraphic succession of the northern Jasper Park region of Alberta, summarized in Figure 2, crops out in northwesterly trending valleys and mountain ridges that occur in two broad physiographic units, the Alberta Foothills belt, and the Front Ranges of the Rocky Mountains (Figs. 1 and 3). These rocks, although recognized as an interesting and variable sequence of strata, marked generally by rapid facies variations in relatively short lateral and vertical directions, have not previously been studied in detail. The succession is thick and the lithologies are in part repetitious, so that recognition of stratigraphic units is difficult despite the excellent exposure of many of the sections measured. Discrimination of stratigraphic boundaries between rock units is generally subtle and, in consequence, close section spacing is necessary for accurate correlation. To meet this need, 50 stratigraphic sections were sampled in detail at 10 foot intervals, and analyses of insoluble residue, maximum grain size, and qualitative and semi-quantitative mineralogical composition were undertaken. Stratigraphic cross-sections summarize some of these data (Figs. 9A and 9B).

PREVIOUS GEOLOGICAL WORK

The Triassic rocks of the Jasper region were first studied by Paréjas and Collet (1931). Allan (1933) described a gypsum occurrence at Mowitch Creek, which was revisited and examined in more detail by Govet (1961). Warren (1945), in a study of the Triassic Faunas of the Canadian Rockies, indicated the occurrence of gypsum and other evaporites at the base of Mt. Cinquefoil. In the course of regional field mapping, Lang (1947), Irish (1951, 1954, 1955, and 1965), and Mountjoy (1960, 1962), have described, summarized, and attempted to correlate the Triassic of the Jasper region with other areas of Alberta. Descriptions of Triassic rocks in these reports are very brief and general, outlining only the main lithological and faunal associations. Recent, more detailed work includes papers by Manko (1960), Colquhoun (1960), Westermann (1962), and Barss, et al. (1964).

Manuscript received Nov. 29, 1967
Author's address: Institute of Sedimentary and Petroleum Geology
Geological Survey of Canada, Calgary, Alberta.

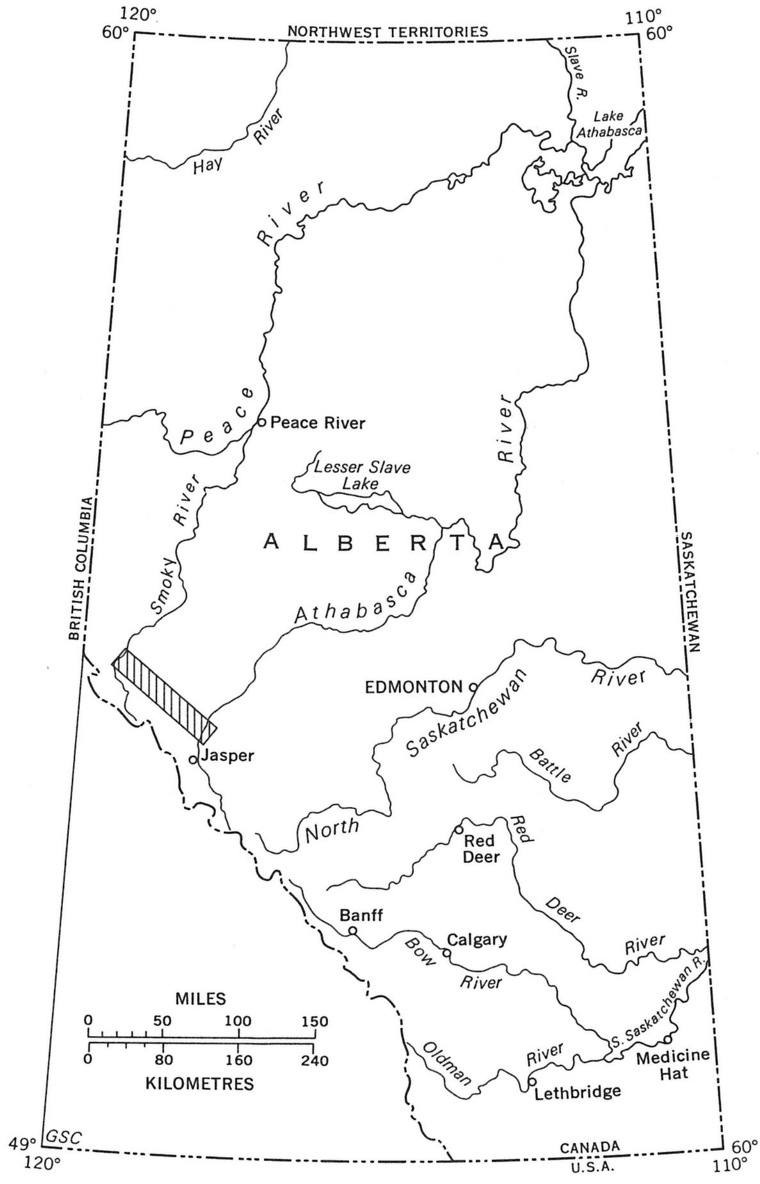

Figure 1. Index map showing location of area.

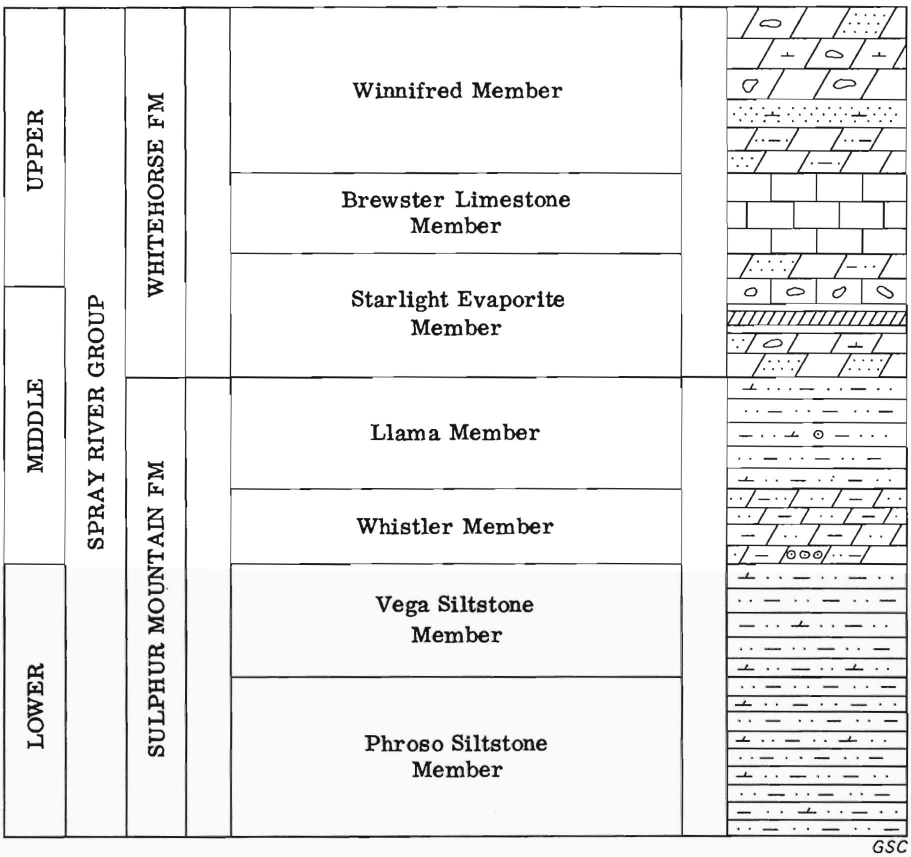

Figure 2. Table showing the Triassic nomenclature proposed in this report

METHODS OF INVESTIGATION

Investigations were concentrated upon the study of 50 stratigraphic sections, measured during the summers of 1962 and 1963. Three of the above sections were examined in the vicinity of Banff for the purpose of correlation with the type section of the Sulphur Mountain Formation and with a view to establishing any homotaxial relations that exist between the two areas. The choice of sections was dictated by their accessibility, amount of rock exposure, structural deformation, and proximity to each other. The Triassic succession, being largely incompetent, has been subjected to severe folding and faulting and, in consequence, complete and suitable stratigraphic sections are difficult to find. Because of this general lack of complete sections, stratigraphic studies were attempted where any recognizable members or formations were present. Because of structural deformation by folding and faulting, some thickness measurements recorded in the more incompetent members of the Sulphur Mountain Formation may not represent true values. Measurements taken at two sections in axial and flank positions of a major anticline (Monoghan anticline, Fig. 3), revealed the axial sections to be 7 per cent thicker than those measured in the flank positions. Close correspondence of field measurements suggests that this difference is real and, consequently, implies that minor and some major thickness variations in the Sulphur Mountain Formation, such as demonstrated in the upper three members in Figures 9A and 9B, may be attributed to tectonic rather than depositional causes. However, the writer considers that most thickness values obtained in the field represent true values, subject to normal field measurement errors resulting from actual and assumed dip variations in outcrop and covered intervals.

Most sections in folded strata are located by necessity in the flank position and most thickness variation is considered to be due to basin infilling and, also, to pre-Triassic topography as demonstrated for the thickness variations shown by the basal Phroso Siltstone Member.

The structural complexity in the region prevented reliable estimates of displacement of the major thrust sheets from being made and, consequently, palinspastic reconstruction was not possible.

All samples, tentatively classified in the field, were subjected to a more refined microscopic classification in the laboratory. Oriented specimens containing directional structures such as crossbedding, flute casts, and groove casts, were taken for further laboratory examination. Gross structures were measured and recorded in the field.

PHYSIOGRAPHY

The Triassic succession crops out along northwesterly trending valleys and mountain ridges in each of the two broad physiographic units, the western Foothills, and the Front Ranges. These divisions are based on, and controlled by, a series of southwesterly dipping thrust sheets which, from west to east, are known as the Chetamon, Colin, Greenock, Rocky Pass, Miette, Perdrix-Boule, and Folding Mountain (Fig. 3).

Elevations in the area range from 3,300 feet in the Foothills, to 8,500 feet in the Blue Creek region of the Front Ranges, with the average elevation for most of the area being approximately 5,000 feet. Maximum relief, about 4,500 feet, occurs near Smoky River where river flats have an average elevation of 3,500 feet and surrounding mountain summits range up to 8,000 feet above sea level. Most sections were located above tree line (6,000 to 6,500 feet) because exposure is better at these altitudes.

The region is drained by two main river systems, the Smoky to the northwest and the Athabasca to the southeast (Fig. 4). For a more detailed and comprehensive discussion of the physiography, the reader is referred to regional reports by Lang (1947), Irish (1951, 1954), and Mountjoy (1960, 1962).

ACKNOWLEDGMENTS

The research for this paper was prepared under the general supervision of F.W. Beales to whom the writer is indebted. Sincere thanks are extended to E.W. Mountjoy of McGill University (formerly of the Geological Survey of Canada) for introducing the writer to the present problem, and assisting with and discussing initial field preparations. G.C. Taylor and D.F. Stott critically reviewed the manuscript; their helpful suggestions and constructive criticisms are very much appreciated. Thanks are accorded E.M. Manko of Imperial Oil Limited for supplying locality information on many of the stratigraphic sections visited. Fossils collected during the course of field work were identified and dated by E.T. Tozer of the Geological Survey of Canada.

STRATIGRAPHY

NOMENCLATURE

Although Triassic strata in Western Canada have been most extensively studied in the Liard and Peace River regions of British Columbia and Alberta, the present investigation is mainly concerned with the Jasper-Banff regions of central Alberta.

Much of Alberta and northeastern British Columbia has been mapped by government and oil company geologists. A recent publication of the Alberta Society of Petroleum Geologists (1964) has assembled and synthesized all available stratigraphic information of Western Canada up to the end of 1962, including the Triassic strata of the Jasper region and other areas mentioned above. The stratigraphic nomenclature of these regions is summarized in part by Figure 5; however, a more detailed terminology of these regions can be found in appropriate reports. Figure 6 is an isopachous map, modified after Barss, et al. 1964, illustrating the total Triassic thickness throughout the Rocky Mountains.

In 1907, Dowling recognized the presence of possible Triassic strata in the Cascade Coal Basin. Warren (1927, 1945), described and designated as the type locality of the Spray River Formation a Triassic section in the Spray River Gorge, southwest of the town of Banff. He recognized two members, the Sulphur Mountain and the Whitehorse, although only assigning a definite type section for the Sulphur Mountain Member. Whitehorse Creek near Cadomin, Alberta, was suggested as a possible type locality of the Whitehorse Member. Best (1958) followed Warren's suggestion and designated this the type locality for the Whitehorse Member.

Triassic strata were first described in the Jasper region by Paréjas and Collet (1931). As previously noted, the Triassic succession was divided into two members, a lower Sulphur Mountain Member, and an upper Whitehorse Member. In the Jasper area these two members were subsequently elevated to formational status (Mountjoy 1960), and have been considered by most geologists to be homotaxial with the Spray River Formation of the Banff area described by Warren (1945).

The stratigraphic nomenclature used in this report is shown in Figures 2 and 7.

SPRAY RIVER GROUP

The Spray River Group, consisting of siltstone, silty shale, dolomite, limestone, and intraformational breccia, is divided into a lower Sulphur Mountain Formation and an upper Whitehorse Formation, with each formation characterized by distinct lithofacies that facilitate subdivision into members. All member contacts are recognizable by lithological variation. Faunal zonation is impracticable except on a very broad scale, owing to the scarcity and poor preservation of fossils.

The Spray River Group, which varies in thickness from 575 feet at Levi Creek, to a maximum of 2,800 feet at Dinosaur Pass, disconformably overlies chert and cherty dolomites of the Rocky Mountain Group throughout most of the region. In the more easterly sections, however, the entire Rocky Mountain Group is missing and the Triassic sequence rests on the underlying cherty dolomites of Formation D of the Rundle Group (Mountjoy, 1962, p. 33). The Spray River Group is overlain disconformably by the Jurassic Fernie Group which progressively truncates the Whitehorse Formation in an easterly and northeasterly direction.

SULPHUR MOUNTAIN FORMATION

Triassic strata in the Jasper region have, in the past, been divided into the Sulphur Mountain ahd Whitehorse Formations. Recently, however, Manko (1960) divided the Sulphur Mountain Formation into four informal lithological divisions as shown in Figure 7. The contact with the overlying Whitehorse Formation was placed at the top of the upper Siltstone member, coincident with that selected and mapped by most geologists working in the Jasper area. Westermann (1962) disagreed with this choice of contact, and instead suggested placement of the contact near or at the base of Manko's Black Shale member. He correctly suggested that the Sulphur Mountain - Whitehorse formational contact as used by Manko and other geologists, was not in agreement with the original definition proposed by Warren (1945). Furthermore, he suggested that the Sulphur Mountain Formation should include only a fauna of Scythian age, although admitting that the Black Shale member and Upper Siltstone member of Manko resemble the strata referred to in Warren's original definition of the Sulphur Mountain Member. The problem of formation definition in the Jasper region arose from the original definition of Warren (1945) for the Banff area. Warren (1945, p. 483) stated, "the division into members is based directly on lithological characteristics but paleontological evidence may be useful". Warren made only a brief statement concerning the lithological characteristics and thickness measurements. The contact controversy arose from the assertion that the Sulphur Mountain Member contains only a fauna of Early Triassic age, though geologists in the Jasper region have long recognized that beds assigned to the Sulphur Mountain Formation contain a fauna of Early and, in part, Middle Triassic age, suggesting the inclusion of younger strata in the Sulphur Mountain Formation. Warren did not indicate precisely the strata from which the Triassic fauna was collected, but the fauna he obtained from the Whitehorse Member included such index fossils as *Nathorstites* cf. *mcconnelli*, *Ceratites* (*Gymnotoceras*) *blakei*, *Daonella dubia*, *Hornesia* cf. *socialis*, and *Lingula selwyni*. This fauna is characteristic, in part, of what is herein termed the Whistler and Llama Members of the Sulphur Mountain Formation.

The writer examined the type section at Spray River Gorge and a section located near the headwaters of Panther River. At both localities thickness measurements in the order of 1,200 feet were obtained for the Sulphur Mountain Member, recorded from the base of the Triassic to the base of the Whistler Member as defined in the Jasper region. The Whistler Member contains only a Middle Triassic fauna. This is in agreement with the placement of the Whitehorse-Sulphur Mountain contact by Westermann, when defined on the basis of paleontological evidence. The confusion and controversy have arisen partly because of colour and lithological descriptions of strata present at the Banff type section. The Whistler and Llama Members of the Sulphur Mountain Formation are dark grey to yellow-brown and, therefore, simulate the colour and lithological attributes of the Sulphur Mountain Member described by Warren. These stratigraphic variations noted by Warren in the type section of the Sulphur Mountain Member at Banff are very distinct in the Jasper region and, therefore, have resulted in placement of the Sulphur Mountain and Whitehorse contact at the prominent lithological change above the Llama Member.

The confusion arising from the uncertainty of the exact placement of the Sulphur Mountain-Whitehorse contact, and the criteria on which this should be based may be overcome by re-defining the type section of the Sulphur Mountain Formation at Banff to include the younger and previously overlooked strata, which are lithologically more characteristic of the Sulphur Mountain Formation than the Whitehorse Formation. Furthermore, by re-defining the Sulphur Mountain Formation at Banff, the formational boundaries, as recognized and mapped by most geologists in the Jasper region, will remain the same and, consequently, serve as a distinct and useful map unit.

The Sulphur Mountain Formation comprises a dark-grey to rusty-brown weathering sequence of siltstones, silty dolomites and silty, carbonaceous shales, ranging in thickness from 490 feet at the headwaters of Levi Creek, to 1,278 feet on Whistler Creek (Fig. 4). The formation is divisible into four members which are, in ascending order: Phroso Siltstone Member, Vega Siltstone Member, Whistler Member, and Llama Member. An excellent reference section of the Sulphur Mountain Formation in the Jasper region containing the above members, is located at the headwaters of Monoghan Creek at Dinosaur Pass (Fig. 4).

Phroso Siltstone Member

The name Phroso Siltstone Member is proposed for a sequence of siltstones exposed in Phroso Creek, a small tributary of Sulphur River. The type section assigned to the member is located on the east and west sides of Phroso Creek, one-half mile upstream from the junction of Sulphur River (Fig. 4). Strata characteristic of the member were first recognized by Irish (1954), in the Kvass Flats area of Smoky River. Manko (1960), during a regional study of Triassic rocks in the Rock Lake area, recognized a similar sequence of strata to which he applied the name Lower Black Siltstone member, although the name was not suggested as a formal designation nor was any type section suggested. In order to comply with the code outlined by the American Commission of Stratigraphic Nomenclature (1961, p. 645), a geographic name is now proposed. The name "siltstone" is retained to emphasize the dominant size grade of the detrital fraction of the member.

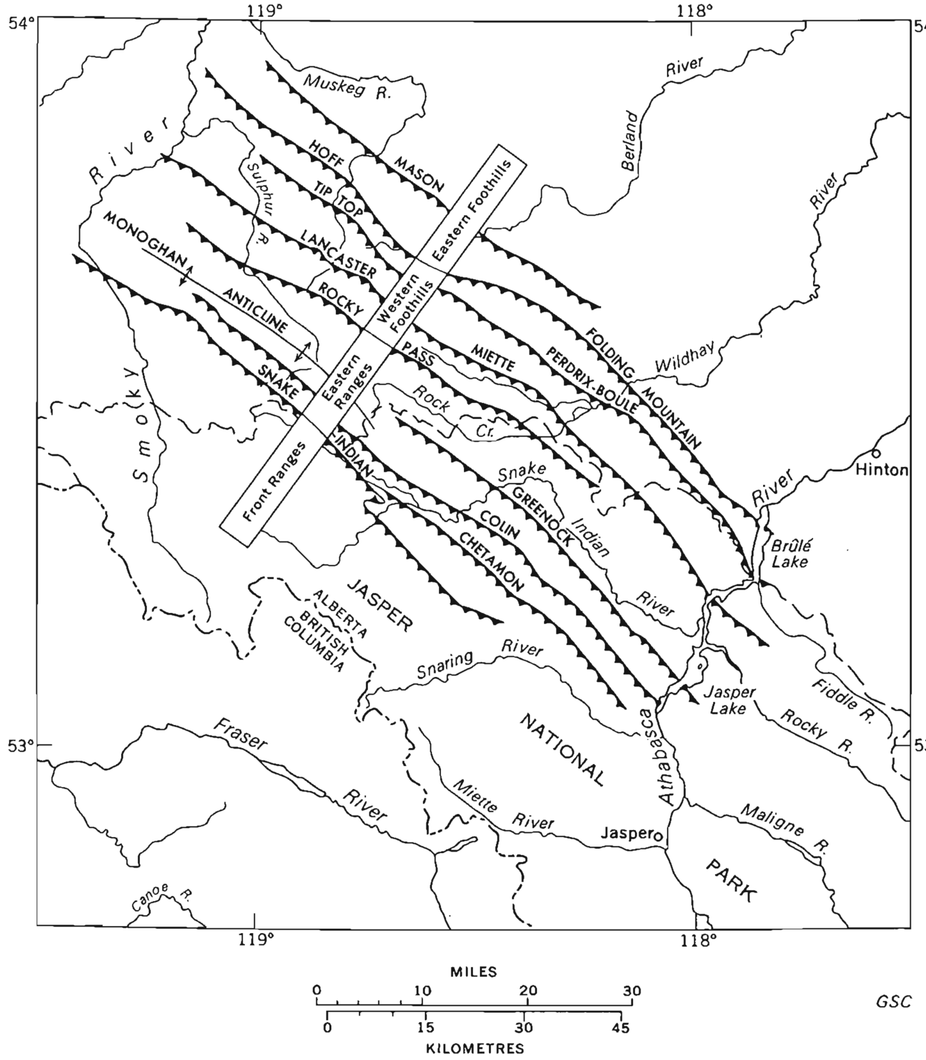

Figure 3. Diagram showing location of major thrust faults and physiographic provinces (after Mountjoy 1962).

The Phroso Siltstone Member comprises a monotonous assemblage of thin-bedded to massive, shaly- to flaggy-weathering, grey-brown to dark grey, carbonaceous, pyritiferous, micromicaceous, siltstones, and silty shales. Several dolomitic siltstone and sandstone beds up to 4 inches thick are intercalated in parts of the unit in the eastern part of the area. The siltstone consists of subangular to angular grains of quartz grading from predominantly silt to very fine-grained sand, fine flakes of mica, and small authigenic micro-aggregates and crystals of pyrite, cemented by finely crystalline, recrystallized dolomite and, locally, calcite. Traces of feldspar, rutile, zircon, tourmaline, and amphibole are distributed throughout the member. The shale includes carbonaceous matter, pyrite, and micaceous minerals, with lesser amounts of quartz and feldspar, and accessory zircon, rutile and tourmaline.

Although the member is markedly uniform, minor textural and mineralogical changes are present. The detrital fraction, consisting mainly of quartz and some feldspar, has been subjected to partial corrosion and secondary silicification, and displays in part a quartzitic texture. Ubiquitous collophane, rarely exceeding 1 per cent by volume, occurs as pellets, subangular grains, and ooliths. Carbonaceous-ferruginous material is one of the most diagnostic mineralogical associations in the member and is generally responsible for the shaly, recessive nature, and distinctive dark coloration of the unit. Unfortunately, the concentration of this material is difficult to estimate owing to the manner in which it is intimately mixed with the carbonate and detrital fractions. Also important and not stressed in previous stratigraphical studies, is the high carbonate concentration, which ranges from 20 to 40 per cent, with an average value of 28 per cent by weight.

Bedding within the member is difficult to recognize. In well-protected or cliff-forming sections the strata consist of massive, laminated, dark grey, carbonaceous siltstones and silty shales. Bedding in some of the more easterly sections may be recognized by the absence of laminated zones, or by different resistances to weathering.

Laminations form one of the most notable features of the member and, along with the carbonaceous matter, are responsible for the platy- to shaly-weathering nature of the unit. Two main types of laminae have been noted and are illustrated by Plates VI and VII A. The first and more common type is horizontal, regular to lenticular, ranges in thickness up to 1/8 inch, and is generally confined to the western, thicker, stratigraphic sections. Laminations of the second type are horizontal to inclined (crossbedded), very lenticular and in part contorted, and commonly restricted to the eastern sections. The laminations are composed of two mineral associations. The first is light grey, and consists of quartz and some feldspar, cemented with finely to medium-crystalline dolomite, and minor amounts of calcite. The second association consists of dark grey to black laminae, composed of quartz and feldspar in a matrix of carbonaceous material, pyrite, mica, and clay minerals; the whole being cemented with finely crystalline dolomite. Laminations having a high organic and micaceous content also appear to contain a small amount of clay, although microscopic identification was not possible owing to the contaminating and masking effect of the opaque carbonaceous and ferruginous matter in the matrix. Lenticular pyrite laminations, up to one-half inch thick, have been noted in some western sections.

The Phroso Siltstone Member can be readily recognized and mapped throughout the Jasper and other regions of Alberta, although minor facies changes occur as noted between the Jasper and Banff areas. Near Banff the member is considerably thicker, and contains a sub-rhythmic development of interbedded, resistant, dolomitic siltstone. This sub-facies has not been observed in the Jasper region.

The Phroso Siltstone Member has a minimum thickness of 150 feet at the head of Levi Creek, and a maximum thickness of 463 feet in the vicinity of Blue Creek. The type section is 386 feet thick. These variations were recorded at the eastern and western extremities of the study area, and indicate a stratigraphic thinning to the northeast (Figs. 9A and 9B). Most of the local thickness variation noted in the member can be attributed to the uneven erosion surface upon which the Triassic sediments were deposited, but the influence of tectonic thickening and thinning should not be discounted.

The contact of the Phroso Siltstone Member with the underlying Rocky Mountain and Rundle Groups is disconformable. Sections east of the Persimmon, Starlight, and De Smet Ranges overlie cherty dolomites of the Rundle Group, whereas, sections west of these ranges overlie brown cherty sandstones of the Rocky Mountain Group. The contact with the overlying Vega Siltstone Member is conformable and distinct, even though, in some eastern sections, it is transitional. The contact is placed beneath the first repeated occurrence of resistant, dolomitic, siltstone beds as illustrated by Plate II A.

Figure 8 illustrates the paucity of fossils collected and identified from the member. A few pelecypods, poorly preserved ammonites, and indeterminate fish skeletal fragments were gathered, mainly from the lower and upper parts of the unit. Claraia stachei (Bittner), the most common fossil, is generally confined to the thicker more resistant, non-laminated, dolomitic siltstone beds. These beds, although rare, have a much lower carbonaceous-ferruginous content than the enclosing laminated, shaly siltstones. This suggests that environmental conditions were more suitable to the growth and preservation of the Claraia specimens. During deposition of the more resistant strata, the pelecypods flourished, but with the return of reducing or euxinic conditions, the fauna died out, or moved to a more favourable environment. On the basis of faunal evidence an Early Triassic Griesbachian age is suggested for the member.

Vega Siltstone Member

The name Vega Siltstone Member is here proposed for a sequence of well-indurated, cyclical, alternations of medium grey, carbonaceous, pyritiferous, dolomitic siltstone to silty dolomite, and shale (Figs. 9A and 9B). Thin-bedded, well-laminated, micromicaceous, carbonaceous, fissile to shaly-weathering, dolomitic siltstones, and silty, quartzose shales, are intercalated throughout the unit, decreasing in frequency from the base upwards. The type section is located near the headwaters of Mowitch Creek, on the south side of Vega Peak (Fig. 4). Strata characteristic of the member were first recognized by Irish (1954) in the Kvass Flats area of Smoky River. In the region north of Athabasca River, Manko (1960) recognized a similar stratigraphic sequence to which he applied the name Blocky Brown Siltstone member. The writer found the base of the member to generally display a blocky appearance, but a more definitive and descriptive term would be "flaggy" (Pettijohn, 1957, p. 159). This term is applicable to the lower and middle parts but does not describe the upper part of the unit which, in the eastern sections, is medium- to thick-bedded. The term "blocky" or "flaggy" may be applied equally well to strata of the Phroso Siltstone Member in the easterly sections of the region, as well as to the same strata in the Banff area, and would therefore create difficulties in defining and recognizing the contact between the two members.

The cyclical development which is one of the most interesting and characteristic features of the unit is readily apparent throughout the Jasper region, and has been observed, by the writer, as far south as the headwaters of Panther River and Spray River Gorge in Banff National Park. The base of a typical cycle consists of a thin, uniform layer of well-laminated, carbonaceous-pyritiferous, micromicaceous, silty, quartzose shale, and shaly-weathering siltstone. The unit is generally soft, crumbly, and fissile, owing to the high concentration of carbonaceous matter, and is of variable thickness, although averaging between 1 and 2 inches. In some sections the unit may be up to 5 feet thick. A thin, regularly laminated to cross-laminated, dolomitic siltstone to silty dolomite bed generally overlies the shaly siltstone sequence. Locally, it contains a large content of pyrite and organic matter, and is commonly lenticular, varying in thickness from one-half inch to 2 inches. The unit is succeeded by a repetition of the underlying, regularly laminated, shaly siltstone and silty shale sequence, or by a thick, resistant, non-laminated to slightly laminated, dolomitic, siltstone bed. This bed averages 6 inches but occasionally reaches 2 feet in thickness, excluding massive flow roll beds that may be up to 10 feet thick. The cycle is then repeated with the deposition of shaly siltstones and silty shales. At Mumm Creek (Section 6, Fig. 4) some of the thick resistant beds of the cycles, near the top of the member, display structures and laminations similar to those outlined by Bouma (1962), as being indicative of turbidite deposits. For example, the beds contain a zone of parallel lamination, followed by a zone of ripple lamination, and finally a zone of parallel lamination. No pelitic interval occurs, a feature described by Bouma as characterizing the top of a typical turbidite cycle. Furthermore, no graded bedding occurs owing, perhaps, to the fine-grained nature of the sediments involved.

The Vega Siltstone Member is similar mineralogically to the Phroso Siltstone Member. The detrital fraction consists mainly of quartz and minor amounts of soda and potash feldspar which display varying degrees of secondary silicification and carbonate corrosion. Accessory minerals include zircon, apatite, collophane, muscovite, rutile, tourmaline, glauconite, pyrite, and opaque organic matter. One notable exception to the mineralogical similarity with the underlying Phroso Siltstone

Member is the dolomite concentration which is generally much higher in the Vega member, ranging from 23 per cent to 48 per cent by weight. The dolomite occurs as a recrystallized cement and is finely to very finely crystalline. The high dolomite content of the member creates difficulties in the classification of field samples because the distinction between silty, quartzose dolomite or dolomitic, quartzose siltstone is commonly dependent on laboratory investigation.

The Vega Siltstone Member ranges in thickness from 160 feet on Wildhay River to 442 feet on the northeast flank of Llama Mountain anticline. The thickness of the type section on Mowitch Creek is 284 feet. These values suggest a progressive sedimentary thickening to the northwest, however, exceptions are found in some of the easterly sections within the area (Figs. 9A and 9B).

Flow rolls (Plate IV), one of the most unusual structures of the member, are confined to the eastern part of the study area and developed only in the upper 30 to 40 feet of the member. Other names applied to this structure are ball-and-pillow structure, hassock structure, pseudo-nodules, flow structure, and slump balls (Potter and Pettijohn, 1963, p. 148). They are best developed at Rock Lake and Fiddle River (Fig. 4), where they occur at the base of massive, non-laminated, siltstone beds up to 10 feet thick. The flow rolls consist of bulbous protrusions, generally concentrically layered (Plate IV A), up to 2 feet in diameter, surrounded by carbonaceous, argillaceous, shaly siltstone and shale. Their origin is attributed to the sinking of the thicker, denser beds into thinner, less competent units that were of lower specific gravity while in an unconsolidated or semi-consolidated condition. Recently, Shearman (1964) has suggested, and demonstrated experimentally, the mechanism by which some flow rolls or load casts may form. No orientation has been observed, therefore eliminating any hypothesis of gravity or tectonic sliding. Other notable sedimentary structures found in the member include flute casts, groove casts, bounce casts, convolute and current ripple-laminations, and oscillation ripple-marks. These structures are commonly associated with shallow-water deposition or with turbidite facies.

The Vega Siltstone Member is conformable on, and transitional with the underlying Phroso Siltstone Member. The contact with the overlying Whistler and Llama Members is probably conformable, and is coincident with the first occurrence of a prominent lithological change. The contact with the Whistler Member is placed, in most sections, at the base of an intraformational, phosphatic, pebble-conglomerate, ranging in thickness from 2 inches to 6 inches and which, at some places, is fossiliferous. Furthermore, a distinct compositional change is indicated by the colour and weathering nature of the Whistler Member. The contact with the Llama Member, in sections where the Whistler Member is absent, is placed at a generally distinct colour and compositional change between the two members.

The Vega Siltstone Member in the Jasper region contains few fossils (Fig. 8). Those collected include ammonites, pelecypods, fish skeletons, and fish fragments. The most important fossil collected from the member was <u>Euflemingites</u> (<u>Flemingites</u>) sp., which serves as an excellent index fossil throughout Triassic strata of Alberta. Tozer suggests a Smithian age for the fauna.

Whistler Member

The name Whistler Member is here proposed for a sequence of recessive, silty, quartzose, carbonaceous, pyritiferous, slightly phosphatic, medium- to dark grey-weathering dolomite (Figs. 9A and 9B). Bedding is thin and at some places indistinct, with minor resistant, intercalations of dolomitic siltstone that are confined to the upper part of the member where they are conspicuous within the recessive strata. The siltstone intercalations are commonly lenticular to nodular, up to 6 inches thick, and are locally very calcareous. They contain a prolific fauna of ammonites, pelecypods, and braciopods. The type section of the Whistler Member is located on Whistler Creek, a small stream draining into Sulphur River (Fig. 4).

The first published description of strata diagnostic of the Whistler Member was made by Manko (1960), who called a dark grey- to black-weathering sequence of silty, phosphatic, clayey, carbonaceous shale, containing a prolific Beyrichites fauna in the upper 10 to 15 feet, the Black Shale member. In the field, the terminology of Manko was tentatively employed but, detailed laboratory investigation of insoluble residues, and microscopic examination, showed that most sections examined and described, contained over 50 per cent carbonate minerals. It was decided, therefore, to delete the term shale and substitute a geographic name to avoid possible mineralogical misunderstanding.

The member contains three prominent minerals which are, in order of decreasing abundance, dolomite, quartz, and organic matter. Accessory minerals include pyrite, calcite, collophane, feldspar, mica, and some common "heavy minerals" such as zircon, rutile, tourmaline, and glauconite. Clay minerals may be present, but are masked by the opaque organic and ferruginous content. The detrital fraction consists mainly of angular quartz, ranging from predominant coarse silt to lesser amounts of very fine-grained sand. Secondary silicification and quartzose cement are present, but not developed to the same degree as that found in the lower two members of the formation. The carbonate fraction is composed of a finely to very finely crystalline dolomite mosaic, with locally, presumed, re-crystallized calcite as cement or as large white vug fillings and nodules up to 2 inches in diameter. The Whistler Member has a high carbonate content, which ranges from 24 to 83 per cent by weight, with an average of 66 per cent for the member. Collophane is present as nodular pebbles, grains, grain coatings, and cement, varying in concentration both laterally and vertically in the member. The collophane is commonly confined to the basal 2 feet of the member in a conglomerate that is, in some places, richly fossiliferous. The conglomerate is composed of very irregular to elongate, angular to well- rounded pebbles of black to dark grey collophane up to 1 inch in diameter and up to 4 inches in length, imbedded in a poorly indurated, quartzose, silty to sandy dolomite matrix and cement.

The general lithology of the Whistler Member closely resembles that of the Phroso Siltstone Member. The coloration, recessive nature, organic-carbon-aceous content, fine, regular to lenticular laminations, thin to indistinctly bedded nature, and pyrite concentrations of the two members are strikingly similar. The most notable differences are: (1) the average carbonate concentration, which is higher for the Whistler Member, and (2) the member thickness which is greater in the Phroso Siltstone Member. The environment and conditions of deposition would, therefore, be similar to those postulated for the Phroso Siltstone Member. The partially to wholly covered intervals, black coloration, and recessive nature, combine to make the Whistler Member an easily recognized stratigraphic unit in the Triassic succession of the region.

The Whistler Member attains a maximum thickness of 140 feet on Blue Creek near the Natural Arch, and a minimum measured thickness of 12 feet on Mount Greenock. The member is absent at two sections and, possibly, other areas southeast of Athabasca River, because of syn-depositional thinning and a probable facies change to the Llama Member. The member becomes progressively thinner in an easterly direction across the topographic strike of the region, a property common to all members of the Sulphur Mountain Formation.

The Whistler Member lies concordantly on the Vega Siltstone Member. But, the presence of the intraformational phosphatic conglomerate at the base of the Whistler Member suggests the possibility of a disconformity between the two members. The upper contact with the Llama Member is conformable, and is transitional at some places but abrupt at others. At most sections it is abrupt and is placed at the first occurrence of a resistant, thick, massive sequence of siltstones and silty dolomites. The transitional contact,which is confined to the eastern sections, is characterized by a zone, 10 to 25 feet thick, of interfingering lithofacies of the Whistler and Llama Members. The contact is arbitrarily placed in the centre of this sequence. The transition zone is overlain by medium- to thick-bedded dolomitic siltstones and silty dolomites, as found in areas where the contact is sharply defined.

The Whistler Member contains the Beyrichites-Gymnotoceras fauna. This fauna has long been recognized in other parts of Alberta and British Columbia. Three of the most important and easily recognized fossils are Gymnotoceras sp., Daonella dubia, and Spiriferina stracheyi, all of which serve as excellent correlation and index fossils of the Middle Triassic Anisian stage. Gymnotoceras sp., one of the more commonly observed fossils in the succession is generally distributed throughout the member. However, Daonella dubia, in contrast, serves as both a vertical and a lateral faunal horizon marker. Generally, Daonella is found in the upper 10 feet of the member, but was not observed in sections east of the Persimmon, Starlight, and De Smet Ranges. This, suggests a restricted lateral distribution which may imply that this fossil is confined to the deeper areas of the Triassic sea. Spiriferina stracheyi was collected from the lower 10 feet of the Whistler Member at Mowitch Creek, Westermann (1962) undertook a systematic study of this fossil in the Canadian Rockies, and concluded that the Spiriferina stracheyi horizon represented the base of the Anisian Beyrichites-Gymnotoceras-Parapoponoceras fauna of both the Whitehorse and Toad Formations of other regions.

The Anisian Beyrichites-Gymnotoceras fauna of Alberta and British Columbia serves as an excellent biostratigraphic marker. At Banff, Warren (1945) collected

Daonella dubia, Hornesia cf. socialis, Arcestes sp. Ceratites (Gymnotoceras) blakei, and Nathorstites cf. mcconnelli from strata which he assigned to the Whitehorse Member but which is herein included in the Whistler Member and lower part of the Llama Member of the Jasper region. Warren did not indicate the exact stratigraphic positions or sections from which he obtained the Middle Triassic fauna; therefore, correlation of the remaining fauna with particular stratigraphic horizons in the Jasper region is not possible. It is likely that the remainder of the fauna listed by Warren would be found in strata equivalent to the Llama Member.

Faunal correlation of the Whistler Member with the Toad Formation of the northern regions of the province is well established. Pelletier (1964, p. 6) collected such index fossils identified by Tozer as Hungarites sp., Gymnotoceras sp., Parapopanoceras tetsa, Gymnotoceras helle, Daonella sp., Ptychites sp., and Arcestes sp. from the upper strata of the Toad Formation in the Peace River district. In the Liard River area of northeastern British Columbia, McLearn and Kindle (1950) reported the occurrence of Beyrichites sp., Gymnotoceras sp., Parapopanoceras sp. and Longobardites sp., from the Toad Formation.

Llama Member

Strata characteristic of the upper unit of the Sulphur Mountain Formation were first noted by Irish (1954) near Smoky River. However, the first positive recognition of these beds as a distinct and diagnostic entity was made by Manko (1960) north of Athabasca River where he named the unit the Upper Siltstone member. During the course of field work, the term Silty Dolomite Member was used (Gibson 1965) patterned after Manko's (1960) Upper Siltstone member. Insoluble residue and mineralogic analyses show that the average content of insoluble minerals is only slightly greater than 50 per cent and never exceeds 60 per cent. The terms "siltstone" and "dolomite" thus present difficulties of field identification, and it was decided to eliminate the size and compositional connotation attached to the strata. The name Llama Member is here proposed for an assemblage of medium to dark grey-brown and yellow-brown, carbonaceous, pyritiferous, slightly micaceous, brown to yellow-brown weathering, silty to sandy quartzose dolomite, and dolomitic siltstone, with some interbedded fissile, carbonaceous, silty shale. Interbedded shales are sparsely distributed throughout the member, but are more common in the eastern sections. These shales probably represent a facies equivalent to the Whistler Member. The type section assigned to the member is located at Llama Mountain on the northeast side of Muddywater River (see Fig. 4).

The mineral composition of the Llama Member is similar to that found in the other members of the Sulphur Mountain Formation, but with slight differences in texture and relative content. Dolomite is the most abundant single constituent and occurs primarily as a cementing agent. It is a secondary replacement that has been recrystallized, thus eliminating textures and microstructures present in the original rock framework. Rarely, ghost-like, well-rounded, grains of carbonate can be recognized, suggesting that much of the carbonate now present as cement may have originally been deposited as discrete grains. Manko (1960, p. 28) and Best (1958,

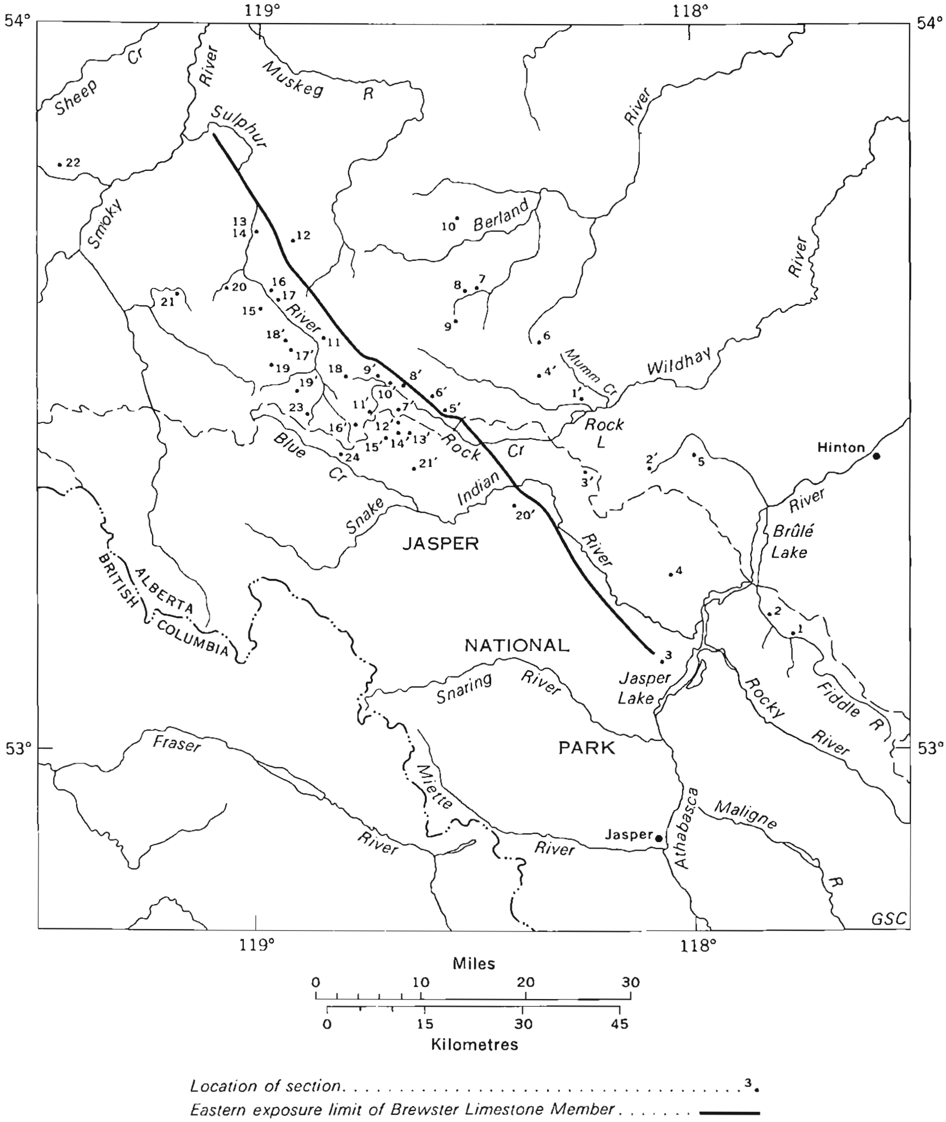

Figure 4. Map showing locations of Triassic sections and the eastern exposure limit of Upper Triassic Brewster Limestone Member, Jasper National Park Region of Alberta

p. 42) suggested that dolomite increased from the base to the top of the member in their respective study areas. These observations are generally valid but the increase is very erratic, and at one section (see Fig. 4, Section 4) at the headwaters of Strawberry Creek the reverse trend was noted. The base, there, has a general carbonate concentration of 65 per cent while at the top of the member the concnetration is about 35 per cent. The detrital fraction, in order of relative abundance, consists of quartz, orthoclase and plagioclase feldspar, authigenic and detrital pyrite, organic-carbonaceous matter, collophane, mica, and common "heavy minerals". Two interesting and useful mineral occurrences from the above list are quartz and collophane. The quartz occurs as angular to sub-rounded grains, and is cemented partly with secondary quartz overgrowths in some of the more quartzose dolomitic siltstone and sandstone strata. It displays a quartzitic texture, a feature common to all members of the Whitehorse and Sulphur Mountain Formations. A maximum grain size study utilizing mainly quartz grains, showed that the grain diameters display a progressive size increase from the base to the top of the member, which suggests a progressive shallowing of the water. Furthermore, the member displays a pronounced maximal grain size increase over the Whistler and other members of the Sulphur Mountain Formation, suggesting a regressive facies that was clearly established for the top of the Whistler Member, and may well have commenced during deposition of the Whistler strata. Collophane occurs as black to dark grey chips, grains, fossil shell fragments, and pebbles, the latter up to 1 inch in diameter. It occurs sparingly throughout the unit, with a slightly higher concentration in the lower half of the member. A significant feature of the collophane is its usefulness in recognizing and correlating the Llama Member throughout the Jasper and other regions of Alberta. The collophane occurs as whole and comminuted, blue-black, phosphatic lingulid and orbiculoid shells and shell fragments. At some locations it forms zones up to 1 inch thick at the top and bottom of bedding planes. Although poorly preserved and, consequently, not specifically identifiable, these phosphatic brachiopods contribute a useful local lithological criterion for correlation purposes, as they are limited to strata of the Llama Member.

The Llama Member ranges in thickness from a minimum of 28 feet in the eastern extremities of the region at Adam's Lookout and Fiddle River, to a maximum of 490 feet at Dinosaur Pass near the Chetamon Thrust Fault. These values demonstrate a progressive and rapid thickening to the southwest. The member has the greatest thickness variation of all members in the Sulphur Mountain Formation, with a thickness difference of 462 feet in a horizontal distance of 22 miles.

Distinct, clearly defined, bedding planes are generally difficult to recognize in the very thick beds. However, close examination of unweathered surfaces reveals faint traces of dark to light grey, argillaceous-carbonaceous, wavy to regular laminations similar to those described in the Phroso Siltstone Member.

The Llama Member is overlain conformably and transitionally by the Starlight Evaporite Member of the Whitehorse Formation. The contact is generally transitional but readily evident, based on a colour and lithological contrast between the medium greys and browns of the Llama Member, and the light greys and yellows of the Starlight Evaporite Member. The colour change commonly ranges through an interval of 25 to 35 feet in some sections. In the thinner eastern sections, the transitional colour zone is narrower and consequently quite distinct. The colour change is accompanied by an abrupt lithological change as demonstrated on Monoghan Creek. The upper beds of the member consist of yellow-brown, dolomitic siltstone and very fine-grained sandstone. The basal strata of the Starlight Evaporite Member consist of thinner beds of sandy, fine- to medium-grained, quartzose, limestone and dolomite. The colour and compositional change between the two members is very marked, permitting easy recognition of the contact. It has been suggested by Barss et al. (1964) that a possible unconformity exists at this horizon but the writer, during field investigations, found no evidence to suggest the existence of an unconformity.

The Llama Member, like the lower two members of the Sulphur Mountain Formation, is sparsely fossiliferous (Fig. 8). The most important fossil group within the member is that of the brachiopods represented by the index fossil Spiriferina cf. stracheyi. This fossil may be used for biostratigraphic correlations and age determinations with other areas of Alberta and British Columbia, but is not considered to be a useful criterion for rock stratigraphic correlation because of its distribution in the underlying Whistler Member. Similarly, Daonella dubia and Gymnotoceras sp., also collected from the member, do not serve as useful criteria for rock stratigraphic correlation, because of their similar occurrence in the Whistler Member. They do, however, serve as biostratigraphic criteria for correlation with other areas of Alberta and British Columbia. The fauna of the Llama Member indicates a Middle Triassic age. The lower part of the member, possibly the lower 10 to 20 feet, is of Anisian age, while the remainder is of Ladinian age.

WHITEHORSE FORMATION

The Whitehorse Formation between Athabasca and Smoky Rivers comprises a sequence of light-weathering, multicolored, locally sandy, limestones and dolomites, with minor amounts of calcareous and dolomitic sandstones and solution breccias. Locally, lenticular gypsum and anhydrite beds, that form distinctive sedimentary units up to 200 feet thick, occur in the lower part of the formation. The formation ranges in thickness from a minimum of 82 feet at the headwaters of Levi Creek, to a maximum of 1,650 feet at Dinosaur Pass (Fig. 4). The Whitehorse Formation overlies transitionally the Sulphur Mountain Formation and is overlain, in most areas, disconformably by the Nordegg Member of the Fernie Group.

The term "Whitehorse Member" has long been employed by field geologists for a sequence of light grey, chalky limestones, overlying a dark laminated sequence of strata (Sulphur Mountain Member). Best (1958) described the type section for these Whitehorse strata at the junction of Whitehorse and Drummond Creeks, but this section differs from the Whitehorse Member described by Warren (1945). At Cadomin, strata characteristic of the Whistler and most of the Llama Members are absent and strata equivalent to these members were formerly placed in the basal Whitehorse Member by Warren (1945). The Whitehorse Formation at Cadomin rests on a thin succession of beds belonging to the Llama Member. The type section of the Whitehorse Formation consists mainly of a poorly indurated dolomite facies. The thickness at Cadomin is 282 feet, which is far less than the average thickness of the Whitehorse Formation north of Athabasca River. It is, therefore, desirable to designate a supplemental reference section more characteristic and representative of the thickness and lithology encountered throughout the entire Jasper area north of Athabasca River. The best section available, illustrating the different facies of the formation, is located at Dinosaur Pass which is also the locality for a reference section of the Sulphur Mountain Formation. Unfortunately, a large covered interval exists in the lower part of the formation where structural complexity is suspected.

The Whitehorse lithofacies north of Athabasca River was first described as a distinct member of the Spray River Formation by Lang (1947, p. 21), while mapping the Brûlé and Entrance areas of Alberta. Irish (1951, p. 12) indicated that the Whitehorse Member, first named by Warren, (1945), and subsequently raised to formational status, was a persistent mappable unit, traceable from the type locality at Cadomin to at least Smoky River. In 1960, Manko subdivided the Whitehorse Formation in the Rock Lake area into discrete lithofacies which are, in ascending order, the Evaporitic member, the Carbonate member, and the Red Bed member. During the present investigation only the Evaporitic member and the Carbonate member of these three units were found to have widespread distribution. The Red Bed member was noted only at one locality, near the Snake-Indian-Chetamon thrust fault. East of this region the member has not been observed. The writer recognized three discrete and mappable units throughout most of the report area which are different to those of Manko. They are, however, more distinct and persistent and comprise, in ascending order, the Starlight Evaporite Member, the Brewster Limestone Member, and the Winnifred Member. The Brewster Limestone Member is absent from sections east of the Persimmon, Starlight, and De Smet Ranges. Figure 7 illustrates the member or unit relationships between those defined by the writer and those of other geologists of the region.

Starlight Evaporite Member

The name Starlight Evaporite Member is here proposed for one of the most distinctive and diagnostic members of the Whitehorse Formation, as well as one of the most unique stratigraphic assemblages of the Triassic succession. The type section of this member is designated as that occurring at Llama Mountain.

The characteristic lithology of part of the member was first recorded by Allan (1933) during the investigation of a gypsum occurrence on Mowitch Creek. Manko (1960), was the first to indicate a unique assemblage of strata, up to 900 feet thick, at the base of the Whitehorse Formation. This was described as a heterogenous "mixture of sediments showing pronounced facies changes from east to west, with considerable interfingering and wedging out." He called this sequence of strata the Evaporite member. The term Starlight Evaporite Member is a revision of the name employed by Manko (1960). It is derived in part from the Starlight Range, the site of Allen's gypsum occurrence, and in part from the predominant mineral assemblage characteristic of the member. The designated type section illustrates suitably all facies characteristic of the member in the study area, including its occurrence at the type section of the Whitehorse Formation at Cadomin.

The member comprises a complex sequence of buff, yellow, light grey to reddish-brown weathering, interbedded, interfingering, and lenticular carbonates, sandstones, siltstones, shales, and solution breccias, with local intercalated beds and lenses of gypsum (Figs. 9A and 9B). The carbonate consists of limestone and dolomite in about equal proportions with, perhaps, a small increase in limestone content in the western sections. The limestone generally contains quartz sand, is thin- to thick-bedded, locally "chalky", poorly indurated, and commonly forms the cement of the solution breccias. Dolomite occurs as thin to medium beds intercalated throughout the unit. It is locally sandy to silty, and displays fine, regular, silt laminations in some sections. The finely crystalline nature of some of the dolomite associated with gypsum beds is thought to indicate a primary origin (Weber, 1962). Calcareous and dolomitic, very fine-grained to fine-grained, quartz sandstone and lesser amounts of siltstone are sparingly distributed throughout the unit, comprising, in part, a "red bed" facies in some of the eastern and western sections of the region. The composition of these beds is difficult to assess in hand specimen and precise identification can only be made by an insoluble residue analysis. The solution breccias which form the most prominent and diagnostic lithological type, are generally medium- to thick-bedded. The angular clasts consist of quartzose, ferruginous limestone and dolomite, cemented with medium to coarsely crystalline calcite. The breccia facies has a variable thickness, but generally thickens toward the west. Gypsum occurs as thin, regular to lenticular, intercalated beds up to 6 inches thick, and also as thick lenses as seen at McDonald Gulch, Corser Gulch, and Brewster's Wall.

Despite its markedly different physical appearance, the Starlight Evaporite Member is mineralogically similar to the Sulphur Mountain Formation. Carbonate is the most abundant mineral and occurs in fine to very fine crystalline mosaics. Quartz, commonly averaging between 60 to 70 microns in diameter, forms the next most abundant mineral in the member. Most grains are in part corroded and angular, but grains between 500 and 1,000 microns in diameter are well-rounded, showing only a slight degree of carbonate corrosion. The feldspar content is much less than that found in the Sulphur Mountain Formation and rarely exceeds 1 per cent. It occurs as angular to well-rounded grains of orthoclase, microcline, and plagioclase. Other less common minerals recorded include chert (generally authigenic) mica, pyrite, rutile, zircon, tourmaline, and collophane. The latter mineral shows a marked decrease in concentration from the underlying Sulphur Mountain Formation.

Collapse or solution breccias characteristic of the member were observed at all sections, but the thickness of the facies varied greatly from region to region and sometimes from section to section. In the eastern sections, collapse breccias form only a minor part of the total lithology. The origin of the breccias has been ascribed to the solution and removal of gypsum and anhydrite with the subsequent collapse of the overlying beds. Another diagnostic feature of the member, and one seldom stressed by previous workers is the number of facies changes present within the member, especially in the western sections. These changes are so rapid, that bedding or facies correlation between most sections in the same locality is not possible. This makes sedimentary trends difficult to study in detail, or qualitatively on a comparative basis. Sections having the most prominent facies changes were commonly associated with evaporite occurrences. One example of a prominent facies change may be illustrated by a small lens of gypsum, up to 40 feet thick, that is exposed on the south side of a mountain above Brewster's Wall (Fig. 4, Section 23). Immediately opposite, on the north side of the mountain at the equivalent stratigraphic interval, no gypsum was developed and in its place occurs a sequence of recessive "chalky" limestones and dolomites, with interbedded dolomitic solution breccia. At McDonald Gulch, a similar facies change can be observed. There, white gypsum beds interfinger laterally with calcareous and dolomitic quartzose sandstones, and microcrystalline dolomites.

Primary sedimentary structures are not common, though well-formed, simple and planar cross-stratification indicating a current transport direction from the northeast was observed at some sections. The solution breccias and associated "chalky" weathering limestones and dolomites locally display a "honeycomb structure", a feature also noted by Irish (1954, p. 11) in the Whitehorse Formation of the Kvass Flats area. The structure (Plate VII B) has resulted from the solution and removal of soft "chalky" angular carbonate fragments, leaving behind a rigid framework of limestone or dolomite cement.

The Starlight Evaporite Member increases in thickness from east to west across the topographic strike of the region (Figs. 9A and 9B). The minimum reliable thickness obtained was 103 feet, measured at Adam's Lookout. There is, however, one section at the head of Levi Creek where the member has a thickness of 47 feet. However, a covered interval of 50 feet exists between strata typical of the Llama Member and strata typical of the Whitehorse Formation suggesting that the Starlight Member at this locality is less than 97 feet thick. If so, this section would contain the minimum thickness of strata comprising the Starlight Evaporite Member in the region. The maximum thickness measured occurs at Dinosaur Pass, where 761 feet were recorded. The original thickness of the member may have been slightly greater than that evident today, particularly in the western regions. It has been suggested that solution of evaporites creates cavities or voids, causing collapse of overlying beds and the formation of the breccia. The regularity of the bedding, except for disturbed zones associated with the gypsum lenses, suggests that collapse has not been great. Manko (1960, p. 33) suggested that the Evaporitic member was originally much thicker than it is now, but the evidence for this is not convincing and it seems more likely that little reduction in thickness has taken place.

The lower contact of the Starlight Evaporite Member is transitional but the upper contact, in sections west of the Persimmon, Starlight, and De Smet Ranges, is sharp and abrupt with the overlying member. In these western sections a notable composition and weathering change is evident between the members which permits

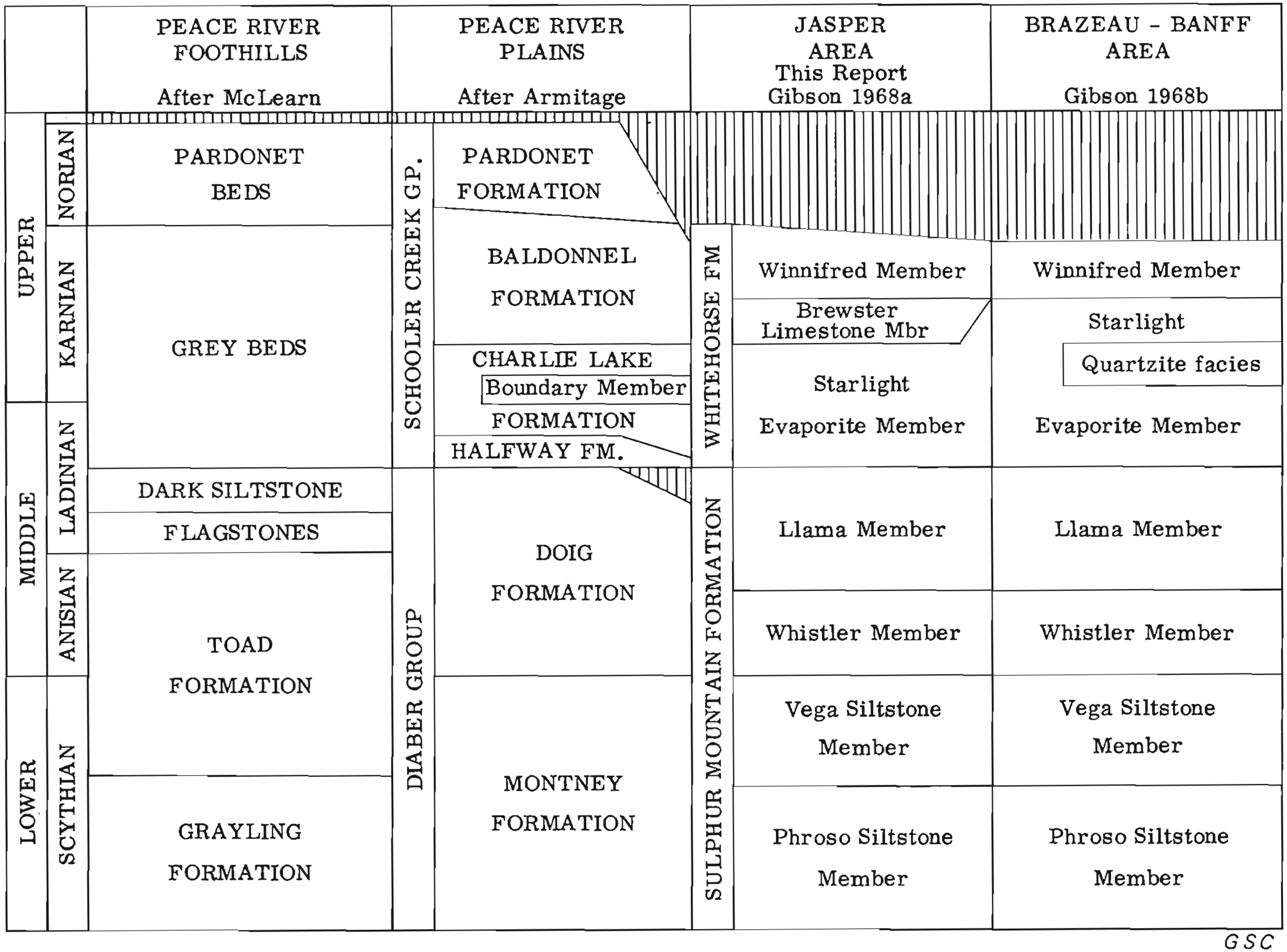

Figure 5. Triassic correlation table.

easy recognition and placement of the contact. Across the contact the lithology changes from recessive, yellow to light grey, "chalky", sandy to silty, limestones, dolomites, and solution breccias of the Starlight Evaporite Member, to resistant, cliff-forming, bioclastic, medium grey-weathering limestones of the Brewster Limestone Member. East of the Persimmon, Starlight and De Smet Ranges, the Brewster Limestone Member is absent and the Starlight Evaporite Member is overlain by the Winnifred Member. The contact there is transitional through about 15 feet of beds. There is generally a marked lithological contrast between the two members, but not as prominent as that found in the western sections overlain by the Brewster Limestone Member.

The Starlight Evaporite Member is one of the least fossiliferous lithofacies in the Triassic succession (Fig. 8). Identifiable fossils collected include the pelecypods Gervillia sp., Lima sp., Myophoria sp., and Germanonautilus sp. These faunas, previously considered of Late Triassic age, could be as old as Middle Triassic.

Brewster Limestone Member

The name Brewster Limestone Member is here proposed for an assemblage of resistant, medium- to dark grey-weathering, medium- to thick-bedded, relatively pure, pelletoid, fossiliferous limestones, with local intercalations of slightly silty to sandy quartzose dolomite (Figs. 9A and 9B). The designated type section of the member is on Whistler Creek, approximately one and one-half miles from the junction of Sulphur River (Fig. 4).

The member forms a very distinct unit of the Triassic succession because of its cliff-forming, resistant nature (see Plate III, A). Irish (1954) observed strata characterisitic of the member at Llama Mountain. Manko (1960) reported the occurrence of clean limestone "rich in crinoids, pelecypods, gastropods, bryozoa, and algae", near the top of the Evaporitic member. These strata are assigned to the Brewster Limestone Member.

Calcite accounts for over 90 per cent of the rock. It occurs as cement and as the main detrital fraction. Other minerals present, but only as traces, are quartz, feldspar, mica, collophane, pyrite, carbonaceous matter, and some "heavy minerals" such as rutile, zircon, tourmaline, and apatite.

The cement ranges from sparite to micrite, all of which has been thoroughly recrystallized, thus masking the original texture of the rock. The grains are composed of three distinct types of calcite detritus. The first and most common consists of comminuted crinoid, echinoid, brachiopod, and pelecypod debris, which is generally elongate, well-rounded, and which ranges in size from 35 microns to 5 mm in diameter. The second type of carbonate detritus consists of elongate, structureless pellets averaging 140 microns in size. They are composed of micrite which appears to have undergone some recrystallization. Third in abundance, but certainly the most conspicuous type of detritus, consists of very well-rounded, spherical grains and ooliths. Most of these are about 400 microns in diameter although some range up to 1,000 microns. The grains, some of which contain nuclei of organic fragments, consist of micrite. Many of the ooliths are observed to have a much coarser degree of recrystallization in their centres, and most of them display two concentric bands. A few have as many as four layers. At one section fibrous calcite was observed which consisted of large, elongate, wavy, dark grey, filaments of calcite up to 6 inches long. Fibrous calcite is generally considered to form under shallow-water conditions. The calcite detritus of the member decreases in content to the east where, in some sections, it is negligible.

The quartz occurs as authigenic crystals and as subrounded grains, ranging in diameter from 35 to 106 microns. The authigenic quartz crystals are commonly found in the thicker sections of the member. Dark grey chert lenses and nodules up to 2 inches in diameter occur thoughout the region; the concentration being higher in the east. Pyrite is ubiquitous throughout the member. It is present as minute, irregular, authigenic micro-aggregates and cubes. Collophane occurs as a replacement of detrital carbonate and rarely exceeds 1 per cent by volume.

The Brewster Limestone Member is confined to the region west of the Persimmon, Starlight and De Smet Ranges, and is one of the thinnest members of the Triassic succession, ranging from a minimum measured thickness of 11 feet near Ram Pass on the southwest side of Snake Indian River to a maximum of 205 feet at Brewster's Wall. East of these mountain ranges, the member is absent probably as a result of facies change.

The underlying contact with the Starlight Evaporite Member is placed at a prominent lithological break where a faunal change also occurs between the two members. The overlying contact with the Winnifred Member is conformable and similarly placed at a prominent lithological change between the two members.

The Brewster Limestone Member serves as a lithological and biostratigraphic marker in the recognition of Upper Triassic strata. It is the most fossiliferous member of the entire Triassic succession yet yields the fewest entire and identifiable specimens. Fortunately, two of the three genera identified are excellent index fossils of the Late Triassic Karnian stage. *Terebratula* cf. *julica* Bittner, and *Mysidioptera poyana* McLearn, were obtained on the southwest side of Smoky River. These two species were assigned a Karnian age by Tozer, who considers this zone equivalent to the *Mysidioptera poyana* zone of the Peace River district. The occurrence of *Mysidioptera poyana* in the strata of the Brewster Limestone Member constitutes the most southern record of an Upper Triassic fauna in Western Canada. The Upper Triassic boundary can, therefore, be extended as far south as Athabasca River, and as far east as the De Smet, Starlight, and Persimmon Ranges, which contain the most easterly recognized exposures of the member.

The *Mysidioptera poyana* faunule of the Jasper area has been correlated with the same faunule in the subsurface Baldonnel Formation of the Peace River district (Hunt and Ratcliffe, 1959). This is in agreement with the suggested correlation of the Brewster Limestone Member with the Baldonnel Formation based on physical stratigraphy.

Winnifred Member

The name Winnifred Member is here proposed for those strata comprising the upper member of the Whitehorse Formation. The type section of the member is located at Dinosaur Pass, at the same locality suggested as a reference section for the Sulphur Mountain Formation. It was selected because it affords the thickest, and most continuously exposed section of the Winnifred Member in the Jasper region.

Strata equivalent to the Winnifred Member went unrecognized until Best (1958) drew attention to two lithological assemblages in the Cadomin-Nordegg area (Fig. 7). Manko (1960) recognized two lithofacies above the Evaporitic member; the lower, he called the Carbonate member and the upper, the Red Bed member. The Red Bed member was recognized from Blue Creek northwest as far as Smoky River and forms the upper part of the Winnifred Member (Fig. 7). The Red Bed facies crops out along the Colin Thrust Sheet, at Natural Arch, Brewster's Wall, and at Dinosaur Pass. At Winnifred Pass to the northwest near Smoky River, the facies was not observed. On Monoghan Creek, 4 miles downstream from Dinosaur Pass, there was no indication of the Red Bed facies. Therefore, it appears that the Red Bed member noted by Manko is very local, and is a tongue or facies within the Winnifred Member rather than a new and separate member of the Whitehorse Formation. During field investigations, the writer tentatively termed the above lithological assemblage as the Upper Carbonate member (Gibson 1965).

The member comprises a homogenous assemblage of strata, consisting of resistant to slightly recessive, medium- to thick-bedded, yellowish- to medium dark grey-weathering, sandy to silty dolomite and limestone. Intercalated beds of collapse breccia, "shale," and phosphatic, quartzose sandstone, occur sparingly in the thicker sections within the area. Dolomite is the dominant rock type, generally comprising over 75 per cent of the strata. Locally, in the western sections, it is very quartzose and phosphatic. In the eastern regions it is thick- to medium-bedded, and often displays a distinct mottled coloration. Limestone, commonly rich in quartz, forms the second most abundant rock type in the member. The quartz content locally approaches 50 per cent of the rock. The intercalated sandy limestone beds are generally confined to the thicker sections of the western region. A small part of the total assemblage consists of sandstone and this is more common in the western region of the study area. The sandstone beds are usually cemented with calcite, and rarely with dolomite. They are poorly indurated and recessive. "Shales", sparingly distributed in the member, are actually sandy to silty, argillaceous, fissile dolomites. A small amount of solution breccia is found in the "red bed" facies of the three western sections. These breccias differ in colour from those of the Starlight Evaporite Member in that they are commonly reddish brown, with minor occurrences of greens and yellows. These colours are not found in the Starlight member with the exception of the exposure on Fiddle River.

Dolomite and calcite are the dominant minerals, comprising over 75 per cent of the mineral constituents. The carbonate, predominatly dolomite, consists of a recrystallized mosaic in which the pre-existing textures and structures have been eliminated. The calcite occurs mainly as sparry cement. Dolomitized crinoid columnals are common and are associated with a small quantity of spherical dolomitic grains up to 560 microns in diameter. These grains are structureless, micritic, and probably are dolomitized ooliths which are similar to those observed in the Brewster Limestone Member at Dinosaur Pass. In both occurrences they are associated with large well-rounded grains of quartz and feldspar. The remaining detrital fraction, similar in character and concentration to that in the underlying members of the Whitehorse Formation, consists of quartz, feldspar, mica, and common "heavy minerals" such as tourmaline, rutile, and zircon. Hydrocarbons, pyrite, clay, carbonaceous matter, and collophane are also present in trace amounts.

Vugs filled with chert or with a mixture of quartz and calcite are characteristic. The chert consists of dark to medium grey, wavy lenses, averaging between 9 and 12 inches long, and ovoid nodules, rarely banded, averaging 2 inches in diameter. The chert is confined to the lower third of the member and has never been observed within or above the red bed facies of the western region. The chert content and distribution diminishes in an easterly direction, especially east of Rock Creek. The vugs are one of the most common sedimentary structures of the member. They range up to a maximum size of 2 inches in diameter but average 3/4 inch, and are lined or filled with white or colourless calcite and quartz. Commonly they are found in dense, resistant, conchoidal-fracturing dolomites, which also contain the highest concentration of chert nodules. Sharply defined bedding, ranging in thickness from 1 to 3 feet, forms a diagnostic feature of the member. In contrast, bedding in other members of the Whitehorse Formation is generally obscure.

Facies changes hinder detailed correlation within the member, such that delineation of any particular bedding sequence is generally impossible between closely spaced sections, especially in the western regions. One of the best examples of a major facies change can be demonstrated on Monoghan Creek. The "red bed" unit so prominently displayed at Dinosaur Pass can not be recognized in the equivalent stratigraphic position four miles downstream. There, the unit is represented by dark weathering, silty to sandy limestones and dolomites.

The member ranges in thickness from a maximum of 735 feet at Dinosaur Pass, to a minimum of 9 feet on Wildhay River near Rock Lake. This thickness variation gives the Winnifred Member the greatest net thickness difference of any member in the Triassic succession of the area. The westerly increase in thickness is not as pronounced as is inidcated by the above maximum thickness measurements, because Dinosaur Pass appears to have been the site of local thickening. The average thickness of the member in the vicinity of the Colin Thrust Fault is 300 feet. Despite the much greater thickness in the western sections, pre-Jurassic erosion is suggested by the occurrence of a phosphatic, sandy, conglomerate at the top of the member. The thicker sections appear to be confined to the Colin Thrust Sheet, but the exact thickness of the member in the adjoining thrust sheet to the west is masked by the Chetamon Thrust Fault, which truncates the upper part of the member. The Chetamon Thrust Fault has brought Cambrian quartzites over the top of the carbonates of the Winnifred Member.

The Winnifred Member is disconformably overlain, in all sections, by either the Nordegg or Rock Creek Members of the Jurassic Fernie Group. It is overlain in the central and western region by a phosphatic, quartzose, chert-pebble conglomerate, varying in thickness from 2 inches to 2 feet. The strata overlying the conglomerate consist of slightly silty carbonaceous limestone with a few beds of black fissile shale typical of the Fernie Group. This conglomerate was not observed east of the Persimmon, Starlight, and De Smet Ranges, although a marked lithological contrast exists (Plate I, F). At most sections the Fernie consists of carbonaceous shales with thin interbedded limestone units, all typical of the Nordegg Member. The lower contact as previously mentioned, is everywhere conformable and distinct.

The Winnifred Member is very fossiliferous (Fig. 8), but the degree of preservation is exceedingly poor, making specific and generic identification almost impossible. The fauna consists largely of pelecypods with some brachiopods and gastropods. No significant index fossils were collected from the member. The few fossils identifiable from the Winnifred Member of the Jasper region suggest a Late Triassic age, possibly equivalent to part of the Norian stage already recognised in northeastern British Columbia.

CORRELATION

The local correlation of all members and formations described in the present investigation has been well established in the Jasper region. Correlation with members and formations of other regions of Western Canada, mainly northeastern British Columbia, is less certain. However, an excellent summary has been provided by Barss, et al. (1964) and the reader is referred to this work for a more comprehensive picture. The following suggestions are based on reports of other workers, and a brief field examination in 1965 of some Triassic localities in northeastern British Columbia. Figure 5 is a chart representing the Triassic formations and members of the Jasper region, and their implied correlation with better-known Triassic areas of Western Canada.

The Phroso Siltstone, Vega Siltstone, Whistler, and part of the Llama Member are equivalent in age to the Toad-Grayling and Montney Formations of the surface and subsurface in the Peace River area, but exact stratigraphic equivalence must await more work in intervening areas. Because of the contained Claraia fauna and their lithological similarity, the Phroso Siltstone Member is correlated with all or part of the Grayling and basal half of the Montney Formation. The Vega Siltstone Member may be correlative with the upper part of the Grayling and lower half of the Toad Formation. Pelletier (1964) described the Toad Formation as being characterized in part by calcareous, dark grey, platy siltstones and shales, alternating with sequences of calcareous, dark grey, massive siltstones. This description is similar to that of the lithology of the Vega Siltstone Member, except that very few calcareous strata are interbedded in the Jasper region. The Whistler Member is considered to be equivalent, in part, to the upper part of the Toad Formation and possibly to the base of the subsurface Doig Formation. Correlation is based mainly on the presence of the Beyrichites-Gymnotoceras fauna, and to a lesser degree on phosphate occurrences. Pelletier noted small, black, phosphatic pebbles and irregular fragments in the lower part of the Toad Formation 800 to 1,000 feet below its upper contact. Similar phosphate occurrences were noted by Colquhoun (1962) in strata similar to the Whistler Member. Clark (1961) recognized a phosphate pellet zone 130 feet below the top of the Toad Formation. Armitage (1962) indicated the presence of a prominent phosphate horizon at the contact between the Montney Formation and the Doig Formation. The description, by Armitage (1962, p. 41), of the basal 110 feet of the Doig Formation closely resembles that of the strata typical of the Whistler Member of the Jasper region. It is suggested by the writer that the phosphate zone designated by Armitage at the base of the Doig Formation may, in fact, be stratigraphically equivalent to the phosphate zones noted by Hunt and Ratcliffe, Colquhoun, Pelletier, and clark in the Toad Formation. Positive correlation is not possible without additional fossil criteria.

The Llama Member of the Sulphur Mountain Formation is considered to be homotaxial with the upper part of the Toad Formation and upper part of the Doig Formation. Evidence supporting this conclusion is based mainly on lithological similarity, and to a lesser degree on an environmental similarity implied by the occurrence of a characteristic Lingula specimen. The Sulphur Mountain Formation therefore correlates with the subsurface Daiber Group designated by Armitage, and the surface Grayling and Toad Formations of Kindle.

The Starlight Evaporite Member of the Whitehorse Formation is stratigraphically equivalent to the Halfway and Charlie Lake Formations. Armitage (1962) recognized a prominent limestone unit containing oil-stained and leached skeletal material which he called the Boundary Lake Member, and which he considered as a local member of the Charlie Lake Formation confined to the Peace River district.

The writer considers the Brewster Limestone Member to be lithologically and faunally correlative with part of the Baldonnel Formation. Hunt and Ratcliffe (1959), Colquhoun (1962), and Armitage (1962), describe the Baldonnel Formation as an allochthonous, fine-grained, partly bioclastic limestone, composed of comminuted pelecypod, crinoid, and brachiopod fragments. It contains minor amounts of sandstone, siltstone, residual chert and is, in part, bituminous. All of the above characteristics are found in the Brewster Member but, because of a lithologic similarity between the Brewster Limestone and Boundary Lake Members, the possible correlation of these two members must not be overlooked. The Brewster Limestone Member in the Jasper region is considered to represent the base of the Late Triassic Karnian stage. The Charlie Lake Formation is considered by Hunt and Ratcliffe (1959), Best (1958), and Govett (1961) as of Late Triassic age. Although the Starlight Evaporite Member may be homotaxial with the Charlie Lake Formation, the Late Triassic age suggested for the latter has not been conclusively demonstrated. Exact correlation of the Winnifred Member with strata in the Peace River district is

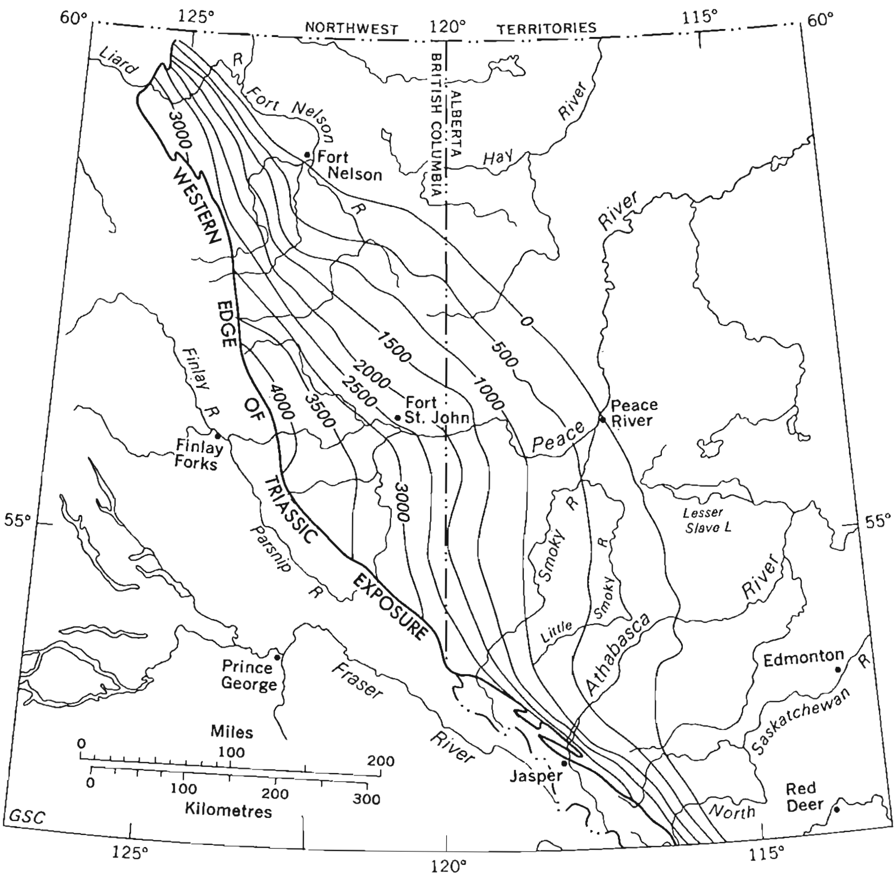

Figure 6. Isopachous map of Triassic strata.
(modified after Barss, et al., 1964.)

uncertain, although there is a lithological similarity to parts of the Baldonnel Formation, especially in the Peace and Halfway River area. The Whitehorse Formation in the Jasper region, therefore, appears to be lithologically equivalent to the Halfway, Charlie Lake, and Baldonnel Formations of the Peace River region.

PALEOENVIRONMENTS OF TRIASSIC SEDIMENTATION IN THE JASPER AREA

INTRODUCTION

Because of a general lack of sedimentological studies, few suggestions have been made concerning the detailed depositional history of the Triassic succession in the Jasper region other than the inference of deposition under shallow or deep water conditions. It has been difficult to establish a suitable modern-day analogy for this Triassic succession. Recently, however, Barss et al. (1964) have summarized ideas and hypotheses of other workers as well as their own interpretations, in an attempt to unravel the complex Triassic depositional history of Western Canada. In trying to compare ancient and modern sedimentary environments, difficulty may arise in matching sedimentary features between the two environments, as was found to be the case in the Jasper region. The following discussion and interpretation which is similar in part to that presented by Barss et al. (1964), must, therefore, be considered only as a possible working hypothesis.

Triassic strata in the Jasper region were deposited in what is generally referred to as the Cordilleran Miogeosyncline. The study of mineral variety and concentration, and a paleocurrent analysis suggests that the allochthonous sediments of the Sulphur Mountain and Whitehorse Formations were derived from an east to northeasterly source area of low relief, consisting of pre-exisiting sediments of a composition similar to an orthoquartzite or protoquartzite. Prior to Triassic deposition, erosion took place, as indicated by the absence of the Rocky Mountain Group from the eastern parts of the region, and also by the pebble conglomerate at the base of the Sulphur Mountain Formation.

SULPHUR MOUNTAIN FORMATION

Phroso Siltstone Member

The Triassic period began with a marine transgression, probably from the west, during which time strata of the Phroso Siltstone Member were deposited. The major environment is considered to have been a marginal, shallow, shelf area, analogous to the southeastern coast of the United States. Available evidence, gathered from field and laboratory studies, suggests that deposition took place in a restricted, shallow-water environment, or where burial was sufficiently rapid to prevent decomposition of organic matter at the sediment-water interface. Two modern sub-environments exhibit some characteristics found in the sediments of the Phroso Siltstone Member. These are the "tidal flat environment" as recognized in the Dutch Wadden Sea area, and the "deltaic environment" recognized offshore from the mouths of the Mississippi and Niger Rivers. Although certain similarities such as texture, sedimentary structures, bedding, and laminations, suggest deposition in a tidal flat environment (see Van Straaten, 1961, and Potter and Glass, 1958), the lack of typical features in the Phroso rocks such as channel deposits and limited areal distribution suggests that the comparison is not appropriate. Deposition in a deltaic-type of environment appears more appropriate according to the existing information. Owing to the long existing, classic definition and illustration of a delta, in which it has been incorrectly figured as a series of steeply dipping beds, bound at the top and bottom by a set of gently sloping strata, many ancient sedimentary deposits of deltaic origin have gone unnoticed. Modern investigations have revealed that deltaic foreset beds commonly do not exceed a slope of 1 degree, thus making field recognition in areas of steeply dipping strata impossible. In sections located along the northeastern fringes of the study area, the Phroso Siltstone Member generally consists of alternating layers of coarser-grained, well-sorted, sandy silt, and finer material such as carbonaceous-ferruginous, silty clay or clayey silt. Furthermore, the Phroso strata contain well-formed laminations, some of which are horizontal and regular, other crossbedded, and some wavy and distorted. (Plates VI, and VII A). These characteristics are commonly found in the "delta-front" deposits of some modern deltas such as the Mississippi Delta (Scruton, 1955). Phroso strata of the thicker, western sections exhibit characteristics suggesting deposition in deeper water (Plate VI, A). Sediment deposition farther from the source area reflects a slightly different set of characteristics, in that deposits are thicker, more massive, and display less sharply defined, vertical textural changes. These are thought to have been deposited and distributed according to their settling velocities. Deposition is generally rapid enough to exceed oxidation of the organic matter contained within the sediments. The presence of sparse, non-laminated beds of coarser grained siltstone within the regularly laminated stratigraphic sequence may be attributable to turbidity currents. Water depth during sediment deposition was probably less than 20 fathoms, analogous to the depths at which the delta front silts are being deposited by the Mississippi River. It may be suggested that Triassic strata in the Jasper area,although similar in appearance to ancient deltaic deposits, are too extensive to be of this origin. However, some modern deltas such as the Niger Delta on the west coast of Africa have a very wide lateral distribution. There, the delta has a coastal length of approximately 120 miles.

The composition of the sediments reflects the nature of the climate, topography, and type of source material. The dominance of quartz as a major detrital constituent and the presence of a carbonate cement, together with its fine size, suggests a topographically low-lying source area. Trace amounts of feldspar and other less stable minerals indicates derivation from pre-existing sediments. Sedimentation was rapid enough to permit burial and preservation of some of the organic matter before it became completely oxidized. The available evidence suggests that sediments of the Phroso Siltstone Member have a greater resemblance to sediments of a modern deltaic environment than to a tidal flat environment. Sediments of these environments exhibit many similar macroscopic characteristics.

Vega Siltstone Member

Following deposition of the Phroso Siltstone Member the seas probably regressed slightly. The silts and very fine-grained sands of the Vega Siltstone Member are somewhat coarser than those in the underlying beds. The Vega sediments are characterized by an irregular cyclical alternation of a thin band of silty, argillaceous, organic sediment followed by a thicker, more massive bed of silt or very fine-grained sand. The thicker, more resistant beds are considered to be indicative of periods of rapid sediment influx. The fine, regular laminations indicate deposition by gravity settling below wave base. Locally, the sediment was distributed by current and wave action as shown by ripple-marks and crossbedding. Deposition of argillaceous, fine, regularly laminated, silty shale to shaly siltstone, containing a large amount of organic and ferruginous material, followed deposition of the thick siltstones. This lithology simulates that described for the thicker sections of the Phroso Member. The general stratigraphic appearance, together with the occurrence of such structures as flute casts, bounce casts, and cross-laminations indicates that deposition may have occurred as a result of turbidity currents. All such features are characteristic of flysch or turbidite deposits but are not confined to turbidite deposits. Owing to the lack of the critical diagnostic features attributable to turbidite deposits such as coarse graded beds with considerable fine-grained intervening sediment, and a mixed or displaced fauna within the coarser sediment (Dott, 1962); the Vega Siltstone Member is assumed to have been deposited in relatively shallow water in which the accumulating sediments were periodically disturbed by wave action. The mineralogical composition of the member reflects a source area composed of pre-existing sediments. The cyclical development suggests an alternating or fluctuating climatic regime such that, during periods of high rainfall and consequent flooding, large quantities of sediment were brought into the depositional basin and distributed by weak marine currents and, perhaps, by shallow-water density currents. The end of Vega time is generally marked by a break in the faunal succession and by a phosphatic pebble conglomerate, suggesting a hiatus in deposition and possibly a further small marine regression.

Whistler Member

The Middle Triassic or Anisian stage was initiated by a transgression similar to that postulated for the Phroso period. The depositional environment is considered to have been similar to that of the Phroso Siltstone Member, except that deposition took place under deeper, more tranquil, euxinic conditions. The deposition of terrigenous sediment was very slow, as indicated by the sparse detrital content. The member contains a high organic phosphate concentration in the basal part so that

<table>
<tr><th>Irish (1954)</th><th>Best (1958)</th><th>Mountjoy (1960)</th><th>Manko (1960)</th><th colspan="3">Gibson (1968) This report</th></tr>
<tr><td rowspan="3">Unit A</td><td>Dolomite - sandstone facies</td><td rowspan="3">WHITEHORSE FORMATION</td><td>Red Bed member / Carbonate member</td><td rowspan="7">SPRAY RIVER GROUP</td><td rowspan="3">WHITEHORSE FORMATION</td><td>Winnifred Member</td></tr>
<tr><td rowspan="2">?
Evaporite facies</td><td rowspan="2">Evaporitic member</td><td>Brewster Limestone Member</td></tr>
<tr><td>Starlight Evaporite Member</td></tr>
<tr><td rowspan="3">Unit B</td><td rowspan="2">Upper siltstone unit</td><td rowspan="4">SULPHUR MOUNTAIN FORMATION</td><td>Upper Siltstone member</td><td rowspan="4">SULPHUR MOUNTAIN FORMATION</td><td>Llama Member</td></tr>
<tr><td>Black Shale member</td><td>Whistler Member</td></tr>
<tr><td>?
Middle dolomite unit</td><td>Blocky Brown Siltstone member</td><td>Vega Siltstone Member</td></tr>
<tr><td>Unit C</td><td>Lower siltstone unit</td><td>Lower Black Siltstone member</td><td>Phroso Siltstone Member</td></tr>
</table>

GSC

Figure 7. Table showing comparison of nomenclature used for the Spray River Group in the Jasper region.

the environment of deposition may have been similar to that suggested by Bushinski (1964) for the genesis of shallow-water phosphate. The composition of the detrital constituents again implies a provenance of pre-existing sediments.

Llama Member

The area underwent regression near the end of Whistler time. The results of a maximal grain size study showed an increase in average grain diameter upward in the member which suggests that the regression was slow in the beginning but later became more rapid. A climatic and/or environmental change is suggested by the general nature of the sediments. The colour changes progressively from dark greys at the base, to lighter greys and yellows toward the top, indicating a decrease in the carbonaceous and ferruginous content of the member. This feature may be indicative of arid conditions developing in the source area or, to changing water conditions where oxidation was more prevalent. The lack of organic matter may be due also to a slow depositional rate which permitted normal oxidation to remove the organic and iron content. The latter explanation is favoured because of the postulated arid conditions. Arid conditions would have produced a decreased water flow in river systems thus decreasing their carrying capacity and, thereby, reducing the amount of the detrital and organic material carried into the depositional area. Because of the thick, generally unlaminated nature, and mineralogical composition of the strata, the Llama Member is considered to have been deposited close to the shore in a shallow-water, marine environment.

WHITEHORSE FORMATION

Starlight Evaporite Member

At the end of Sulphur Mountain time, the sedimentary environment changed from a deltaic shelf to a shallow-marine lagoon comparable, in some ways, to the area existing today off the Texas Gulf Coast. In early Whitehorse time, marine regression was at a maximum. This resulted in the irregular distribution of isolated barrier bars which served as restrictions to water flow and, together with a dry climate, created evaporitic conditions. Red beds, gypsum, and solution breccias were developed at this time. The isolated and sparse gypsum occurrences are due, perhaps to these offshore bars which served as barriers to water circulation and resulted in the formation of hypersaline conditions in the small isolated basins. Hematite staining associated with the gypsum and red-bed facies suggests atmospheric exposure that caused oxidation of the iron. Hunt and Ratcliffe (1959, p. 588) advocated a similar environment of deposition for sediments of the correlative Charlie Lake Formation in the Peace River district. Similar suggestions were advanced by Pelletier (1960, 1961, 1962, 1964), and Armitage (1962). In contrast, Clark (1961, p. 129) postulated that breccias and mottling found in the Charlie Lake Formation of northeastern British Columbia, had formed by submarine slumping, with the resulting brecciation and sediment mixing, causing the present appearance of the strata. The breccias in the Jasper region, at some places, are associated with gypsum which suggests a genesis resulting from the solution of gypsum and the subsequent collapse of the overlying strata.

The transporting capacity of large river systems would be greatly diminished under semi-arid to arid climatic conditions resulting in a general decrease of terrigenous detritals and the consquent relative increase in carbonate deposition. The occurrence of an overlying thick sequence of relatively pure, detrital, organic limestones is evidence that, toward the end of the evaporitic period, marine conditions and, possibly, the climate also, underwent a significant change.

Brewster Limestone Member

During the initial stages of Upper Triassic or Karnian sedimentation the seas transgressed toward the east, onlapping the sediments of the Starlight Evaporite Member. Shallow-water, marine conditions prevailed and a prolific fauna developed and flourished along the margins of the depositional basin. Evidence supporting this hypothesis includes the presence of a large comminuted fauna within the member, and the occurrence of ribbon-like, fibrous calcite. However, these conditions were short lived. The seas again regressed resulting in a shallowing of the water with resulting turbulence. The fauna was killed, comminuted by wave action, swept into the deeper parts of the shelf area, and deposited as a blanket over the carbonates of the Starlight sediments. At the close of the period, shallow-water, evaporitic conditions returned to part of the western region where collapse breccias and red beds now occur.

Winnifred Member

During the final stages of Triassic deposition, marine conditions returned, with the seas transgressing from west to east. Shallow-water conditions are suggested by the occurrence of crossbedding and granular phosphate accumulations. The proportion of organic matter increases from the base to top of the Winnifred Member, indicating a departure from arid conditions. At the termination of the Triassic period, the Jasper region underwent erosion, or a period of non-deposition. This conclusion is based on the presence of a conglomerate unit at the base of the Fernie Group, and a stratigraphic gap suggested by the absence of beds equivalent to the Pardonet Formation that occurs to the northwest.

ECONOMIC GEOLOGY

Oil and Natural Gas

Triassic rocks of northeastern British Columbia and northern Alberta contain most of the presently known gas and oil reserves in the region. Most production is from the Halfway and Charlie Lake Formations, with minor production from a postulated shoreline facies of the Montney Formation. In the Jasper region the search for oil and gas has in general been negligible, probably owing to the proximity of the National Park, the inaccessibility of some of the more favorable areas, the structural complexity, the erosional truncation, and the failure to recognize stratigraphic equivalents of the producing zones of the Peace River district. Some drilling has been attempted at the following locations within the Foothills belt. At Solomon Creek, near section 5, a well was drilled and abandoned because of subsurface structural complexities. A second well was drilled in the same general region on the west flank of the Folding Mountain Anticline, but again with negative results. Triassic strata were encountered in both holes with no trace of oil or gas. In the Pierre Greys Lake map-area a well was sunk to depth of 10,709 feet, again with no results from the Triassic succession; however, a small gas show occurred in the Rundle Group. Other wells were drilled in the vicinity of Rock Lake near the northeastern boundary of Jasper National Park, and also near the town of Mountain Park. From these two wells 10,000 cubic feet, and 13 million cubic feet of gas per day respectively were recovered. At Rock Lake, production, although uneconomical, was from the Whitehorse Formation. The other showing was obtained from a porous, coquinoid, dolomite facies occurring in the Middle Dolomite zone as defined by Best (1958). A similar zone has been recognized and drilled north of Edson Alberta, and has proven to be a productive gas horizon.

Exploration should presently be concentrated in locating stratigraphic zones equivalent to known oil and gas producing strata in northeastern British Columbia, as well as the two showings in the Jasper region and surrounding district. The coquinoid dolomite unit in the Sulphur Mountain Formation was not recognized during field investigations, which suggests that it is confined to the southeast side of Athabasca River, and particularly to the Eastern Foothills Belt. This suggestion does not preclude the possibility of the facies occurring in unexposed strata along the northeastern boundary of the study region, especially in the subsurface. Nevertheless, the Sulphur Mountain Formation seems unfavorable as a possible producing horizon because of the impervious and tight nature of the strata.

The Whitehorse Formation, because of its porous and permeable character, appears to be a more favorable assemblage for future exploration. Hydrocarbon stains and strong petroliferous odours were encountered in the Winnifred Member and, at some places, in the Brewster Limestone Member. If the latter member is correlative with the Baldonnel Formation or the Boundary Member of the Peace River district, these strata should be regarded as a target for exploratory drilling in order to outline and delimit the facies along strike. Current investigations however, indicate that the unit is confined to the northwestern part of the area. The member has not been found east of the Persimmon, Starlight, and De Smet Ranges of Jasper Park, and has not been observed south of Athabasca River. The underlying Starlight Evaporite Member is characterized by numerous porous and permeable zones interbedded with tight, dolomite zones. Only at Dinosaur Pass were any hydrocarbon residues seen in the member. Nevertheless, the Whitehorse Formation appears to be the most promising member for future exploration because of its permeability and porosity, and because suitable source beds occur below in the Sulphur Mountain Formation and excellent cap rock occurs above it in the Fernie Group.

Further discoveries will thus depend on the ability to recognize and trace all members similar to the productive horizons of the Peace River district. When exact correlation has been established, drilling may be attempted in the hope of locating and delimiting possible producing zones. As drilling proceeds, the improved paleoenvironmental reconstruction that should be possible may greatly enhance the chances of finding oil.

Gypsum

Several gypsum occurrences have been noted in the region. The size, nature, and quality do not, at the present time, appear to be of economic significance. Other areas and rock formations within Alberta contain much larger gypsum reserves and would, therefore, be given preference in exploration and development. Mineral exploration and development is forbidden within Jasper National Park, thus ending further consideration and development of the Mowitch Creek deposits, the only ones worthy of economic consideration. The gypsum distribution in the Triassic succession of the Jasper area is erratic and patchy; the gypsum occurring as small lenses. It is generally confined to the thicker sections in the central and western parts of the map-area. Therefore, further exploration should proceed along strike to the northwest and southeast of the Mowitch Creek deposits. Subsurface exploration in the Foothills area, because of the known stratigraphic relationships in the Whitehorse Formation, appears to be unattractive.

Phosphate

Phosphate occurs sparingly throughout most of the Triassic succession of the map-area. Because of its sparse distribution and relatively low concentration, economic development does not appear feasible under present market conditions. Three occurrences are worthy of mention: (1) at the contact of the Phroso Member with either the Rundle or Rocky Mountain Groups; (2) at the base of the Whistler Member; and (3) in the Winnifred Member of some western sections. At the base of the Phroso Siltstone Member, pebbles and grains of phosphate occur with silts and sands of the member. A generally persistent occurrence of phosphate is found at the base of the Whistler Member where at Mount Greenock, phosphate occurs as pellets, oolites, and organic fragments in a bed ranging in thickness from 6 inches to 1 foot. Throughout the remainder of the area, the phosphatic conglomerate at the base of the Whistler Member is between 2 and 6 inches thick, and occurs as subrounded to angular pebbles and clasts in a silty to sandy dolomite matrix and cement. In the Winnifred Member lenticular concentrations of phosphate occur as grains and small pellets. Collophane is also present in the Winnifred Member near and at the contact with the Fernie Group in most of the western sections.

The most promising phosphate zone is that at the base of the Whistler Member where the higher concentrations are within the boundaries of Jasper Park.

Building Stone

One other feature worthy of economic consideration is the presence of building stone. Most government buildings at Banff are constructed of siltstone slabs from strata equivalent to the Vega Siltstone Member of the Sulphur Mountain Formation. However, this member in the Jasper region is generally characterized by an uneven bedding thickness, thus making the rock unsuitable for facing stone. The best stone occurs in the more easterly sections, in the vicinity of Rock Lake and Athabasca River, where more evenly bedded zones occur at the base of the member.

SUMMARY

Because of the numerous investigations and constant stratigraphic refinement in the treatment of the Triassic succession of northeastern British Columbia, there was a demonstrated need for similar studies in the Jasper region to facilitate correlation with both the Peace River area and the Banff area to the south. The foregoing study demonstrates that the uniform and often repetative strata of the Sulphur Mountain Formation, and the highly variable strata of the Whitehorse Formation, are readily amenable to subdivision into distinct lithological members in the Jasper region. Previously, stratigraphic correlation with the Banff region was uncertain and even more nebulous with regions to the north owing to the lack of sufficient field and laboratory data. The present investigation has provided the necessary data for Triassic correlation between the Jasper and Banff areas of Alberta and the Peace River region of British Columbia. The controversial problem of where to place the contact between the Sulphur Mountain and Whitehorse Formations was resolved by detailed correlation of the rocks of the Jasper and Banff areas. Because recognition of the Sulphur Mountain Formation was clouded by conflicting lithological and faunal criteria, it was deemed necessary to re-define the Sulphur Mountain Formation, to include younger strata.

The foregoing discussion also indicates, in part, the complexity of the depositional history of the Triassic succession in the Jasper region. Based on the study of field and laboratory data, it is suggested that sediments of the Sulphur Mountain Formation formed during minor marine transgressions and regressions in a deltaic-type of environment analogous in some ways to those off the mouths of the present Mississippi and Niger Rivers. In contrast, sediments of the Whitehorse Formation are thought to have been deposited in a more restricted shallow-water, marine environment, similar in some ways to the Texas Gulf Coast area of the United States. The occurrence of gypsum, solution breccias, and red beds in the Triassic succession of the Jasper region, indicate that deposition took place, at times, in a highly saline, shallow-water, evaporitic environment.

REFERENCES

Allan, J.A.
1933: A new Deposit of Gypsum in the Rocky Mountains, Alberta; Trans. Can. Inst. Min. and Met., vol. 36, pp. 619-35.

American Commission on Stratigraphic Nomenclature
1961: Code of Stratigraphic Nomenclature; Am. Assoc. Petrol. Geol. Bull., vol. 45, no. 5, pp. 645-65.

Armitage, J.H.
1962: Triassic Oil and Gas Occurrences in northeastern British Columbia, Canada; J. Alta. Soc. Petrol. Geol., vol. 10, no. 2, pp. 35-56.

Barss, D.L., Best, E.W., and Meyers, N.
1964: in Geological History of western Canada; edited by R.G. McCrossan and R.P. Glaister; Alta. Soc. Petrol. Geol., Calgary, Alberta, pp. 113-36.

Best, E.W.
1958: The Triassic of the North Saskatchewan-Athabasca Rivers area; Alta. Soc. Petrol. Geol., Guide Book; Eighth Ann. Field Conf. pp. 39-49.

Bouma, A.H.
1962: Sedimentology of some Flysch Deposits; Elsevier Publishing Company, Amsterdam, New York.

Bushinski, G.I.
1964: On Shallow-Water Origin of Phosphorite Sediments; Developments in Sedimentology, vol. 1; Elsevier Publishing Company, Amsterdam, London, and New York, pp. 62-70.

Clark, D.R.
1961: Primary Structures of the Halfway Sand in the Milligan Creek Oil Fields, British Columbia; J. Alta. Soc. Petrol. Geol., vol. 9, p. 109.

Collett, L.W. and Paréjas, E.
1931: Resultats de l'expedition geologique de l'Universite de Harvard dans les Montagnes Rocheuses du Canada; Compte Rendu de Seances, Soc. Phys. Hist. Nat. Geneve; vol. 48, pp. 61-67.

Colquhoun, D.J.
1960: Triassic Stratigraphy of Western Central Canada; Univ. Illinois, Ph.D. dissertation.

Colquhoun, D.J.
1962: Triassic Stratigraphy in the Vicinity of Peace River Foothills, British Columbia; Edmonton Geological Society, Guide Book, No. 4.

Dott Jr., R.H., and Howard, J.K.
1962: Convolute Lamination in Non-Graded Sequences; J. of Geology, vol. 70, pp. 114-121.

Dowling
1907: Report on the Cascade Coal Basin, Alta.; Geol. Surv. Can., Publ. 949, 37 pp.

Gibson, D.W.
1965: Triassic Stratigraphy near the northern Boundary of Jasper National Park, Alberta; Geol. Surv. Can., Paper 64-9.

1966: Triassic Stratigraphy and Petrology between the Athabasca and Smoky Rivers of Alberta; Univ. Toronto, Ph.D. Thesis.

1968b: Triassic Stratigraphy between Athabasca and Brazeau Rivers of Alberta; Geol. Surv. Can., (Paper in press).

Govett, G.J.S.
1961: Occurrence and Stratigraphy of some Gypsum and Anhydrite Deposits in Alberta; Res. Council Alberta, Bull. 7.

Hunt, A.D., and Ratcliffe, J.D.
1959: Triassic Stratigraphy, Peace River area, Alberta and British Columbia; Am. Assoc. Petrol. Geol., Bull., vol. 43, pt. 1, pp. 563-89.

Irish, E.J.W.
1951: Pierre Greys Lakes Map-Area, Alberta; Geol. Surv. Can., Mem. 258.

1954: Kvass Flats, Alberta; Geol. Surv. Can., Paper 54-2.

1955: Adams Lookout, West Half, Alberta; Geol. Surv. Can., Paper 54-9.

1965: Geology of the Rocky Mountain Foothills, Alberta; Geol. Surv. Can., Mem. 334.

Lang, A.H.
1947: Brulé and Entrance Map-Areas, Alberta; Geol. Surv. Can., Mem. 244.

MacKenzie, W.S.
1965: The Geology of the Southesk Cairn Carbonate Complex; Univ. Toronto, Ph.D. Thesis.

Manko, E.M.
1960: The Triassic of the Rock Lake area; Edmonton Geol. Soc. Guide Book, 2nd Ann. Field Trip. pp. 25-42.

McCrossan, R.G. and Glaister, R.P., Editors
1964: Geological History of Western Canada; Alta. Soc. Petrol. Geol., Calgary, Alberta. /1965/

McLearn, F.H., and Kindle, E.D.
1950: Geology of Northeastern British Columbia; Geol. Surv. Can., Mem. 259.

Mountjoy, E.W.
1960a: Miette, Alberta; Geol. Surv. Can., Map 40-1959.

1960b: Structure and Stratigraphy of the Miette and adjacent areas, eastern Jasper National Park, Alberta; Univ. Toronto, Ph.D. Thesis.

1962: Mount Robson (Southeast) Map-Area, Rocky Mountains of Alberta and British Columbia; Geol. Surv. Can., Paper 61-31.

Pelletier, B.R.
1960: Triassic Stratigraphy, Rocky Mountain Foothills, northeastern British Columbia; Geol. Surv. Can., Paper 60-2.

1961: Triassic Stratigraphy of the Rocky Mountains and Foothills northeastern British Columbia, 94K and N (parts of); Geol. Surv. Can., Paper 61-8.

1962: Triassic Stratigraphy of the Rocky Mountains and Foothills, Peace River District, British Columbia; Geol. Surv. Can., Paper 62-26.

1964: Triassic Stratigraphy of the Rocky Mountain Foothills between Peace and Muskwa Rivers, northeastern British Columbia; Geol. Surv. Can., Paper 63-33.

Pettijohn, F.J.
1957: Sedimentary Petrology; Harper Geoscience Series, 2nd Edition, 1957, pp. 249, and

Potter, P.E., and Glass, H.D.
1958: Petrology and Sedimentation of the Pennsylvanian sediments in Southern Illinois: A Vertical Profile; Illinois Geol. Surv., Rept. 204.

Potter, P.E., and Pettijohn, F.J.
1963: Paleocurrents and Basin Analysis; Academic Press Inc., Publishers, New York.

Scruton, P.C.
1955: Sediments of the Eastern Mississippi Delta; Soc. Econ. Paleon. Min. Spec. Pub. No. 3, pp. 21-50.

Shearman, D.J.
1964: On the Penecontemporaneous Disturbances of Bedding by "Quick-sand" Movement in the Devonian Rocks of North Devon; Developments in Sedimentology Vol. 1, Elsevier Publ. Co., Amsterdam, London, New York, pp. 368-370.

Straaten, L.M.J.U. Van
1961: Sedimentation in Tidal Flat Areas; J. Alta. Soc. Petrol. Geol., vol. 9, pp. 203-26.

Tozer, E.T.
1965: Lower Triassic Stages and Ammonoid Zones of Arctic Canada; Geol. Surv. Can., Paper 65-12.

Warren, P.S.
1927: Banff Area, Alberta; Geol. Surv. Can., Mem. 153.

1945: Triassic Fauna in the Canadian Rockies; Am. J. Sci., vol. 243, pp. 480-91.

Weber, J.
1962: The Chemical and Crystallochemical Approach to the Dolomite Problem; Univ. Toronto Ph.D. Thesis.

Westermann, G.E.G.
1962: The Mid-Triassic Brachiopod "Spiriferina" stracheyi (Salter) from the Canadian Rocky Mountains; J. Alta. Soc. Petrol. Geol., vol. 10, pp. 593-609.

APPENDIX

Measured Sections

Section 1. Spray River Group; Monoghan Creek-Dinosaur Pass; Sec. 32, Twp. 52, Rge. 7W6. Southeast side of Monoghan Creek, commencing at the first prominent intermittent stream northeast of Dinosaur Pass.

SPRAY RIVER GROUP (2,834 feet)

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	WHITEHORSE FORMATION (1,651 feet)		
	Winnifred Member (735 feet)		
	(Type Section)		
105	Dolomite, very quartzose, slightly calcareous and carbonaceous; finely crystalline, with detrital fraction fine- to very fine-grained; medium grey, and weathering light to medium dark yellow-brown-grey; medium-bedded, beds up to 1 foot thick; poorly preserved brachiopod or pelecypod fragments 10 feet below contact; GSC loc. 58435 fine, regular to slightly wavy, coarse-grained, quartzose sand laminations; quartz content decreases toward top; resistant; unit represents top of Whitehorse Formation and contact with Fernie Group	19	2,834
104	Dolomite, very quartzose, carbonaceous to pyritiferous, slightly phosphatic; finely to medium crystalline; detrital fraction very fine-grained; medium dark grey with slight brownish tint, weathering medium brownish grey; medium- to thick-bedded; beds up to 4 feet thick; well-preserved pelecypod molds and casts in lower 15 feet - Pleuromya ? sp. GSC loc. 58437; a few phosphatic grains and fragments; faint trace of colour laminations in upper 10 feet; resistant	33	2,815
103	Conglomerate and silty, quartzose shale; conglomerate is dolomitic, consisting primarily of rounded to subangular light grey to medium grey dolomite pebbles and		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	cobbles up to 2 inches in diameter but averaging one-half inch; abundant subrounded, black, phosphate pebbles and grains and some chert pebbles; matrix consists of silty to sandy, quartzose, finely crystalline dolomite; shale is dark grey with brown tint, soft, crumbly and pyrite-stained; unit medium- to medium-dark grey, weathering medium to dark brownish grey; conglomerate lenticular, in places up to 2 feet thick: possibility of small fault; in part covered; conglomerate represents disconformity and a possible base for Fernie Group; unit recessive	5	2,782
102	Dolomite, quartzose, slightly argillaceous; very finely to finely crystalline; terrigenous fraction very fine-grained; medium dark to medium light grey with slight green tint in upper 1 foot; weathering light to medium yellow-brown-grey; medium- to thick-bedded, beds up to 3 feet thick; fine, regular to lenticular, silt to very fine-grained sand laminations; small, weathered, pyrite nodules and grains; relief on upper bedding surface 2 inches; slightly recessive to resistant	37	2,777
101	Dolomite, very quartzose in part, slightly calcareous; very finely to finely crystalline; detrital fraction very fine-grained; light grey with yellow tint in part, weathering light grey with slight green tint; medium- to thick-bedded, beds up to 3 feet thick; regular to wavy, silt and sand laminations in part; weathers shaly and rubbly near top; 3 prominent, 1 inch thick, weathered pyrite bands within unit; unit appears to be argillaceous near top; slightly recessive	13	2,740

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
100	Dolomite, with some limestone and intraformational breccia; slightly quartzose; very finely to finely crystalline; light grey, weathering light grey; indistinctly bedded, but in places wavy beds up to 9 inches thick; limestone is lenticular; some vugs; coarse-grained sand laminations in part; green, shaly-weathering, pyritiferous dolomite zone in upper 10 feet; resistant to slightly recessive	27	2,727
99	Dolomite, with some limestone breccia; dolomite calcareous, quartzose, may be in part argillaceous; finely crystalline; very light grey to light olive-grey to pale red, weathering light grey to reddish brown; medium-bedded, beds up to 2 feet thick but usually indistinctly bedded; breccia consists of angular, light grey, dolomite clasts up to 2 inches in diameter, in a medium to coarsely crystalline, calcite matrix; 3-foot "red-bed" zone at top of unit; calcite-lined and filled vugs up to 1 inch in diameter; faint trace of regular to wavy, colour laminations in lower 10 feet; unit represents top of "red-bed" sequence; slightly recessive	28	2,700
98	Dolomite and limestone, brecciated in part, quartzose; angular, calcite and dolomite clasts up to 1 inch in diameter in a fine-grained to finely crystalline, calcite and dolomite matrix; dolomite, finely crystalline; yellowish grey to medium olive-grey to pale reddish brown with, in part, greenish grey mottling; weathering light grey to reddish brown; medium-bedded, beds up to 1 foot thick with wavy bedding planes; a few intercalated black to dark grey, fissile, shale-like beds in lower 10 feet; petroliferous stains in some of the breccia; resistant to slightly recessive	30	2,672

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
97	Dolomite, limestone, and limestone breccia, quartzose, possibly argillaceous in part; breccia consists of subangular to angular, reddish brown and greenish grey dolomite and sandy quartzose limestone clasts up to 2 inches in diameter in a very fine-grained, quartzose, coarsely crystalline, calcite matrix; dolomite and limestone finely to medium crystalline; unit is pale reddish brown to very light grey to greenish grey; weathering reddish brown to light greenish grey; mottled in part; medium-bedded, beds up to 1½ feet thick; intercalated beds of faintly laminated, very light grey dolomite; beds slightly contorted owing to presence of underlying fault; "red-beds" soft, crumbly, and porous; slightly recessive; unit forms base of prominent "red-bed" sequence	40	2,642
96	Limestone and limestone breccia, dolomitic, slightly quartzose; unit in part classed as dolomite breccia; subangular to angular dolomite clasts, yellow to very light grey up to 1 inch in diameter, in a very fine-grained, quartzose, calcite and dolomite matrix; yellowish grey to pale greenish yellow, weathering greyish yellow to light grey; medium-bedded up to 1 foot thick, with wavy bedding planes; recessive	11	2,602
95	Dolomite, slightly quartzose, calcareous in part; very finely crystalline; yellowish grey to light olive-grey, and weathering light grey; indistinctly bedded; some interbedded limestone; scattered calcite-lined vugs up to one-quarter inch in diameter; in part covered; recessive; unit represents probable base of Manko's (1960) Red Bed Member	10	2,591

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
94	Limestone and dolomite, slightly quartzose; finely crystalline; light olive-grey to yellowish grey, weathering light grey to yellow-grey; indistinctly bedded, but appears to be medium-bedded; white, calcite-lined vugs up to one-half inch in diameter; abundant hair-like calcite-filled fractures; unit complicated by small thrust fault; slightly recessive	13	2,581
93	Dolomite, very calcareous in part, slightly quartzose; finely crystalline; light grey to yellowish grey, weathering medium grey to light orange-grey; medium- to thick-bedded, beds up to 3 feet thick; some white, calcite-filled vugs; resistant to slightly recessive	20	2,568
92	Dolomite, carbonaceous to petroliferous; finely to medium crystalline; yellowish grey with medium grey mottling, weathering medium grey to orange-yellow-grey-brown; mainly indistinctly bedded but in places medium- to thick-bedded, beds up to 3 feet thick; calcite-filled vugs; grey mottling appears to be in part pyritiferous; resistant to slightly recessive	20	2,548
91	Dolomite, and small amounts of limestone; dolomite very calcareous, quartzose; medium to coarsely crystalline; pale yellowish brown to yellowish grey, weathering light grey to light greyish yellow; medium-bedded, beds up to $1\frac{1}{2}$ feet thick; minor amounts of light grey, chert lenses and nodules with former up to 1 foot long; upper 2 feet consists of limestone; resistant	24	2,528

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
90	Dolomite, slightly quartzose and phosphatic, calcareous in part; finely to medium crystalline; pale yellowish brown to yellowish grey, weathering light yellow-grey; medium- to indistinctly bedded, with some beds up to 2 feet thick; medium to light grey, elongate, chert nodules up to 3 inches in diameter; some white, calcite-lined vugs up to 2 inches in diameter; upper part of unit chalky; slightly recessive to resistant	17	2,504
89	Dolomite, slightly quartzose and calcareous; finely to medium crystalline; dark grey to medium olive-grey, weathering dark grey to dark yellow-grey; medium-bedded, beds up to 2 feet thick; prominent dark grey, wavy to lenticular bands, lenses, and nodules, with the latter up to 3 inches in diameter; poorly preserved pelecypods 11 feet from top; very strong petroliferous odour in lower 10 feet; lower 3 feet to 4 feet bituminous; penecontemporaneous slumping or minor faulting present; minor amount of pebble conglomerate; resistant	29	2,487
88	Dolomite, slightly quartzose, carbonaceous, phosphatic, in part calcareous; medium crystalline; medium olive-grey to medium dark grey, weathering dark to medium brownish grey; medium-bedded, beds up to 2 feet thick; crinoid columnal and echinoid fragments throughout unit with highest concentration in lower 3 feet; unit contains phosphatic grains and fragments; fine, wavy to irregular colour laminations; phosphatic fossil fragments on upper bedding surface GSC loc. 58436; white, calcite-lined vugs up to 2 inches in diameter; resistant to slightly recessive	20	2,458

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
87	Dolomite, quartzose, calcareous in part; fine to medium crystalline; medium light grey to medium grey with brownish tint, to very light grey and weathering light grey to yellowish grey; medium bedded, beds up to $1\frac{1}{2}$ feet thick; 2-foot thick, lenticular coquinoid pod at base composed of fragments of pelecypods and/or brachiopods; small amounts of regular to cross-lamination; dark grey, chert lenses and bands up to 1 foot in length; a few black, organic, phosphatic grains and fragments; small normal fault; resistant	11	2,438
86	Dolomite, phosphatic, very quartzose, may be in part, classed as dolomitic, quartzose, very fine-grained sandstone; medium light grey to yellowish grey, weathering yellowish to dark brownish grey; thick-bedded, beds up to 4 feet thick; dark brownish grey, lenticular laminations; well-rounded grains and pellets of black phosphate; resistant	13	2,427
85	Dolomite, quartzose, slightly calcareous; finely to medium crystalline; terrigenous, silt-size grains; light to medium light grey with slight brownish tint, weathering light to dark grey; thin- to medium-bedded, beds up to 1 foot thick; 1-foot thick, shaly-weathering zone at top of unit; dark grey, wavy to regular laminations; center of unit contains pods of crossbedded, vuggy and porous, phosphatic, coquinoid limestone; some dark grey chert nodules; slightly recessive to resistant	29	2,414

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
84	Dolomite, calcareous and very quartzose; detrital quartz medium-grained; light to medium dark grey, with slight brown tint, weathering dark brownish grey; medium- to thick-bedded; wavy to lenticular, dark grey to black chert bands in lower 4 feet; chert nodules up to 6 inches in diameter in upper 10 feet; abundant, poorly preserved, chertified brachiopod and pelecypod fragments; scattered pockets of chert and organic phosphatic fragments up to 6 inches in diameter; minor amount of calcite-lined vugs up to one-half inch in diameter; upper 10 feet contains wavy to regular colour laminations; resistant	20	2,385
83	Dolomite, slightly quartzose, carbonaceous; finely crystalline; medium to medium dark grey, and weathering dark grey; indistinctly bedded; massive in part; weathers shaly to flaggy; very fine, regular to wavy laminations; recessive	12	2,365
82	Dolomite, quartzose, phosphatic and calcareous; very finely to finely crystalline; detrital quartz and phosphate medium-grained; medium to medium dark grey, and weathering medium grey; medium-bedded, beds up to 1 foot thick; 25 to 30 per cent black, wavy to lenticular, chert bands up to 3 inches thick but averaging 1 inch thick, spaced at intervals of 2 inches to 3 inches; granular, 6-inch thick bed of phosphatic limestone at base; phosphate occurs as ovoid grains and well-rounded shell fragments; slightly recessive	4	2,353
81	Dolomite, quartzose, slightly phosphatic; finely crystalline; medium grey to pale yellowish brown, and weathering medium grey to brownish grey; medium-bedded, beds up to 2 feet thick; scattered chert lenses and nodules, with latter up to 3 inches in diameter; some black, phosphatic grains and fragments in upper 10 feet; resistant to slightly recessive	21	2.349

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
80	Limestone, slightly quartzose, gypsiferous; finely to medium crystalline; very light grey to yellowish grey, weathering light grey; medium-bedded, beds up to 1 foot thick; two cherty brachipod or pelecypod bearing bands up to 2 inches thick near top of unit; large elongate (3 inches) gypsum-filled pelecypod molds near base; unit soft, crumbly, and porous; poorly indurated; recessive to slightly recessive	3	2,328
79	Limestone, limestone conglomerate, and dolomite; conglomerate is quartzose, phosphatic, poorly sorted, and consists of subrounded black, phosphate pebbles up to 1 inch in diameter in a sandy, quartzose calcite matrix; limestone and dolomite, quartzose and very phosphatic in part, with phosphate present as pellets and well-rounded grains; finely crystalline; unit yellowish grey, weathering medium to dark grey; indistinctly bedded; calcite-lined vugs up to $1\frac{1}{2}$ inches in diameter in lower 4 feet; cherty in part; slightly recessive.	11	2,325
78	Phosphate and dolomite, very quartzose, slightly calcareous; dolomite very finely to finely crystalline; medium dark grey to dark grey and weathering same; indistinctly bedded; contains abundant crinoid ossicle fragments, in part replaced by chert; lower 1 foot consists of phosphate which occurs mainly as cement but also as well-rounded grains and pellets; upper part of unit calcareous; <u>Pentacrinus</u> sp. ossicles present; slightly recessive	4	2,314
77	Dolomite, slightly calcareous, quartzose, and may in part be classed as dolomitic, quartzose, fine-grained sandstone; very finely to finely crystalline; medium light grey to greyish yellow, weathering yellowish grey to light grey with slight pink tint in upper 4 feet; indistinct		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	to thick-bedded, beds up to 4 feet thick; massive; laminated and mottled in part; minor dark grey chert lenses and nodules in lower 5 feet; upper 4 feet chalky; resistant	26	2,310
76	Dolomite, slightly quartzose and calcareous, phosphatic in part; finely crystalline; detritals fine-grained; medium light grey to yellowish grey, weathering medium grey to yellow-grey; medium- to thick-bedded, beds up to $2\frac{1}{2}$ feet thick; a few white, calcite- and quartz-lined vugs up to $1\frac{1}{2}$ inches in diameter; a few intercalated limestone beds; chert nodules up to 2 inches in diameter in lower 10 feet; collophane grains, pellets, and fragments in upper 10 feet of unit; resistant	20	2,284
75	Dolomite, cherty, slightly quartzose, and slightly calcareous; finely crystalline; light grey to yellowish grey, weathering medium to yellowish grey; medium- to thick-bedded, beds up to 3 feet thick; scattered calcite- and chert-filled vugs up to 2 inches in diameter; abundant dark grey to black chert lenses and nodules, with the latter up to 3 inches in diameter; black phosphate grains and fragments in upper 18 feet; cliff-forming; resistant.	48	2,264
74	Limestone, quartzose, dolomitic in part; finely crystalline; fine quartz grains; light grey to yellowish grey, weathering yellow-brown to dark reddish brown to medium grey near top; indistinctly bedded, in part beds up to 2 feet thick in upper half; wavy colour laminations and bedding planes; mottled, in part, due to weathering; unit represents top of prominent yellowish-weathering zone; a few white, calcite-lined vugs up to one-half inch in diameter; recessive to slightly recessive	20	2,216
73	Covered interval	20	2,196

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
72	Limestone, limestone breccia, and dolomite, chalky, slightly quartzose; breccia consists of very light grey, subangular, dolomite clasts up to 1 inch in diameter, in a finely crystalline, calcite matrix and cement; dolomite, finely to very finely crystalline; unit very light grey to yellowish grey, weathering light yellow-grey; indistinctly bedded; porous and vuggy in part; partly covered; recessive	10	2,176
71	Dolomite, and lesser amounts of limestone, slightly quartzose; yellowish grey to medium dark grey, weathering medium to yellow-grey; indistinctly bedded; coarse, wavy, colour laminations in limestone; dolomite slightly calcareous; unit weathers flaky in part; unit in part covered; recessive	10	2,166
70	Limestone to sandstone; limestone medium crystalline; sandstone fine-grained; very light grey to yellowish grey, weathering light yellowish brown-grey; indistinctly bedded, but appears to be medium-bedded; some white vugs lined or filled with calcite; weathers shaly to flaggy; covered in part; recessive; unit represents base of prominent yellow-weathering recessive zone	40	2,156
69	Limestone, slightly quartzose; finely to medium crystalline; medium grey with brown tint to pale yellowish brown, weathering medium to light grey; medium-bedded, beds up to 2 feet thick; small amount of crinoidal fragments; possibility of small normal fault at base, but no obvious repetition, may be bedding plane slip; unit resistant	11	2,116

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
68	Limestone, slightly quartzose; finely crystalline; brecciated in part; breccia forms upper 2½ feet with angular, limestone clasts up to 6 inches in diameter but averaging three-quarters of an inch; appears to be intraformational breccia; medium to medium dark grey, weathering medium grey; indistinctly bedded; no obvious crinoidal fragments; recessive shaly-weathering zone 2 feet from top; unit slightly recessive to resistant, and marks probable base of Winnifred Member	6	2,105
	Brewster Limestone Member (155 feet)		
67	Limestone, bioclastic, slightly quartzose, cherty; bioclastic matter consists of well-rounded, medium- to coarse-grained crinoid, echinoid, pelecypod and/or brachiopod fragments, cemented with finely crystalline calcite; medium to medium dark grey with brown tint, weathering medium grey with slight yellow tint; thick-bedded; contains medium grey chert lenses up to 1 foot long by 4 inches thick, and nodules up to 2½ inches in diameter; upper 3 feet silty to sandy and contain very little crinoidal detritus; pelletoid in part; unit slightly recessive to resistant and represents top of member	45	2,099
66	Limestone, bioclastic, slightly argillaceous, and quartzose; organic detritus medium- to coarse-grained, cemented by finely crystalline calcite; unit in part pelletoid and oolitic, with ooliths iron-stained; medium to medium dark grey with slight brown tint, weathering medium grey to yellowish grey; indistinctly bedded; very massive and cliff-forming; upper 10 feet contains Pentacrinus columnals; unit well-fractured; resistant	60	2,054

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
65	Limestone, bioclastic, slightly quartzose; organic fragments medium- to coarse-grained, and consist of crinoid, echinoid, pelecypod, and brachiopod well-rounded fragments, in a finely to medium crystalline cement; medium grey with slight brown tint, weathering medium grey; indistinctly bedded, but appears to consist of beds up to $2\frac{1}{2}$ feet thick; medium to dark grey chert nodules up to 3 inches in diameter in lower 10 feet; crinoid and organic fragmental material throughout unit, but decreases in concentration in upper 10 feet of member; cliff-forming and resistant	20	1,994
64	Limestone, bioclastic; very fine- to fine-grained, may be, in part, oolitic and pelletoid; cement finely crystalline; medium dark grey with slight brown tint, weathering medium grey; indistinctly bedded; massive; abundant crinoid columnal fragments; fault breccia present at base with angular fragments up to 4 inches in diameter cemented with white, coarsely crystalline calcite; breccia may be result of large overlying thrust between Jurassic and Cambrian; cliff forming; unit represents base of Brewster Limestone Member; unit very resistant	30	1,974
	Starlight Evaporite Member (761 feet)		
63	Limestone and limestone breccia, dolomitic, bituminous in part, chalky; breccia consists of dolomitic, chalky, subangular clasts up to 1 inch in diameter in a fine-grained to coarsely crystalline, calcite matrix and cement; medium dark grey with yellowish grey clasts, weathering medium to dark grey to yellow-grey; indistinctly bedded; massive; slight undulatory contact with overlying Brewster Limestone Member; resistant to slightly recessive	45	1,944

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
62	Covered interval, talus consists of limestone and limestone breccia, no outcrop control but no talus evidence to suggest faulting	380	1,899
61	Limestone breccia, slightly quartzose; angular, dolomite and chalky limestone clasts and blocks up to 1 foot in diameter, but averaging 2 to 3 inches in diameter, in a coarsely crystalline, calcite matrix and cement; yellowish grey to pale yellowish brown with yellow mottling, weathering medium yellow-grey; indistinctly bedded; unit forms "Dinosaur" of pass; cliff-forming; contains large caverns; very vuggy and porous; trace of gypsum; resistant	13	1,519
60	Covered interval, talus consists of limestone, limestone breccia, and dolomite which is slightly calcareous and quartzose; it is finely to medium crystalline; yellowish grey to very light grey, weathering light grey; minor outcrop along ridge of pass with medium beds up to 9 inches thick; abundant calcite-lined vugs up to 1 inch in diameter; poorly preserved salt? pseudomorphs; small, organic-like, elongate pellets on one bedding surface up to one-quarter inch long; limestone and solution breccia same as unit 61; very recessive; unit represents base of prominent recessive covered zone	68	1,506
59	Limestone, dolomitic, bituminous in part; medium to coarsely crystalline; medium dark grey, weathering medium to light grey; indistinctly bedded; vuggy and porous; minor quartzose sandstone intercalations; unit weathers with very rough surface; resistant	18	1,438
58	Limestone and limestone breccia; breccia consists of limestone and chalky dolomite, subangular clasts up to 3 inches in diameter, in a coarsely crystalline, calcite matrix and cement; limestone in part very quartzose, and		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	is medium crystalline; light to very light grey with yellow tinting, weathering medium grey to yellow-grey; indistinctly bedded, but appears to be medium-bedded with very wavy bedding planes; very vuggy and porous; vugs in places empty and calcite-lined, up to $1\frac{1}{2}$ inches in diameter; in part covered; in places breccia clasts obvious only on a weathered surface; upper 10 feet contains sparse, intercalated beds of calcareous, quartzose sandstone; unit forms dipslope; slightly recessive	20	1,420
57	Limestone, and minor dolomite, slightly quartzose; bituminous in part; finely to medium crystalline; limestone in part very dolomitic; very light grey to yellowish grey, weathering medium to yellow-grey; medium- to thick-bedded with beds over 2 feet thick; mottled owing to bituminous matter; slightly recessive to resistant	18	1,400
56	Covered interval	25	1,382
55	Limestone, slightly quartzose; finely crystalline; in part brecciated, with subangular clasts up to 1 inch in diameter in a fine-grained, calcite matrix; medium light to light grey with yellowish grey clasts, weathering medium to yellowish grey; appears to be medium- to thick-bedded; center of unit contains prominent, quartzose, poorly indurated, sandstone band; very vuggy and porous in part; upper part of unit partly covered; recessive	10	1,357

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
54	Limestone and dolomite; finely to very finely crystalline; dolomite slightly quartzose, and is medium light grey with orange tinting; limestone, medium light grey with brown tint; unit weathers medium to dark grey to greyish yellow; indistinctly bedded; weathers shaly to flaggy; dolomite forms basal 1 to 2 feet; limestone resembles solution breccia but no obvious clasts; slightly recessive	10	1,347
53	Dolomite, and minor limestone breccia, slightly quartzose, in part chalky; very finely crystalline except for breccia which forms 10 inch thick beds 5 feet from base, and consists of very light grey, angular, dolomite clasts up to 1 inch in diameter, in a very fine-grained, calcite matrix; very light grey to medium grey, weathering yellowish to medium grey; medium- to thin-bedded, with wavy bedding planes; upper 1 foot weathers shaly, may be argillaceous; faint trace of regular, to slightly wavy laminations; slightly recessive to resistant	10	1,337
52	Limestone, and some dolomite, quartzose; finely crystalline; quartz very fine-grained to silt-size; medium light grey to very light grey to yellowish grey, weathering medium grey to yellow-grey; medium- to thin-bedded, beds up to 1 foot thick with wavy bedding planes; faint trace of laminations; dolomite forms uppermost bed; recessive	10	1,327
51	Limestone, slightly quartzose; finely crystalline; medium light grey to yellowish grey, weathering medium grey; indistinctly bedded, but appears to be thick-bedded; unit resembles solution breccia limestone, but no obvious clasts; fractured; porous in part; recessive	23	1,317

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
50	Covered interval, talus consists of limestone and limestone breccia	15	1,294
49	Dolomite, slightly quartzose, calcareous in part; finely crystalline; light grey to yellowish grey, weathering medium to light grey with slight yellow tint; medium-bedded; very vuggy, calcite-lined vugs up to one-half inch in diameter; wavy to irregular laminations; unit slightly recessive to resistant where exposed; upper part of unit covered	10	1,279
48	Dolomite, slightly quartzose; finely crystalline; yellowish grey to medium light grey, weathering dark greyish yellow; mottled in part; medium-bedded, beds up to $1\frac{1}{2}$ feet thick; very irregular wavy laminations; abundant calcite-lined vugs up to 1 inch in diameter; unit recessive except for lower 6 feet which are resistant	26	1,269
47	Dolomite, slightly quartzose; finely crystalline; yellowish to medium olive-grey, weathering light grey to light yellow-grey; mottled in upper 10 feet; indistinct to medium-bedded, beds up to 2 feet thick; discontinuous wavy laminations; poorly indurated in part; calcite-lined vugs up to 2 inches in diameter; minor black phosphatic grains and fragments; upper 3 feet forms recessive notch; unit slightly recessive to resistant	20	1,243
46	Dolomite, slightly quartzose; very finely crystalline, conglomeratic in part, with subrounded to subangular clasts up to 1 inch in diameter; medium grey, weathering light grey to yellow-grey; beds over 2 feet thick; regular to wavy colour and silt laminations; slightly recessive	8	1,223

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
45	Dolomite, quartzose, may be argillaceous in part; finely crystalline; light to medium olive-grey, weathering greenish to purplish yellow-grey; thin-bedded, beds up to 3 inches thick; weathers shaly in part; one resistant bed in centre of unit; fine, regular to wavy, colour laminations; small normal fault with displacement of 10 feet; unit recessive	2	1,215
44	Dolomite, very quartzose, in part may be classed as dolomitic quartzose sandstone; very fine-grained; unit consists mainly of dolomite, very finely crystalline; yellowish grey, weathering light grey to light yellow-grey; medium-bedded, beds up to 1 foot thick; a few thin beds; a little intraformational conglomerate with clasts up to 1 inch in diameter; coarse, wavy, sand and silt laminations, very blotchy in part; dolomite in part breaks with conchoidal fracture; resistant	13	1,213
43	Dolomite and sandstone, very quartzose, slightly calcareous; sandstone fine- to very fine-grained, carbonate medium to coarsely crystalline; greyish yellow, weathering medium yellow-grey; indistinctly bedded, but appears to be thick-bedded; minor intraformational conglomerate; poorly preserved pelecypods in centre of unit GSC loc. 58438; regular, coarser-grained, quartz sand laminations; minor calcite-lined vugs; poorly indurated in part; unit represents base of Whitehorse Formation with contact allocated in part on basis of prominent weathering and colour change; unit slightly recessive to resistant	17	1,200

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	SULPHUR MOUNTAIN FORMATION (1,183 feet)		
	Llama Member (489 feet)		
42	Dolomite, very quartzose, may be in part classed as dolomitic quartzose sandstone; sandstone very fine-grained; unit grey, weathering brownish to yellowish grey; indistinctly bedded, but appears to be medium-bedded, beds up to 2 feet thick; bitumin-stained bed at base of unit; faint trace of regular to wavy colour laminations; resistant to slightly recessive; unit forms abrupt contact with overlying Whitehorse Formation	8	1,183
41	Siltstone, quartzose, very dolomitic, slightly carbonaceous and/or pyritiferous; light grey to yellowish grey, weathering yellow-brown grey; medium-bedded, beds up to 1 foot thick; very irregular, coarse, wavy, quartzose silt and sand laminations; organic phosphatic flecks and fragments throughout unit; thin, lenticular bed of phosphatic conglomerate in lower 20 feet; resistant to slightly recessive	50	1,175
40	Siltstone to dolomite, slightly carbonaceous and/or pyritiferous, very quartzose, possibly argillaceous; carbonate finely to very finely crystalline; pale yellowish brown to yellowish grey, weathering yellow-grey-brown; medium- to thick-bedded, beds over 3 feet thick; dark grey, very wavy to irregular, hair-like, carbonaceous laminations near top; phosphatic Lingulid flecks and fragments throughout, plus indeterminate poorly preserved pelecypod and brachiopod molds and casts in upper 10 feet; minor phosphatic-pyrite-like pebbles in upper 20 feet; may be small fault present but no obvious displacement; resistant	40	1,125

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
39	Siltstone, quartzose, very dolomitic, may be in part classed as silty, quartzose dolomite, carbonaceous and/or pyritiferous; carbonate finely crystalline; pale yellowish brown to medium olive-grey, weathering yellow-grey-brown; indistinctly bedded, but appears to be thick- to medium-bedded; massive; scattered, large, blue-black, phosphatic Lingulid molds and casts; abundant, black, phosphatic flecks and organic fragments; irregular, wavy to lenticular, carbonaceous-like laminations; a few vugs up to one-half inch in diameter in lower 20 feet; thin, 2-inch, pebble-conglomerate band 20 feet above base; resistant to slightly recessive	40	1,085
38	Siltstone, quartzose, very dolomitic, carbonaceous, slightly phosphatic; very light to medium olive-grey, weathering dark yellow-grey-brown; thick-bedded, beds up to $2\frac{1}{2}$ feet thick; in part indistinctly bedded; abundant phosphatic flecks and fragments throughout unit; two 2-inch thick lenticular beds of phosphatic pebble-conglomerate near top and base, with subrounded pebbles up to $1\frac{1}{2}$ inches in diameter; well-fractured; weathers rubbly in places; lower 10 feet vuggy; resistant	40	1,045
37	Siltstone, quartzose, dolomitic, may be in part classed as silty, quartzose dolomite; carbonaceous, and possibly argillaceous; pale yellowish brown, weathering yellow-grey-brown; thick-bedded; wavy to lenticular, carbonaceous-pyritiferous laminations; fractured in places; two, weathered, one-half inch thick, pyrite bands in lower 10 feet; resistant	21	1,005

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
36	Siltstone, quartzose, very dolomitic, carbonaceous, in part phosphatic; pale yellowish brown, weathering medium to dark yellow-brown-grey; medium- to thick-bedded; 6-inch thick band phosphatic pebble-conglomerate 2 inches below top of unit; elongate, subrounded pebbles up to $1\frac{1}{2}$ inches in diameter; upper 3 feet very vuggy; abundant pyrite staining; scattered phosphatic Lingulid fragments; resistant to slightly recessive	7	984
35	Siltstone, quartzose, very dolomitic, carbonaceous, pyritiferous, and possibly argillaceous; medium to medium dark grey, weathering medium to dark yellow-grey-brown; medium- to thick-bedded, beds up to 5 feet thick; wavy, quartzose to dolomitic, silt to sand laminations in upper 30 feet; scattered, white, calcite-lined vugs up to one-half inch in diameter in lower 20 feet; fractured; in part mottled; resistant to slightly recessive	53	977
34	Covered interval, outcrop higher on ridge same as unit 33	10	924
33	Siltstone, quartzose, very dolomitic, carbonaceous, slightly pyritiferous, may be in part argillaceous; medium grey to pale yellowish brown, weathering yellow-grey-brown; indistinctly bedded, but appears thick-bedded with beds over 3 feet thick especially upper 10 feet; massive; small vugs up to one-half inch in diameter; well-fractured; black, phosphatic pebbles up to 1 inch in diameter forming small lenses and pockets of conglomerate; appears as if pebbles were deposited on unconsolidated silts, as there are deformed and compacted laminations around pebbles; phosphate flecks and fragments throughout unit; coarse colour banding and laminations in upper 10 feet; very resistant	40	914

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
32	Siltstone, quartzose, very dolomitic, and may be in part classed as silty, quartzose dolomite, slightly pyritiferous, and carbonaceous; carbonate finely crystalline; medium olive-grey to pale yellowish brown, weathering medium yellowish grey; indistinctly bedded; weathers massive; pyrite grains and well-rounded, elongate, phosphatic pebbles up to $1\frac{1}{2}$ inches in diameter in upper 30 feet; well-fractured; wavy, irregular, carbonaceous laminations near base; resistant to slightly recessive	60	874
31	Siltstone, quartzose, very dolomitic, may be classed in part as silty quartzose dolomite, carbonaceous, and pyritiferous; may be argillaceous in part; carbonate finely crystalline; medium dark grey with slight brown tint, weathering dark yellow-brown-grey with prominent $1\frac{1}{2}$-foot thick resistant, yellowish orange marker bed 20 feet from top; indistinctly bedded, but appears medium- to thick-bedded; a few black, phosphatic grains and fragments, and white, calcite-lined vugs up to one half inch in diameter in upper 20 feet; weathers rubbly in part; somewhat lenticular, carbonaceous laminations; resistant to slightly recessive	30	814
30	Siltstone to dolomite, quartzose, pyritiferous and carbonaceous; dolomite finely crystalline; medium dark to dark grey, weathering yellowish brown to brownish grey; indistinctly bedded, but appears to be medium-bedded; prominent $1\frac{1}{2}$-foot thick, resistant, yellow-grey weathering marker horizon in upper 10 feet; very poorly preserved ammonite impression of the Gymnotoceras type; very faint trace of colour laminations; lower 30 feet weathers flaky to rubbly, but overlying beds more massive; unit slightly recessive	50	784

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
29	Dolomite, very quartzose, may be in part classed as dolomitic siltstone, possibly argillaceous, carbonaceous and/or pyritiferous; finely crystalline; medium dark to dark grey with brown tint, weathering dark yellowish brown-grey; indistinctly bedded, but appears to be medium-bedded; several beds up to 1 foot thick; very wavy to irregular colour laminations in part; very poor ammonite impression; weathers shaly to flaggy; slightly recessive to recessive	10	734
28	Dolomite to siltstone, quartzose, pyritiferous and/or carbonaceous, micromicaceous; carbonate finely crystalline; medium dark grey to light to medium olive-grey, weathering dark to medium yellow-brown; indistinctly bedded; massive in part; lower 7 feet contains molds and casts of Daonella cf. dubia, and Gymnotoceras? sp. (GSC loc. 58386); represents transition to the Whistler Member; weathers very flaggy; resistant to slightly recessive	30	724
	Whistler Member (91 feet)		
27	Covered interval, no precise upper contact of member with overlying Llama Member; contact based on prominent weathering change between the two members	40	694
26	Dolomite to siltstone, very quartzose, pyritiferous and/or carbonaceous; carbonate finely to very finely crystalline; medium dark to dark grey, weathering dark grey to medium grey; indistinctly bedded; faint trace of pyritiferous wavy laminations; unit partly covered; recessive	10	654

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
25	Covered interval, talus same as unit 26	10	644
24	Siltstone, very quartzose and dolomitic, carbonaceous, pyritiferous, possibly argillaceous; medium dark to dark grey, weathering medium to dark grey; indistinctly bedded; phosphate flecks and fragments; well-preserved ammonites of the Gymnotoceras-Beyrichites type (GSC loc. 58387); small amount of weathered pyrite grains; only lower part of unit exposed; recessive	10	634
23	Siltstone to dolomite, quartzose, micro-micaceous, pyritiferous to carbonaceous; carbonate finely to very finely crystalline; dark grey with slight brownish tint, weathering dark grey; indistinctly bedded; fine, regular to slightly wavy, pyritiferous laminations; weathers shaly to flaggy; poorly preserved ammonite impressions in upper 10 feet; talus fossils include, Germanonautilus sp., Longobardites cf. nahwisi, Gymnotoceras Helle, Ceratites hayesi, Parapoponoceras sp. (GSC loc. 58385); small amounts of weathered pyrite grains and fragments; lower half of unit covered; recessive	20	624
22	Conglomerate, quartzose, phosphatic, dolomitic; subrounded, flattened, phosphate pebbles and fragments up to $1\frac{1}{2}$ inches in diameter in a very fine-grained to silt-size quartzose, pyritiferous, dolomite matrix; medium dark to dark grey, weathering medium to dark yellowish grey; indistinctly bedded; pebbles and fragments in bands 2 inches to 3 inches thick; conglomerate lenticular in part; phosphatic bone fragments; scattered pyrite nodules up to 1 inch in diameter; contact with Vega Siltstone placed at base of conglomerate; unit recessive	1	604

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	<u>Vega Siltstone Member (250 feet)</u>		
21	Siltstone, quartzose, dolomitic, slightly carbonaceous; medium dark grey with slight brown tint, weathering medium brown to yellow-grey; indistinctly bedded; fine, regular to slightly wavy, dolomitic laminations; micromicaceous in part; abundant black phosphatic "fish-like" fragments; slightly recessive where exposed; partly covered	19	603
20	Siltstone, quartzose, slightly carbonaceous, very dolomitic, may be in part classed as silty, quartzose dolomite; carbonate finely crystalline; medium dark grey with slight brown tint, weathering medium grey-brown; medium-bedded; fine, regular to slightly wavy, light to dark grey laminations; abundant phosphatic fish or bone fragments near top; partly covered; slightly recessive to recessive	10	584
19	Siltstone, quartzose, micromicaceous, dolomitic, slightly carbonaceous; medium dark grey, weathering medium brown; mainly indistinctly bedded but, in places, thin-bedded; very fine, regular, light grey, dolomitic laminations; weathers flaggy; slightly recessive to recessive	30	574
18	Siltstone, quartzose, carbonaceous, pyritiferous, micromicaceous, very dolomitic, and may be in part classed as silty, quartzose dolomite; carbonate finely to very fine crystalline; medium light grey to light olive-grey, weathering yellow-grey-brown; thin- to medium-bedded, beds up to 1 foot thick, averaging 3 inches to 4 inches in thickness; weathers very flaggy with slabs averaging one-half inch to 1 inch in thickness; 10 to 20 per cent shaly siltstone in lower 20 feet; black, phosphatic fish fragments in upper 20 feet		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	(GSC loc. 58420); fine, regular to lenticular, dolomitic and pyritiferous laminations; resistant to slightly recessive	50	544
17	Siltstone, quartzose, carbonaceous, pyritiferous, micromicaceous, very dolomitic, may be in part classed as silty quartzose dolomite; medium to medium dark grey, weathering yellow-grey-brown; thin- to medium-bedded, beds up to 1 foot thick; 40 per cent of intercalated regularly laminated, silty shale to shaly siltstone beds; thicker beds non-laminated to faintly laminated; beds wavy to lenticular; resistant	50	494
16	Siltstone and silty shale, quartzose, very dolomitic, micromicaceous, carbonaceous, and pyritiferous; medium to medium dark grey, weathering brownish grey to rusty-brown; thin- to medium-bedded, beds up to $1\frac{1}{2}$ feet thick; unit consists of 60 per cent finely laminated, shaly siltstone; thicker beds non-laminated; poorly preserved <u>Euflemingites</u> sp. impressions on thinner beds; small amount of black phosphate flecks; slightly recessive to recessive	20	444
15	Siltstone and silty shale, quartzose, very dolomitic, carbonaceous, and pyritiferous; aphanitic to silt-size; medium grey to medium olive-grey, weathering yellow-grey-brown; thin- to medium-bedded, beds up to $1\frac{1}{2}$ feet thick; shale and shaly siltstone beds comprise 30 to 40 per cent of unit, and display fine, regular to slightly wavy, dolomitic and pyritiferous laminations; thicker beds non-laminated to faintly laminated; resistant	30	424

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
14	Siltstone, quartzose, micromicaceous, very dolomitic; medium dark to dark grey, weathering medium yellow-brown-grey; medium-bedded, beds up to 2 feet thick with well-laminated, fissile, silty shale and shaly siltstone intercalations; thicker beds non-laminated; wavy bedding planes; resistant	21	394
13	Siltstone, quartzose, slightly carbonaceous and pyritiferous, very dolomitic, and may be in part classed as silty, quartzose dolomite; medium dark grey, weathering yellowish brown-grey; thin- to medium-bedded, beds up to 2 feet thick; thin beds regularly laminated; very faint, lenticular to wavy, dolomitic laminations in part; weathers flaggy in part; slightly recessive to resistant; unit represents base of Vega Siltstone Member	20	373
	Phroso Siltstone Member (353 feet)		
12	Siltstone, quartzose, micromicaceous, carbonaceous and/or pyritiferous, very dolomitic; medium dark grey, weathering yellow-grey-brown; indistinctly bedded; fine, wavy to lenticular, pyritiferous to dolomitic, light grey laminations; weathers shaly to flaggy; slightly recessive; unit represents top of member as shown by change in weathering and composition of overlying stratigraphic sequence	43	353
11	Siltstone, quartzose, micromicaceous, very dolomitic, carbonaceous to pyritiferous; medium dark to darky grey, weathering medium greyish brown; indistinctly bedded; very fine, regular to lenticular, pyritiferous laminations; scattered, blue-black, phosphatic fish fragments; weathers shaly to flaggy; slightly recessive	10	310

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
10	Siltstone, quartzose, dolomitic, micromicaceous, carbonaceous, and pyritiferous; medium dark grey, weathering medium brownish grey; indistinctly bedded; very fine, regular to lenticular, pyritiferous laminations; weathering very shaly to flaggy; poorly preserved ammonites; slightly recessive	60	300
9	Siltstone, quartzose, dolomitic, micromicaceous, carbonaceous and pyritiferous; medium dark grey, weathering dark brownish grey; indistinctly bedded, but weathering massive where protected; fine, regular, pyritiferous laminations; weathers shaly to flaggy; poorly preserved ammonite molds and casts in upper 20 feet; slightly recessive to resistant	60	240
8	Siltstone, quartzose, dolomitic, micromicaceous, carbonaceous to pyritiferous; aphanitic to silt-size; medium dark grey, weathering yellowish brown-grey; medium- to indistinctly bedded, with two prominent, lenticular, orange-brown weathering beds up to 10 inches thick in lower 20 feet; massive in part; fine, regular to lenticular, light grey laminations; fine, regular, yellow, pyrite laminations in part; weathers shaly to flaggy in part; slightly recessive to resistant	40	180
7	Siltstone, quartzose, dolomitic, micromicaceous, carbonaceous and, in part, pyritiferous; medium dark to dark grey, weathering yellowish grey-brown; indistinctly bedded; fish jaw or spinal fragments; faint, pyritiferous, regular to lenticular laminations; weathers flaggy in part; massive for most part; cliff-forming; slightly recessive	20	140

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
6	Siltstone, quartzose, dolomitic, very carbonaceous and pyritiferous in part; aphanitic to silt-size; medium dark to dark grey, weathering yellow-brown-grey; indistinctly bedded, but appears to be medium with few beds to $1\frac{1}{2}$ feet thick in upper 10 feet; very fine, regular, pyritiferous laminations; a few black, phosphate chips up to 1 inch in diameter; fish fragments and poorly preserved ammonite impressions in lower 30 feet; resistant to slightly recessive	40	120
5	Siltstone, quartzose, dolomitic, carbonaceous to pyritiferous, and micromicaceous; medium dark to dark grey, weathering medium yellow-brown-grey; indistinctly bedded; fine, regular, light grey, pyritiferous laminations; black, phosphatic fish scales and fragments in lower 5 feet; poor ammonite impressions; cliff-forming; slightly recessive to resistant	30	80
4	Siltstone, quartzose, dolomitic, carbonaceous, pyritiferous, and micromicaceous; carbonate cement finely crystalline; medium dark to dark grey, weathering medium to dark brownish grey; indistinctly bedded, but appears to be medium, beds up to 1 foot thick; fine, regular to lenticular, pyritiferous laminations; poor ammonite impressions in talus; weathers shaly to flaggy in part; scattered, black, phosphatic fragments up to 1 inch in diameter; slightly recessive to resistant	20	50
3	Covered interval, talus same as unit 4	10	30
2	Sandstone, quartzose, dolomitic, slightly phosphatic; very fine-grained; medium dark grey with slight bluish tint, weathering medium to dark grey; indistinctly bedded, but appears to be medium-bedded; intercalated shale beds; mottled in part; pyrite stained; slightly recessive to recessive	10	20

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
1	Sandstone to siltstone, and conglomerate; quartzose, dolomitic; carbonaceous and pyritiferous in part; sandstone very fine-grained; conglomerate forms lowermost 3 inches and consists of subrounded, dark grey, phosphatic, siltstone pebbles up to 3 inches in diameter, but averaging 1 inch, in a fine- to coarse-grained, quartzose, calcareous, phosphatic matrix; conglomerate contains fish teeth up to $1\frac{1}{2}$ inches in length plus other fish skeletal fragments; conglomerate poorly indurated; sandstone and siltstone indistinctly bedded, but display fine, regular, pyritiferous laminations, and weather shaly in part; unit is pale yellowish brown to medium dark grey, weathering dark grey to dark brownish grey; abundant pyrite staining; unit recessive; conglomerate denotes base of Sulphur Mountain Formation	10	10
	ROCKY MOUNTAIN GROUP		
	Sandstone and chert, very quartzose; very fine- to fine-grained; light grey to light olive-grey, weathering medium to dark grey; indistinctly bedded but appears to be medium; chert forms upper contact and is lenticular, varying from 1 foot to 10 feet in thickness; undulatory contact with Sulphur Mountain Formation, with bedding relief up to 1 foot		

BREWSTER LIMESTONE MEMBER

Section 2: Brewster Limestone Member; Whistler Creek; Sec. 11, Twp. 54, Rge. 8W6. Measured on small tributary of Whistler Creek, about 1½ miles from junction with Sulphur River.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Brewster Limestone Member (105 feet) (Type Section)		
5	Limestone, slightly silty, possibly argillaceous; fine- to medium-grained; cemented with finely crystalline calcite; appears to be pelleted in part; medium to medium dark grey, weathering medium grey; indistinctly bedded; contains abundant crinoid and other organic detrital fragments; unit represents top of member, forming sharp and abrupt contact with Winnifred Member; resistant	15	105
4	Limestone, same as unit 3, except contains a few, elongate, chert nodules and lenses up to 3 inches in diameter; poorly preserved Terebratulid molds and casts in upper 10 feet (GSC loc. 58446); well-fractured	30	90
3	Limestone, bioclastic; fine to coarse, well-rounded grains in a finely crystalline cement; may be in part, pelletoid and oolitic; medium to medium dark grey, weathering same; medium- to thick-bedded, beds up to 3 feet thick; minor Terebratulid casts; abundant crinoid and other organic detrital fragments; some pseudopisoliths; well-fractured; resistant	30	60
2	Covered interval, talus consists of limestone	10	30
1	Limestone, bioclastic, slightly argillaceous; fine- to medium-grained with grains cemented with very finely crystalline calcite; pelletoid in part; medium grey with slight brownish tint, weathering medium grey; indistinctly bedded,		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	but appears to be medium; abundant crinoid and other organic detrital fragments; Pentacrinus ossicle observed; scattered white, calcite-filled and lined vugs near top; unit represents base of Brewster Limestone Member; resistant to slightly recessive; underlying strata consist of limestone and dolomite of Starlight Evaporite Member	20	20

Section 3: Starlight Evaporite Member; Llama Mountain; E$\frac{1}{2}$ Sec. 1, Twp. 56, Rge. 11W6. Measured on northeast limb of Llama Mountain Anticline, commencing on southwest side of mountain and continuing over the crest.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Starlight Evaporite Member (628 feet) (Type Section)		
39	Dolomite, very calcareous and may be, in part, classed as dolomitic limestone, chalky, slightly quartzose; very finely crystalline; very light grey; indistinctly bedded, but appears to be medium-bedded; coarse, wavy, colour laminations in part; owing to talus cover on ridge contact with overlying Brewster Limestone Member defined on basis of colour and lithologic change; resistant to slightly recessive	27	1005
38	Limestone, limestone breccia, and dolomite; breccia consists of angular, light yellow, chalky limestone clasts up to 3/4 inch in diameter, in a finely to medium crystalline, slightly silty, calcite matrix and cement; dolomite, very finely crystalline; limestone slightly quartzose and dolomitic; bioclastic in part, consisting of comminuted echinoid, crinoid, brachiopod and pelecypod fragments in a very finely crystalline matrix and cement; unit is medium grey to yellowish grey, weathering yellowish grey to medium grey; partly covered; recessive to slightly recessive	20	978
37	Dolomite, slightly quartzose, may be, in part, calcareous; very finely crystalline; medium light grey to yellowish grey, weathering medium grey to yellow-grey; only talus present on ridge crest; lower 5 feet very earthy and yellow; recessive	10	958

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
36	Limestone, dolomitic in part, very quartzose; may be, in part, classed as calcareous, very fine-grained, quartzose sandstone; finely to medium crystalline; very light grey to yellowish grey, weathering very light grey; indistinctly bedded; scattered vugs up to one-half inch in diameter in upper 10 feet; sparse outcrop, mainly talus cover; soft and crumbly; minor amounts of weathered pyrite grains; recessive	20	948
35	Covered interval, except for small outcrop 53 feet above base; limestone and limestone breccia, slightly quartzose and dolomitic; angular, medium grey to yellow, chalky dolomite clasts up to 3/4 inch in diameter in a finely to medium crystalline calcite matrix, medium grey except for clasts, weathering medium grey to yellow-grey; indistinctly bedded but appears to be medium-bedded; limestone very porous; talus in part consists of yellow and grey, chalky carbonate; recessive	69	928
34	Dolomite, slightly quartzose, very finely crystalline; light to medium light grey, weathering light to medium grey; medium-bedded, beds up to $1\frac{1}{2}$ feet thick; small yellow-weathered pyrite grains in part, forming pinpoint porosity; forms prominent marker horizon below long, grey-yellow weathering, recessive zone below Brewster Limestone Member; resistant	12	859
33	Limestone and dolomite, quartzose, finely to very finely crystalline; pale yellowish brown to greyish orange to medium grey, weathering yellowish orange; indistinctly bedded; very wavy, coarse, colour banding and laminations at top of unit; soft, crumbly, and in part weathers rubbly; unit marks base of a prominent yellow-orange, recessive-weathering zone.	24	847

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
32	Dolomite, slightly quartzose; finely to medium crystalline; light grey with slightly yellow tint, weathering medium to light grey; medium-bedded, beds up to $1\frac{1}{2}$ feet thick; fine, yellow-grey laminations in upper 10 feet; forms prominent, grey-weathering zone; outcrop confined to sides of ridge; slightly recessive	19	823
31	Limestone and dolomite; limestone very quartzose, and may be, in part, classed as very fine- to fine-grained quartzose sandstone; chalky; finely to medium crystalline; dolomite very quartzose and very finely crystalline; silt-size detrital quartz grains; unit is greyish orange, weathering yellowish orange; indistinctly bedded; partly covered; recessive	33	804
30	Dolomite, slightly quartzose, calcareous in part; very finely crystalline; very light to light grey, weathering medium to light grey; in part displays yellow and green tinting; indistinctly bedded, but appears in part to be medium-bedded; white calcite-lined vugs up to one-half inch in diameter in lower 20 feet; porous in part; slightly recessive to recessive	27	771
29	Limestone, very dolomitic, slightly quartzose; very finely crystalline; yellowish grey to medium light to medium grey, weathering medium grey to greyish yellow; medium-bedded, beds up to 2 feet thick; indeterminate organic fragments at base; minor empty vugs up to one-half inch in diameter; slightly recessive to recessive	10	744
28	Limestone, and limestone breccia, quartzose, chalky; breccia consists of angular, yellow-grey, calcareous, dolomite clasts in a sandy quartzose, finely to medium crystalline calcite matrix and cement; quartz grains range from very fine- to fine-grained; yellowish grey, weathering yellow to medium grey; indistinct		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	bedding, but appears to be medium-bedded; porous; unit represents a prominent yellow-grey-weathering zone which serves as a marker horizon; recessive to slightly recessive	33	734
27	Dolomite, quartzose, calcareous; finely crystalline; very light grey to yellowish grey, weathering light yellow-grey; mottled in part; medium-bedded; very vuggy at top; a little breccia at base; resistant	5	701
26	Limestone, slightly quartzose; very finely to finely crystalline; medium grey to yellowish grey, weathering medium grey to light grey; medium- to thick-bedded, beds up to 3 feet thick; light and dark grey, regular, colour banding one-eighth inch to one-quarter inch thick, and intraformational breccia at top of unit; white and yellow-orange, calcite-filled vugs up to 1 inch in diameter; possibility of small normal fault in lower 30 feet; forms prominent resistant-weathering rib	63	696
25	Covered interval, except for small outcrop of limestone and dolomite, slightly quartzose, chalky; finely crystalline; light grey to yellowish grey, weathering greyish yellow to light grey; small amount of pinpoint porosity; talus consists mainly of yellow-weathering carbonate; uppermost part of unit very chalky; recessive	57	633
24	Limestone, chalky; finely to medium crystalline; medium light grey, weathering medium grey; indistinct bedding planes; very crumbly; unit forms base of large recessive notch	7	576

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
23	Limestone, slightly quartzose; finely crystalline; light grey, weathering light grey to light yellow-grey; indistinctly bedded for most part, but appears to be thick-bedded in places, with wavy to lenticular beds; resembles, in part, solution breccia but clasts not obvious; pinpoint porosity in part; slightly recessive	11	569
22	Limestone and limestone breccia; limestone finely to medium crystalline; breccia consists of angular, yellow, dolomite clasts up to 2 inches in diameter in a finely crystalline, slightly sandy to silty, quartzose limestone matrix and cement; medium grey with light and yellow-grey clasts, weathering medium grey to yellow-grey; vuggy and porous, with vugs up to 1 inch in diameter; medium-bedded, beds up to 2 feet thick; lower portion of unit partly covered; slightly recessive to recessive	40	558
21	Limestone and dolomite, slightly quartzose, very chalky; finely crystalline; medium light grey to yellowish grey, weathering light yellowish grey; indistinctly bedded; coarse color-banding; vugs up to one-half inch in diameter; porous; "honeycomb texture" in part; mainly covered; recessive	20	518
20	Dolomite, limestone, and minor sandstone, quartzose, chalky; sandstone quartzose, calcareous, and very fine- to fine-grained; carbonate finely crystalline; unit yellowish grey to light grey, weathering light grey; medium-bedded, beds up to $1\frac{1}{2}$ feet thick; beds wavy to lenticular; well-developed crossbedding in upper 10 feet; small normal fault with displacement of 1 foot in lower 10 feet; limestone in part appears to be microbrecciated; laminated in part;		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	scattered vugs up to 2 inches in diameter; slightly recessive to resistant	21	498
19	Dolomite, slightly quartzose; very finely crystalline; very light grey to yellowish grey, weathering light grey with slight orange mottling; indistinct bedding; abundant white calcite-lined vugs up to 1 inch in diameter; white, calcite veinlets crosscutting bedding planes; resistant to slightly recessive	10	477
18	Dolomite, limestone, and limestone breccia, quartzose, chalky; breccia consists of angular, yellow, dolomitic, chalky clasts up to 1 inch in diameter in a finely crystalline to granular calcite matrix and cement; dolomite and limestone, finely to very finely crystalline; unit medium light grey to yellowish grey, weathering medium to light yellow-grey; medium-bedded, beds up to 1½ feet thick; porous and vuggy in lower 10 feet; abundant white, calcite-lined vugs up to one-half inch in diameter in upper 10 feet; rough-weathered, pock-marked, bedding surfaces; unit partly covered; resistant to slightly recessive	20	467
17	Limestone, chalky, slightly quartzose, dolomitic; finely to medium crystalline; appears to consist, in part, of intraformational micro-breccia; light to medium light grey with yellow-grey irregular laminations and clasts, weathering greyish yellow; indistinctly bedded; scattered outcrop; unit partly covered; well-developed "honeycomb texture" in part; slightly recessive to recessive	14	447

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
16	Dolomite and limestone breccia, slightly quartzose; breccia consists of angular, yellow, silty, chalky clasts up to 2 inches in diameter, in a finely to medium crystalline sandy, quartzose, calcite matrix; dolomite very finely crystalline; yellow to yellowish grey to medium light grey, weathering greyish yellow to medium-grey; indistinctly bedded; upper part of unit mainly dolomite, while lower part talus-covered limestone breccia; recessive	20	433
15	Limestone, very quartzose, may be, in part, classed as very calcareous, quartzose, very fine-grained sandstone; carbonate finely crystalline; terrigenous detritals very fine- to fine-grained; medium light grey with yellow tinting, weathering medium yellowish grey; indistinctly bedded; partly covered; recessive	10	413
14	Dolomite, limestone, and limestone breccia, very quartzose, chalky in part; dolomite and limestone finely to very finely crystalline; breccia consists of angular, yellow, chalky, silty, quartzose dolomite clasts up to 1 inch in diameter, in a finely crystalline, calcite matrix; breccia clasts in part laminated; indistinctly bedded; well-developed "honeycomb texture" in part; talus consists mainly of limestone breccia; weathers shaly in part; partly covered; recessive	10	403
13	Sandstone, quartzose, dolomitic, calcareous; very fine- to fine-grained; yellowish grey to light grey, weathering yellowish grey; medium-bedded, beds up to 1 foot thick; laminated in part; lower $2\frac{1}{2}$ feet displays surface pitted with solution holes and pockets, and "honeycomb texture" in part; upper 2 feet consists of silty to sandy, quartzose dolomite; unit forms probable base of Whitehorse Formation; resistant to slightly recessive	16	393

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	SULPHUR MOUNTAIN FORMATION (1,156 feet)		
	Llama Member (377 feet)		
12	Sandstone, quartzose, very dolomitic, slightly calcareous; very fine-grained; greyish orange to light olive-grey, weathering yellow-grey-brown; indistinctly bedded, but appears to be medium-bedded; mottled near top; unit represents transition zone to overlying Whitehorse Formation; resistant to slightly recessive	6	377
11	Dolomite, very quartzose, silty to sandy; finely to very finely crystalline; pale yellowish brown to medium grey, weathering medium yellowish grey; medium-bedded, beds up to 10 inches thick; very irregular, silt to very fine-grained quartz laminations; mottled in part; forms dip-slope; resistant to slightly recessive	10	371
10	Siltstone to very fine-grained sandstone, quartzose, very dolomitic; unit, in part, may be classed as silty to sandy, quartzose, finely crystalline, dolomite; yellowish grey, weathering medium to dark yellow-grey; medium-bedded, beds up to 1 foot thick; dark grey, hair-like, very wavy, discontinuous laminations; only scattered outcrop; resistant to slightly recessive	36	361
9	Siltstone to dolomite, quartzose, slightly carbonaceous, dolomite very quartzose, and finely crystalline; yellowish grey to medium light grey, weathering medium to dark yellowish grey; medium-bedded, beds up to 1 foot thick; very irregular, dark grey, carbonaceous laminations in lower part of unit; scattered empty vugs up to 1 inch in diameter in upper half of unit; weathers flaggy in part; strata form large dip-slopes on northeast side of mountain; partly covered; resistant to slightly recessive	60	325

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
8	Siltstone to very fine-grained sandstone, quartzose, very dolomitic, may be, in part, classed as silty, quartzose dolomite; yellowish grey, and weathering same; medium-bedded, beds up to 1 foot thick; abundant blue-black, phosphatic grains and organic fragments throughout unit, but generally concentrated on bedding surfaces; faint trace of wavy, dark grey, carbonaceous laminations; white, calcite-lined and filled vugs up to one-half inch in diameter; scattered outcrop; unit represents base of large, tape-measured interval down southwest side of mountain; resistant to slightly recessive	79	265
7	Siltstone, quartzose, very dolomitic; yellowish grey to light grey, weathering medium brownish yellow to light grey; medium-bedded, beds up to 1 foot thick; discontinuous, very irregular laminations; scattered vugs up to one-half inch in diameter; blue-black, phosphatic Lingulid and Orbiculoidea fragments; lower 3 feet may be classed as silty to sandy quartzose dolomite, and forms marker horizon near crest on northeast side of mountain; resistant	8	186
6	Siltstone, quartzose, very dolomitic, may be in part, classed as silty quartzose, finely crystalline dolomite; yellowish grey, weathering yellowish brown-grey; indistinctly bedded, but appears to be thick-bedded; porous; a few dark grey phosphatic chips and fragments; irregular, discontinuous, hair-like laminations; unit forms ridge crest of Llama Mountain; resistant	9	178

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
5	Dolomite, quartzose; very finely crystalline; very light grey to yellowish grey, weathering light grey to light yellow-grey; medium-bedded; abundant, coarse, sand-sized, black, phosphatic, organic fragments throughout unit; serves as prominent marker along southwest side of ridge; resistant	3	169
4	Siltstone, quartzose, very dolomitic, slightly carbonaceous; pale yellowish brown with orange tinting, weathering greyish yellow; indistinctly bedded, but appears to be thick-bedded; black, phosphatic grains and fossil fragments; numerous micro-vugs; cliff-forming and resistant	26	166
3	Siltstone, quartzose, very dolomitic, in part may be classed as finely crystalline, silty, carbonaceous, pyritiferous, and slightly phosphatic dolomite; yellowish grey to dark grey with brown tint, weathering light yellowish grey; indistinctly bedded, appears medium- to thick-bedded; very wavy, irregular, hair-like carbonaceous-pyritiferous laminations; in part mottled; blue-black, phosphatic Lingulid fragments throughout unit; black, phosphatic grains and fragments; micro-vugs in part; resistant	60	140
2	Siltstone, quartzose, very dolomitic and may be in part, classed as silty, quartzose, finely crystalline dolomite; carbonaceous, and pyritiferous; light olive-grey to medium dark grey, weathering yellow-grey; indistinctly bedded, but appears thick-bedded; indeterminate brachiopod and pelecypod molds and casts in lower 30 feet (GSC loc. 58409) phosphatic <u>Lingula</u> and <u>Orbiculoidea</u> fragments in upper 20 feet; dark grey-black, well-rounded, phosphate grains and fragments in part; some wavy, hair-like, carbonaceous laminations; weathers rubbly in part; massive; resistant	60	80

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
1	Siltstone, quartzose, micromicaceous, very dolomitic, carbonaceous, and pyritiferous; dolomite very finely to finely crystalline; dolomite in part as cement; medium to medium dark grey, weathering yellow-grey; indistinctly bedded; weathers shaly to flaggy in part; lower 10 feet transitional to underlying Whistler Member; resistant	20	20

Section 4. Whistler Member; Whistler Creek; SE$\frac{1}{4}$ Sec. 11, Twp. 54, Rge. 8W6. Measured on the southwest limb of prominent anticline near head of Whistler Creek.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Whistler Member (100 feet) (Type Section)		
4	Siltstone to dolomite, quartzose, pyritiferous, argillaceous, and probably carbonaceous; medium dark grey to dark grey with slight brown tint, weathering same; indistinctly bedded; unit contains Daonella sp. Gymnotoceras sp. in upper 1 foot (GSC loc. 58395); pyrite-stained in part; unit forms sharp contact with overlying member; contact defined by more resistant, more quartzose overlying beds; fossils present in upper 6 inches along contact; unit recessive	5	100
3	Covered interval, talus consists of shaly siltstone to dolomite and silty shale; well-laminated in part; shale very soft and crumbly	55	95
2	Siltstone to dolomite, quartzose, carbonaceous, pyritiferous, and possibly argillaceous; micromicaceous partings; dark grey to dark olive-grey, weathering dark brownish grey; indistinctly bedded; fine regular to slightly wavy, pyritiferous, light grey, quartz-dolomite laminations; unit in part weathers flaggy in one-half inch to 1 inch slabs; recessive	30	40
1	Siltstone, quartzose, very dolomitic, pyritiferous, carbonaceous; unit may be classed as silty quartzose dolomite; micromicaceous; dark olive-grey to medium dark grey, weathering dark brownish grey; indistinctly bedded; fine, pyritiferous, lenticular laminations; unit weathers shaly to flaggy; no obvious pebble-conglomerate at base,		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	but possibly present in pockets; very sharp lithologic change with underlying Vega Siltstone Member; unit recessive	10	10

Section 5. Vega Siltstone Member; Mowitch Creek; Sec. 30, Twp. 51, Rge. 5W6, and Sec. 25, Twp. 51, Rge. 6W6. Measured on the north side of Mowitch Creek commencing one-half mile due south of Vega Peak, Jasper National Park.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Vega Siltstone Member (284 feet) (Type Section)		
6	Siltstone, quartzose, very dolomitic, slightly carbonaceous and argillaceous; carbonate finely to very finely crystalline; medium to medium dark grey with slight brown tint, weathering medium to dark grey-brown to yellow-brown; thin- to medium-bedded, beds up to $1\frac{1}{2}$ feet thick; thin beds display fine, wavy to regular, light and dark grey laminations, thicker beds faintly laminated to non-laminated; micromicaceous bedding surfaces; unit in part classed as silty quartzose shale; poorly developed flow rolls in upper 30 feet; typical cyclical development characteristic of member; weathers flaggy in part; slightly recessive	72	284
5	Siltstone, quartzose, very dolomitic, may be in part classed as silty, quartzose, dolomite, slightly carbonaceous and possibly argillaceous; carbonate finely crystalline; medium to medium light grey, weathering medium to dark grey-brown; thin- to medium-bedded, beds up to $1\frac{1}{2}$ feet thick; fine, regular to slightly wavy laminations; bedding in part wavy to lenticular; micromicaceous bedding planes; shaly-weathering strata intercalated with flaggy- to blocky-weathering beds; small normal faults within interval; resistant	52	212
4	Siltstone, same as unit 5, except for more shaly-weathering, siltstone intercalations; slightly recessive	70	160

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
3	Siltstone to silty shale, quartzose, carbonaceous and argillaceous, very dolomitic in part; medium grey, weathering dark grey to rusty brown; thin- to medium-bedded, beds up to 10 inches thick; fine, regular to wavy, light and dark grey laminations; micro-micaceous bedding planes; weathers mainly shaly, but flaggy in part; slightly recessive	20	90
2	Siltstone, quartzose, dolomitic, carbonaceous, and slightly argillaceous; carbonate, finely to very finely crystalline; medium to medium light grey, weathering rusty brown to dark grey-brown; thin- to medium-bedded, beds up to 1½ feet thick; thin beds display fine, wavy to regular laminations, thicker beds faintly to non-laminated; micromicaceous bedding planes; bedding wavy to lenticular in part; typical cyclical development which is characteristic of member, although contains a higher percentage of laminated, shaly-weathering beds; recessive	30	70
1	Siltstone, quartzose, very dolomitic, slightly carbonaceous and argillaceous; light to medium light grey with slightly brownish tint, weathering dark grey-brown to rusty brown; thin- to medium-bedded, beds up to 1½ feet thick; thin beds weather very shaly and display fine, regular to lenticular, light and dark grey laminations; thicker beds generally not laminated; bedding in part wavy to lenticular; small amounts of black phosphate chips near base; resistant to slightly recessive; base of unit contact with underlying Phroso Siltstone Member	40	40

Section 6. Phroso Siltstone Member; Phroso Creek; NW$\frac{1}{4}$ Sec. 4, Twp. 54, Rge. 7W6. Measured on east side of Phroso Creek, immediately below main creek gorge.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Phroso Siltstone Member (386 feet) (Type Section)		
8	Siltstone, quartzose, very dolomitic, slightly carbonaceous; micromicaceous; medium to medium dark grey, weathering dark brownish grey; indistinctly bedded except for the upper 1 foot which contains beds up to 2 inches thick; weathers shaly to flaggy in lower part; unit forms prominent contact with thicker-bedded, overlying, Vega Siltstone Member, slightly recessive to resistant	6	386
7	Siltstone, quartzose, dolomitic, carbonaceous, and slightly pyritiferous, micromicaceous; medium to medium dark grey, weathering dark grey to dark brownish grey; indistinctly bedded; fine, very regular, pyritiferous-carbonaceous laminations; weathers very shaly; fissile, soft, and crumbly in part; cliff-forming; slightly recessive to resistant	20	380
6	Siltstone, quartzose, very dolomitic, carbonaceous, pyritiferous, micromicaceous; medium dark grey, weathering dark brownish grey; indistinctly bedded, but appears medium- to thin-bedded; fine, regular to lenticular pyritiferous-carbonaceous laminations; white calcite-filled fractures cross-cutting bedding; slump structures in upper 10 feet; massive, but where well-exposed very fissile; resistant to slightly recessive	70	360

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
5	Siltstone, quartzose, very dolomitic, carbonaceous and/or pyritiferous, micromicaceous; medium dark to dark grey, weathering dark greyish brown; indistinctly bedded; fine, regular to lenticular, pyritiferous-carbonaceous laminations; a few pyrite bands up to one-quarter inch thick; small amounts of black, phosphatic grains; unit weathers shaly to flaggy; 3-inch thick non-laminated siltstone bed in lower 10 feet; fissile in part; partly covered; slightly recessive to recessive	100	290
4	Siltstone, quartzose, very dolomitic, carbonaceous and/or pyritiferous, micromicaceous; medium dark to dark grey, weathering dark brownish grey; indistinctly bedded; fine to coarse, wavy to irregular, pyritiferous-carbonaceous laminations; poorly developed cross-laminations; scattered pyrite nodules up to one-half inch in diameter; massive in part; in part weathers shaly to flaggy; slightly recessive	80	190
3	Siltstone, quartzose, dolomitic, very pyritiferous and/or carbonaceous, micromicaceous; dark grey, weathering dark grey to dark brownish grey; indistinctly bedded, appears to be medium- to thin-bedded in places; weathers shaly to flaggy owing to the regular to lenticular, pyritiferous-carbonaceous laminations; white, hair-like, calcite fractures crosscutting bedding planes; very fissile in part; recessive	60	110
2	Siltstone, quartzose, pyritiferous, carbonaceous, dolomitic, micromicaceous; medium dark to dark grey, weathering dark grey; indistinctly bedded, appears to be medium-bedded; wavy to irregular, pyritiferous-carbonaceous laminations; weathers shaly to flaggy in part; several thin pyrite lenses and bands up to one-quarter inch thick in upper 10 feet; slightly recessive to recessive	40	50

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
1	Sandstone to siltstone, quartzose, dolomitic, phosphatic; very fine-grained; medium to medium dark grey, weathering dark grey; indistinctly bedded; regular to wavy laminations; lowermost 3 inches consist of conglomerate with pebbles consisting of black, phosphatic, quartzose sandstone up to 2 inches in diameter; conglomerate is pyritiferous; unit forms base of Sulphur Mountain Formation, in part covered; slightly recessive to recessive	10	10
	Underlying strata consist of quartz sandstones of Rocky Mountain Group		

Section 7. Type Section of the Sulphur Mountain Formation; confluence of Goat Creek and Spray River, Banff National Park. Section begins in first intermittent stream gully downstream from junction of Goat Creek and Spray River, and terminates at south end of Spray River Gorge.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	WHITEHORSE FORMATION (Incomplete)		
29	Dolomite, very quartzose in part and may be classed as dolomitic siltstone; very finely crystalline to aphanitic; medium grey to yellowish grey, weathering greyish yellow to yellowish orange; medium-bedded; very vuggy and porous in part; breaks with subconchoidal fracture; unit represents top of controllable outcrop, overlying unit contorted	55	1441
28	Limestone, sandstone, and some dolomite; quartzose; dolomite very silty in part, and may be classed as a dolomitic, quartz siltstone; limestone, medium to coarsely crystalline, and in part very quartzose; sandstone, fine- to medium-grained, quartzose, calcareous and poorly indurated; unit yellowish grey to light to medium light grey, weathering light grey to greyish yellow; very chalky in part; medium-bedded; unit poorly indurated; very porous and vuggy in part; weathers recessive; unit forms sharp and abrupt contact with underlying Sulphur Mountain Formation; Whitehorse Formation measured on southeast side of river at head of artificial pond	83	1386
	SULPHUR MOUNTAIN FORMATION (1,303 feet) Llama Member (20 feet)		
27	Siltstone, quartzose, dolomitic, possibly carbonaceous-argillaceous; carbonate very finely crystalline; medium grey with slight olive tint, weathering dark yellow-grey-brown; medium-bedded, beds up to $2\frac{1}{2}$ feet thick; fine, dark		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	grey, lenticular laminations; well-indurated; blue-black, phosphatic, lingulid fragment near top; unit forms very prominent dip slope at contact with Whitehorse Formation; resistant and cliff-forming	20	1303
	Whistler Member (44 feet)		
26	Siltstone, quartzose, dolomitic, carbonaceous and possibly argillaceous; medium dark to dark grey, weathering same; indistinctly bedded; fine, regular, light grey laminations; small micro-aggregates of pyrite; micro-vugs filled with white calcite near top; few weathered pyrite nodules up to 1 inch in diameter; unit appears more quartzose near Llama Member contact; unit forms sharp contact with resistant Llama Member; weathers recessive	18	1283
25	Covered interval, on opposite side of pond, strata same as above; interval forms sharp contact with underlying Vega Siltstone Member; unit recessive	26	1265
	Vega Siltstone Member (1, 089 feet)		
24	Siltstone and minor dolomite, quartzose, slightly pyritiferous; dolomite occupies upper 4 feet and is slightly quartzose and calcareous, finely to medium crystalline, light grey to yellow-grey mottled, weathers yellowish grey; dolomite contains few micro-vugs filled with weathered pyrite; siltstone is dolomitic and slightly carbonaceous and ferruginous; light olive-grey with slight bluish tint, weathering dull brownish grey; medium- to thick-bedded, beds up to 10 feet thick; fine, regular to slightly wavy laminations in part; massive flow rolls at base; well-indurated; very resistant and forms sharp contact with overlying Whistler Member	79	1239

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
23	Siltstone, quartzose, slightly dolomitic, carbonaceous-argillaceous, and slightly pyritiferous; medium light to medium dark grey with yellowish grey laminations, weathering greyish brown; indistinctly bedded, but appears thin- to medium-bedded; fine to coarse, wavy to lenticular cross-laminations; unit weathers shaly to flaggy; 2-foot thick non-laminated bed 30 feet from base; resistant	63	1160
22	Siltstone, quartzose, dolomitic, slightly ferruginous; unit may be, in part, classed as very fine-grained sandstone; medium grey with slight olive tint, weathering yellowish grey-brown; thin- to thick-bedded, with beds in centre of unit up to 3 feet thick; thin beds contain fine to coarse, lenticular to wavy, laminations; thicker beds faintly to non-laminated; unit slightly recessive	26	1097
21	Siltstone, quartzose, cherty, slightly dolomitic, and possibly carbonaceous-argillaceous; medium to medium dark grey with slight bluish tint, weathering medium grey; medium- to thick-bedded, beds up to 3 feet thick; thick beds contain well-rounded, silicified "balls" or concretions, ranging between 6 and 10 inches in diameter; some wavy, coarse, chert bands in part; trace of coarse, regular to slightly wavy, light grey laminations; resistant	19	1071
20	Siltstone, quartzose, slightly carbonaceous-argillaceous, and dolomitic, possibly ferruginous; medium to medium light grey, weathering dark brownish grey; medium- to thin-bedded, beds up to 10 inches thick; beds very wavy to lenticular, and display "nobby" bedding planes; fine to coarse, regular to wavy, laminations; a little soft sediment slumping; resistant	20	1052

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
19	Siltstone, quartzose, very dolomitic, carbonaceous, slightly ferruginous; carbonate finely crystalline; medium dark grey, weathering same; medium- to thin-bedded; fine, regular to slightly wavy, light grey laminations; resembles Phroso Siltstone strata in part; slightly recessive to resistant	24	1032
18	Covered interval	17	1008
17	Siltstone, quartzose, dolomitic, possibly carbonaceous-argillaceous, and ferruginous; medium dark grey, weathering greyish brown; medium- to thin- to indistinctly bedded; medium beds up to 1 foot thick; unit displays fine, regular to slightly wavy laminations; resistant and cliff-forming	36	991
16	Siltstone, quartzose, dolomitic, carbonaceous, slightly pyritiferous; medium dark grey, weathering same; indistinctly bedded; fine, light grey, regular to lenticular, laminations; resembles strata of Phroso Member; slightly recessive	5	955
15	Covered interval, no outcrop but may represent a Phroso facies; very recessive	75	950
14	Siltstone, quartzose, dolomitic, carbonaceous; medium to medium light grey, weathering greyish brown; thin- to medium-bedded, beds up to 15 inches thick; thin beds display fine, regular laminations; thicker beds faintly to non-laminated; unit displays cyclical bedding characterisitic of Vega Siltstone Member in Jasper region; unit slightly recessive to resistant	15	875

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
13	Siltstone, quartzose, very calcareous, and may be, in part, classed as silty limestone; possibly carbonaceous-argillaceous; carbonate finely to medium crystalline; medium grey with slight olive tint, weathering brownish grey with white oxide coating in part; thin-bedded, beds up to 2 inches thick; fine to coarse, regular to wavy, laminations; thicker beds more calcareous; thinner beds have micaceous bedding surfaces; weathers shaly to flaggy; lower 75 feet resistant, remainder recessive	108	860
12	Siltstone, quartzose, very calcareous, and may be, in part, classed as silty limestone; carbonaceous-argillaceous; carbonate finely to medium crystalline; medium to medium dark grey, weathering dark brownish grey; thin- to medium- to indistinctly bedded; fine, regular to very wavy, crenulated laminations; few beds up to 6 inches thick with micro cross-laminations; calcite content decreases toward base; unit weathers very shaly to flaggy; indeterminate fossil fragments in upper half of unit; white oxide coating in part; slightly recessive	86	752
11	Siltstone, quartzose, dolomitic, slightly calcareous in part, possibly carbonaceous-argillaceous; medium to medium dark grey, weathering greyish brown; thin- to medium-bedded, beds up to 2 feet thick; thin beds display fine, regular to lenticular, light grey laminations; thicker beds faintly to non-laminated; unit displays typical cyclical development characteristic of member in other regions; large dragfold in lower 25 feet; resistant	47	666

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
10	Siltstone, quartzose, dolomitic, very calcareous in part, possibly argillaceous-carbonaceous; carbonate finely crystalline; medium grey, weathering greyish brown; thin- to medium-bedded, beds up to 8 inches thick; fine, wavy to lenticular laminations; beds wavy to lenticular; bounce casts in upper bed of unit; centre of unit weathers very shaly; small amounts of micro cross-laminations; base of unit adjoins dam; unit slightly recessive to resistant; base of unit begins section in Spray River Gorge	87	619
9	Covered interval; no outcrop except near top which is same as overlying unit; taped interval measured from gulley on east side of Spray River, immediately below confluence of Goat Creek, to base of fish dam on west side of Spray River	204	532
8	Siltstone, quartzose, dolomitic, very calcareous in part, carbonaceous-argillaceous; possibly pyritiferous; medium dark grey, weathering greyish brown to rusty brown; thin- to medium-bedded, beds up to 10 inches thick; becomes thinner-bedded toward top; beds wavy and lenticular, and display "nobby" bedding surfaces in part; fine to coarse, wavy to lenticular laminations; thin shale partings between beds; unit represents end of outcrop in stream gully; resistant	22	328
7	Siltstone to silty shale, quartzose, dolomitic, very carbonaceous-argillaceous; siltstone beds very calcareous, and may be, in part, classed as silty limestone; medium dark to dark grey, weathering same with slight brown tint; indistinct to thin-bedded; thin beds up to 2 inches thick are very lenticular, very calcareous, and display fine micro cross-laminations; unit weathers very shaly to flaggy; shaly beds display fine, regular to slightly lenticular laminations; unit		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	resembles Phroso Siltstone facies; recessive to slightly recessive	63	306
6	Siltstone, quartzose, dolomitic, very calcareous in part, carbonaceous-argillaceous; carbonate finely crystalline; medium grey, weathering dark grey-brown to brownish grey; mainly thin-bedded, but few lenticular, very calcareous beds up to 3 inches thick; unit displays fine, regular to wavy to cross-laminations; weathers flaggy; ripple-marks high on cliff; slightly recessive	43	243
5	Siltstone, quartzose, calcareous, carbonaceous-argillaceous; medium dark to dark grey, weathering dark grey brown; thin- to medium-bedded, beds up to 10 inches thick; thin beds display fine, regular to lenticular laminations; thicker beds faintly to non-laminated; few recessive weathering shale zones near base; beds in part lenticular; upper 25 feet forms waterfall; indeterminate ammonite impressions and pelecypods collected from upper 10 feet, (GSC loc. 52944) <u>Claraia</u> <u>stacheyi</u> Bittner; Unit resistant and represents base of Vega Siltstone Member	50	200
	<u>Phroso Siltstone Member (150 feet)</u>		
4	Siltstone, to silty shale, quartzose, calcareous, very carbonaceous, possibly argillaceous and ferruginous; dark grey, weathering same; thin-bedded, beds up to 2 inches thick; beds display fine, regular to lenticular laminations; few thin, wavy, laminated, very calcareous, fossiliferous siltstone beds in lower 10 feet; weathers shaly to flaggy; recessive to slightly recessive	25	150

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
3	Siltstone to silty shale, quartzose, dolomitic, very carbonaceous, slightly calcareous in part, pyritiferous in part; dark grey, weathering same; indistinctly bedded; few beds up to 8 inches thick near top; fine, regular, light grey laminations, thicker beds display micro cross-laminations; white oxide coating on bedding surfaces; typical Phroso strata; weathers very shaly; recessive	50	125
2	Covered interval, except for small outcrop in lower 15 feet which is same as unit 1; very recessive	38	109
1	Siltstone to silty shale, very quartzose, and carbonaceous, pyritiferous, possibly dolomitic; dark grey and weathering same; appears to be thin-bedded except for a 1-foot thick bed at base containing black, siliceous, phosphate nodules, and concretions of weathered pyrite; fine, regular, light grey laminations; very soft, recessive shale zones; unit forms disconformable contact with Rocky Mountain Group; slightly recessive	16	16

PLATES I-VIII

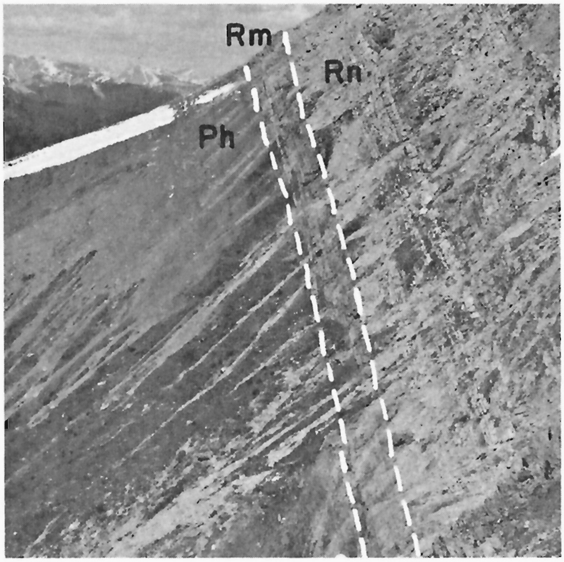

Plate I A.

Contact of Phroso Siltstone Member with Rocky Mountain Group, east side of Sulphur River near Zenda Creek (bedding overturned). Rundle Gp. (Rn); Rocky Mountain Gp. (Rm); Phroso Mbr. (Ph).

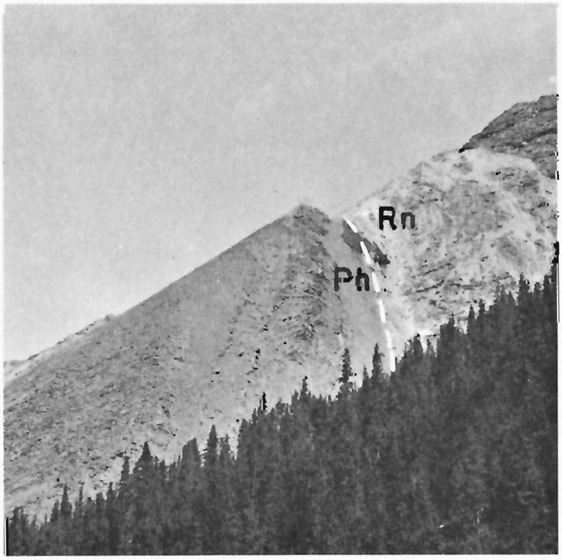

Plate I B.

Contact of Phroso Siltstone Member with Rundle Group at Mumm Creek, illustrating absence of Rocky Mountain Group.

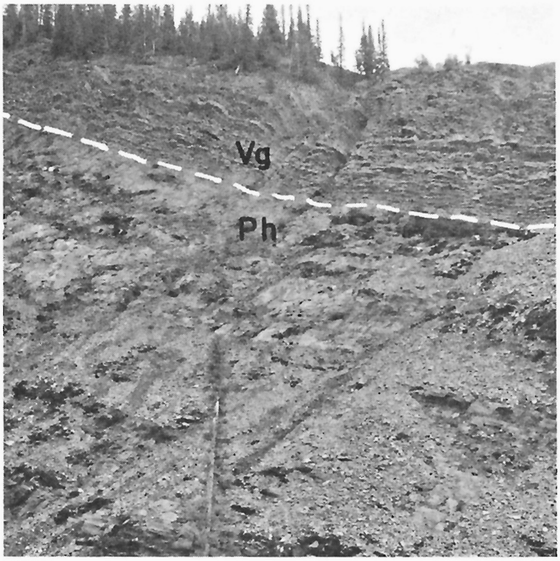

Plate II A.

Contact of Phroso and Vega Siltstone Members at Sulphur Mountain, illustrating prominent lithological change at contact. Phroso Siltstone Mbr. (Ph); Vega Siltstone Mbr. (Vg).

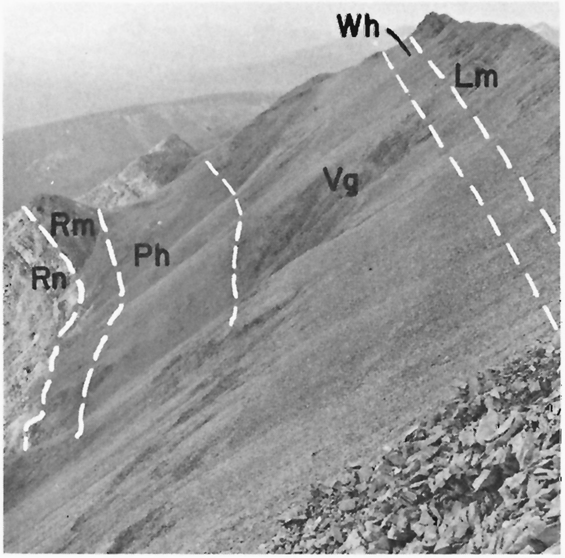

Plate II B.

Type section of Llama Member at Llama Mountain; showing contrast in lithology between light-weathering Rundle Group and the Sulphur Mountain Formation. Rundle Gp. (Rn); Rocky Mountain Gp. (Rm); Phroso Siltstone Mbr. (Ph); Vega Siltstone Mbr. (Vg); Whistler Mbr. (Wh); Llama Mbr. (Lm).

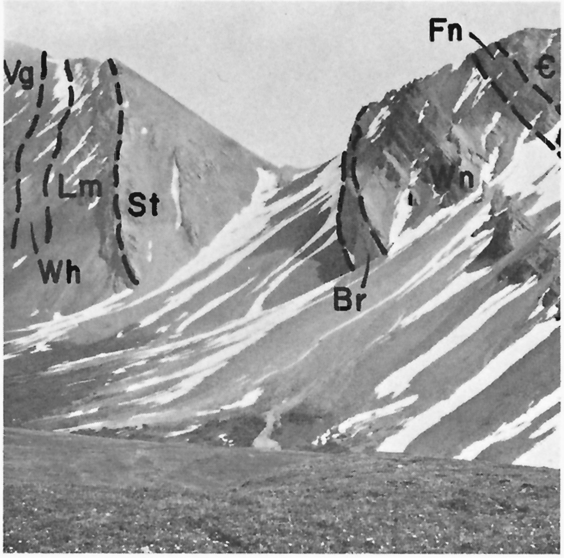

Plate III A.

Contact and lithologic relationships between the Whistler, Llama, Starlight Evaporite, Brewster Limestone, and Winnifred Members at Dinosaur Pass. Vega Siltstone Mbr. (Vg); Whistler Mbr. (Wh); Llama Mbr. (Lm); Starlight Evaporite Mbr. (St); Brewster Limestone Mbr. (Br); Winnifred Mbr. (Wn); Fernie Gp. (Fn).

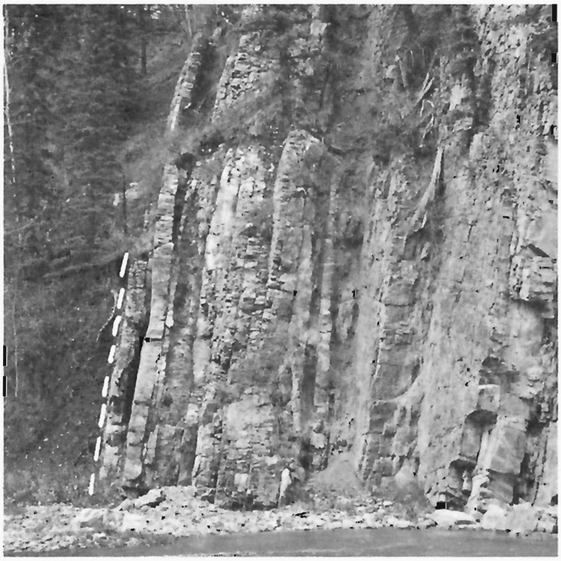

Plate III B.

Contact of Whitehorse Formation and Fernie Group on Fiddle River; note resistant light-weathering nature of Winnifred Member.

Plate IV A.

Flow rolls near top of Vega Siltstone Member, illustrating rounded nature and concentric layering. Seep Creek.

Plate IV B.

Plan view of flow roll bed showing resemblance to boulder conglomerate; note different weathering resistance between rolls and surrounding matrix. Wild Hay River.

Plate V A.

Large scale cross-stratification in the Starlight Evaporite Member at Corser Gulch.

Plate V B.

Flute casts from the Vega Siltstone Member. Lancaster Creek.

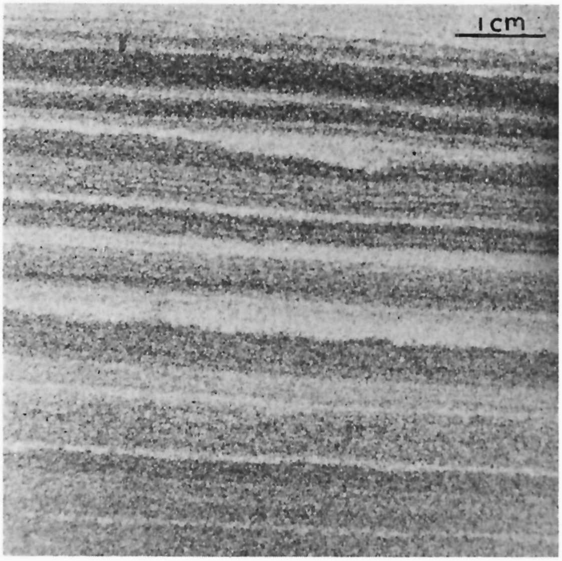

Plate VI A.

Fine, regular laminations from strata of Phroso Siltstone Member.

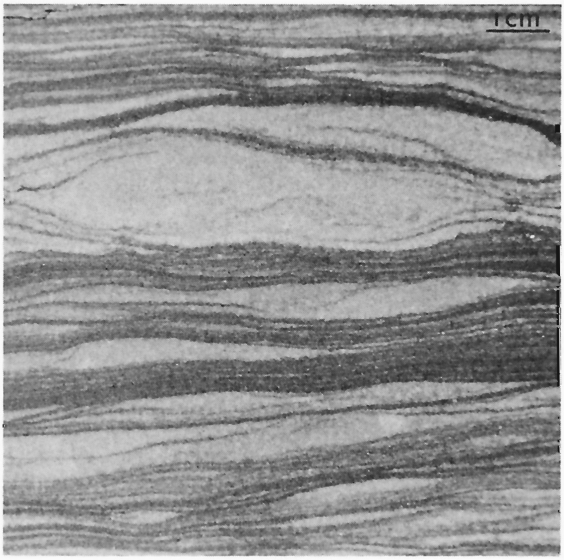

Plate VI B.

Fine, wavy to lenticular laminations from strata of the Phroso Siltstone Member; note similarity to laminae characteristic of a tidal flat environment.

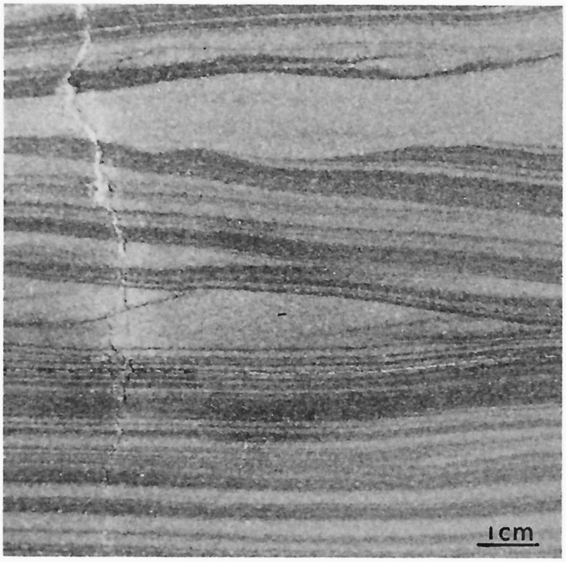

Plate VII A.

Fine, regular laminations at base grading upward into wavy, lenticular laminae with some small-scale cross-laminations in centre. Phroso Siltstone Member.

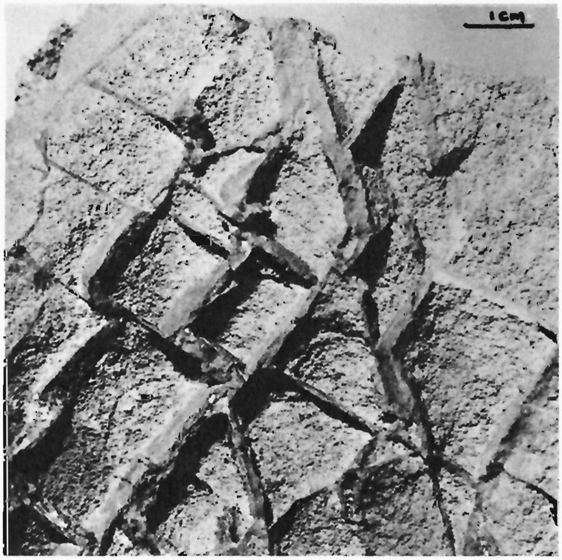

Plate VII B.

"Box work" or "honey comb" texture found in strata of Starlight Evaporite Member.

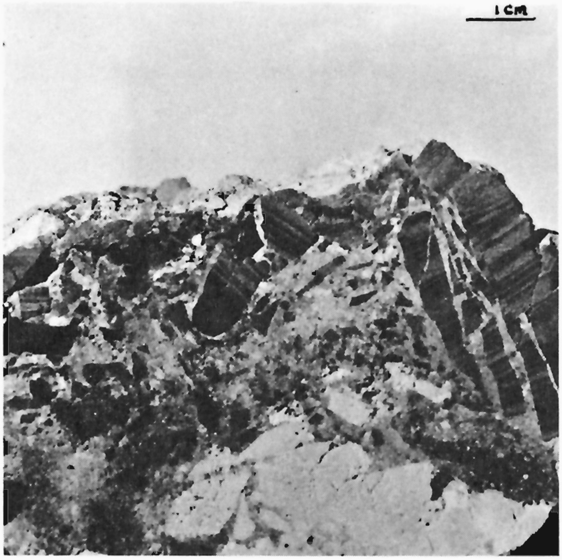

Plate VIII A.

Collapse or solution breccia showing angular laminated nature of fragments. Fiddle River.

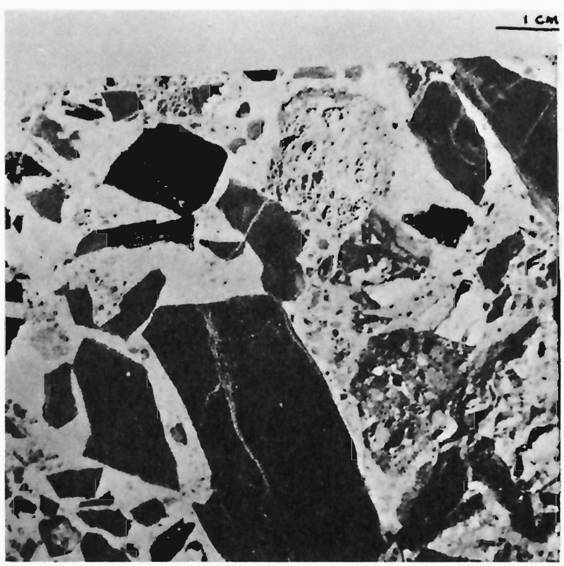

Plate VIII B.

Collapse breccia illustrating porous and angular nature of fragments in a coarsely crystalline limestone matrix. Natural Arch.