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STRATIGRAPHY, SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENTS OF THE COAL-BEARING JURASSIC-CRETACEOUS KOOTENAY GROUP, ALBERTA AND BRITISH COLUMBIA

D.W. GIBSON

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Technical editor

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Word processing

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Artwork by CARTOGRAPHY UNIT
Institute of Sedimentary and Petroleum Geology

Author's address

Geological Survey of Canada
Institute of Sedimentary and Petroleum Geology
3303 - 33rd Street N.W.
Calgary, Alberta T2L 2A7

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PREFACE

Strata of the Kootenay Group have long been of economic interest because of their potential as important sources of thermal and metallurgical coal in Western Canada, but prior to this report little was known about the detailed regional lithostratigraphy and sedimentology of this important coal-bearing succession. In 1975, the author began a four-year investigation of the Kootenay Group. This bulletin provides substantial new information and data on the Kootenay Group in the form of text, isopach maps and cross-sections, and numerous illustrations of lithofacies, lithofacies relationships, age, correlation, rank, distribution and continuity of coal seams, sedimentology, and the major environment of deposition in the Rocky Mountain Foothills and Front Ranges. A regional geological model is presented that will be of assistance in assessing the quality and potential of coal resources in the Kootenay Group in Alberta and British Columbia.

OTTAWA, January 1984

R.A. Price
Director General
Geological Survey of Canada

PRÉFACE

Les couches du groupe de Kootenay sont depuis longtemps d'un intérêt économique certain de l'Ouest canadien à cause de leur potentiel important en charbon à des fins thermiques et mètallurgiques; mais, il est à remarquer qu'avant la parution de ce rapport on possédait très peu de renseignements régionaux d'ordre lithostratigraphique et sédimentologique sur cette importante séquence carbonifère. En 1975, l'auteur entreprit quatre ans de recherche sur le groupe de Kootenay aboutissant à la rédaction de cet ouvrage qui apporte de nouvelles informations sous différentes formes soit, par le texte, par les cartes isopaques et les coupes, par un grand nombre d'illustrations de lithofaciès et leurs inter-relations, renseignements précieux aussi apportés par l'âge, la corrélation, le range, la répartition et la continuité des couches charbonneuses, par le milieu et le mode de sédimentation dans les Foothills et les chaînes Frontales. Le modèle géologique régional décrit apportera une aide des plus valables pour l'évaluation de la qualité et du potentiel des ressources en charbon du groupe de Kootenay localisé en Alberta et en Colombie-Britannique.

OTTAWA, janvier 1984

R.A. Price
Directeur général
Commission géologique du Canada

STRATIGRAPHY, SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENTS OF THE COAL-BEARING JURASSIC-CRETACEOUS KOOTENAY GROUP, ALBERTA AND BRITISH COLUMBIA

Abstract

Strata of the Jurassic-Cretaceous Kootenay Group have long been of economic interest as a readily accessible source of thermal and metallurgical coal. This report attempts to synthesize and describe the geology of the Kootenay Group on a regional basis, by providing detailed information and data on lithofacies, lithofacies relationships, correlation of major rock units, the distribution and continuity of coal seams, and major environments of deposition.

The Kootenay Group, up to 1112 m thick, comprises three formations which, in ascending order, are: the Morrissey, which ranges in measured thickness from 20 to 80 m and comprises a massive cliff-forming succession of fine- to medium-grained sandstone; the Mist Mountain, ranging in measured thickness from 25 to 665 m and comprising an interbedded succession of predominantly nonmarine sandstone, siltstone, mudstone, rare conglomerate, and economically important thin to thick seams of coal; and the Elk, ranging in measured thickness from a zero erosional edge to 590 m and comprising an interbedded sequence of nonmarine sandstone, siltstone, mudstone, shale and, locally, chert-pebble conglomerate and thin seams of coal. The Morrissey Formation can be further subdivided throughout most of the area into the Weary Ridge (lower) and Moose Mountain members.

Economically, the Mist Mountain Formation is the most important formation of the Kootenay Group, containing coal seams up to 18 m thick, which range in rank from medium to high volatile bituminous in the south, to low volatile bituminous to semianthracite in the north. Seams are thicker and more numerous in areas of the Fernie Basin and upper Elk River valley. Coal seams in the Elk Formation are thin, less abundant, regionally discontinuous, and generally lower in rank than those in the Mist Mountain Formation. Coal in the Morrissey Formation is rare and of no economic value.

Petrographic analyses of many thin sections from the Kootenay Group indicate two main detrital components, quartz and lithic rock fragments, the latter including several varieties of chert; grains and pebbles of sedimentary quartzite or quartz arenite; grains of dolostone and limestone, commonly sandy to silty; grains and pebbles of silicified mudstone-argillite; and grains of collophane. The cement consists predominantly of quartz and chert, and less commonly dolomite, calcite and rare clay minerals. Composition and textural relationships indicate that most, if not all, detrital components were derived from pre-existing sedimentary rocks located east of the Rocky Mountain Trench.

The analysis of sedimentary facies, facies relationships, petrographic data, the presence or absence of characteristic megafossil, microfossil and microfloral assemblages, suggest that strata of the Kootenay Group formed part of a major, prograding, clastic wedge, deposited within three major depositional environments. The Morrissey Formation is diagnosed as a beach, beach ridge, and coastal dune depositional environment. The overlying Mist Mountain Formation is interpreted as a fluvial-deltaic-interdeltaic clastic succession, deposited in an environment largely unaffected by marine or brackish water inundations. The Elk Formation represents deposition within a major, coastal, fluvial-alluvial plain depositional environment. In the Front Ranges of the southern Rocky Mountains, the Elk contains strata characteristic of a distal alluvial fan or braidplain depositional environment.

Résumé

Les couches du groupe de Kootenay du Jurassique-Crétacé ont depuis longtemps été une source facilement accessible de charbon thermique et de charbon métallurgique. Le présent rapport résume et décrit la géologie régionale du groupe de Kootenay en fournissant des renseignements et des données détaillés sur les lithofaciès, les liens entre lithofaciès, la corrélation des unités rocheuses majeures, la répartition et la continuité des filons houillers et les milieux importants de sédimentation.

Le groupe de Kootenay, d'une épaisseur maximale de 1112 m, comprend les trois formations suivantes, en ordre ascendant: la formation de Morrissey, dont l'épaisseur mesurée varie de 20 à 80 m, composée d'une succession escarpée de grès fins à moyens; la formation de Mist Mountain, dont l'épaisseur mesurée varie de 25 à 665 m, composée d'une succession interstratifiée de grès d'origine principalement non marine, de silstone, de mudstone, de rares conglomérats et de filons houillers minces à épais, économiquement importants; la formation d'Elk, dont l'épaisseur mesurée varie de zéro à la limite d'érosion à 590 m, composée d'une séquence interstratifiée de grès d'origine non marine, de silstone, de mudstone, de schiste et par endroits, d'un conglomérat à galets à chert et de minces filons houillers. La formation de Morrissey peut être subdivisée en deux niveaux presque partout dans la région: Weary Ridge, niveau inférieur, et Moose Mountain, niveau supérieur.

Du point de vue économique, la formation de Mist Mountain est la formation plus importante du groupe de Kootenay, puisqu'elle contient des filons houillers d'une épaisseur maximale de 18 m. Le charbon varie de la houille bitumineuse à moyenne teneur en matières volatiles à celle à haute teneur dans le sud à la houille bitumineuse à faible teneur en matières volatiles et à la houille anthraciteuse dans le nord. Les filons sont plus épais et plus nombreux dans la région du bassin de Fernie et de la vallée supérieur de la rivière Elk. Les filons houillers de la formation d'Elk sont minces, moins abondants, régionalement discontinus et généralement de classe inférieure à ceux de la formation de Mist Mountain. Le charbon est rare et sans importance économique dans la formation de Morrissey.

L'analyse pétrographique de nombreuses lames minces du groupe de Kootenay indique la présence de deux composants détritiques; le quartz et les fragments de roches lithiques; ces derniers comprennent plusieurs variétés de chert, des grains et des galets de quartzite sédimentaire ou de quartz-arénite, des grains de dolostone et de calcaire souvent sableux à limoneux, des grains et des galets de mudstone-argilite silicifiée et des grains de collophane. Le ciment est composé surtout de quartz et de chert et moins souvent de dolomite, de calcite et de rares minéraux argileux. La composition et les relations texturales indiquent que la majorité, sinon la totalité, des composants détritiques provient de roches sédimentaires déjà existantes situées à l'est du sillon des Rocheuses.

L'analyse des faciès sédimentaires, des liens entre les faciès, des données pétrographiques, de la présence ou de l'absence des macrofossiles caractéristiques, des assemblages microfossiles et microfloraux laisse supposer que les couches du groupe de Kootenay faisaient partie d'une couche clastique progradante majeure qui s'est accumulée dans trois milieux importants de sédimentation. La formation de Morrissey se serait accumulée dans un milieu de plage, de levée de plage et de dune littorale. La formation susjacente de Mist Mountain représenterait une succession fluviale-deltaïque-interdeltaïque, déposée dans un milieu peu influencé par les inondations d'eau marine ou saumâtre. La formation d'Elk représenterait l'accumulation dans une importante plaine alluviale-fluviale côtière. Dans les chaînes avancées des Rocheuses du sud, la formation d'Elk contient des couches de sédimentation caractéristiques d'une plaîne anostomosée ou un cône de déjection distal.

INTRODUCTION

The Jurassic-Cretaceous Kootenay Group occupies part of a northwest trending belt of predominantly nonmarine rocks comprising part of the Rocky Mountain Foothills and Front Ranges of southwestern Alberta and southeastern British Columbia. The Kootenay Group extends from just north of the United States border in the south to the North Saskatchewan River in the north, where it grades laterally into the more marine strata of the Nikanassin Formation (Fig. 1).

Strata of the Kootenay Group have long been of economic interest because of their potential as readily accessible sources of thermal and coking coal, and many geological maps and reports have been prepared over the past 80 years, describing in varying detail the geology and distribution of the Kootenay Group. Many of these reports, however, have been of a specialized interest, dealing with such topics as palynology, paleobotany, sedimentary and coal petrography, and coal rank distribution, or have formed part of regional mapping projects encompassing rocks of all geological ages. Attempts to synthesize, describe in detail, discuss or relate the geology of the Kootenay Group on a regional basis, have been limited. In order to alleviate this problem the writer began a study of the Kootenay succession in 1975, in Alberta and British Columbia, to provide information and data on lithofacies, lithofacies relationships and correlation of major rock units, and the distribution and continuity of coal seams throughout all areas of Kootenay exposure in Alberta and British Columbia. In addition, it was anticipated that the study would provide new data on the major environments, sub-environments and history of deposition of the Kootenay rock succession, as a means of providing a regional geological model that would be of assistance in determining the potential coal resources of the area under study.

The stratigraphy, paleoenvironments and history of deposition of Kootenay strata in the Crowsnest Pass area of Alberta and British Columbia were documented in an earlier paper (Gibson, 1977b). The following report is a continuation of this work and supplements the earlier work by emphasizing the stratigraphy, petrology and correlation of the remaining area underlain by Kootenay strata to the north. Stratigraphic cross-sections, isopachous maps, and petrological data are included to illustrate the regional variations within and between each of the major members and formations of the Kootenay Group.

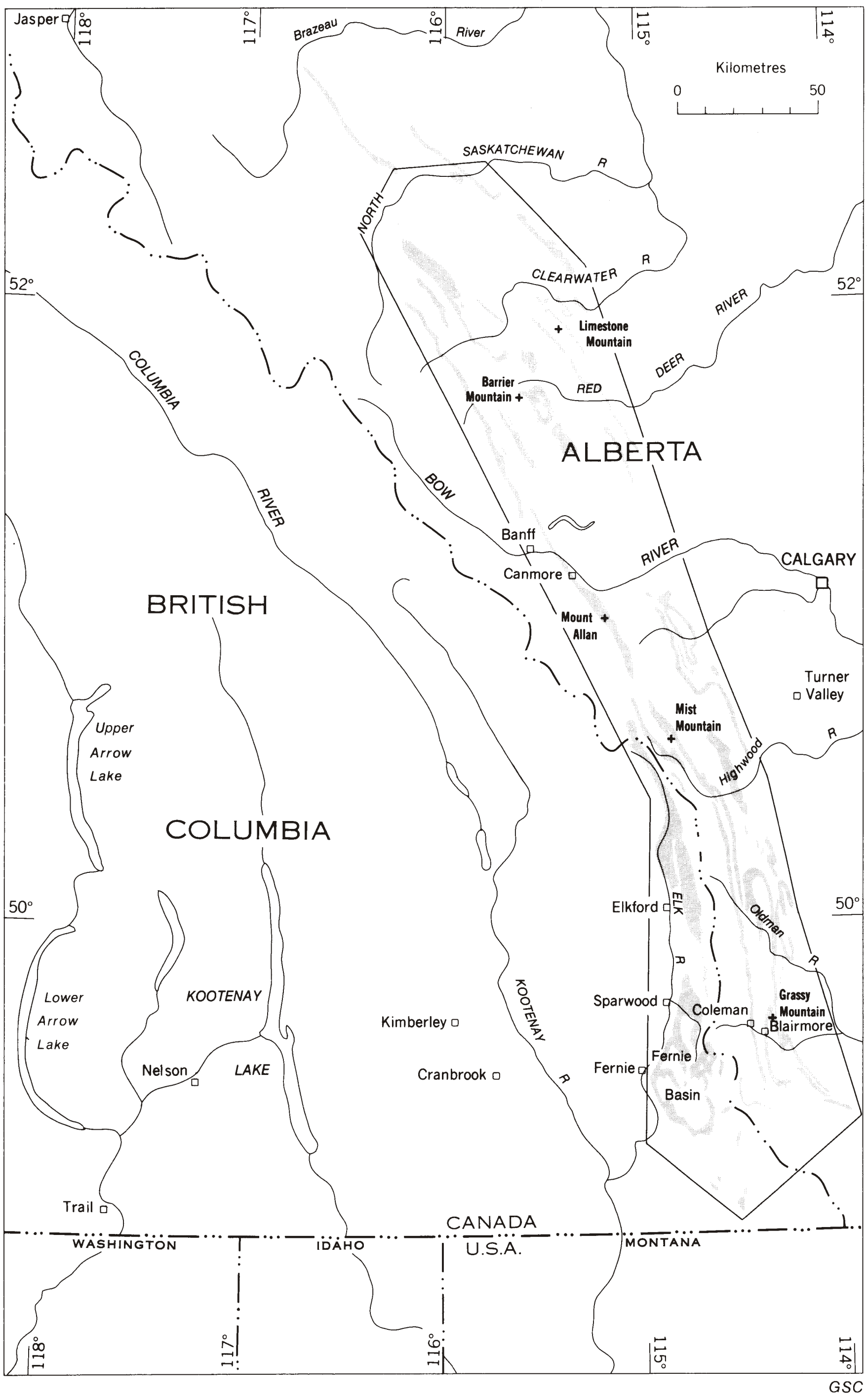

Figure 1. *Index map showing location of study area and geographic distribution of Kootenay Group.*

Previous work

In order to facilitate a chronological discussion of previous work on Kootenay rocks, the area of investigation covered by this report is divided into two parts: the Crowsnest Pass-Fernie Basin area to the south, and the Canmore-Cascade and Bow rivers area to the north. The southern area includes the Rocky Mountain Foothills and Front Ranges between the United States border and the Highwood and upper Elk rivers, while the northern region encompasses the Foothills and Front Ranges between Highwood-Sheep rivers and North Saskatchewan River – the northern limit of Kootenay coal-bearing rocks and limit of the writer's study (Fig. 1). It should be noted that some previous studies concerning Kootenay strata involve both areas.

Crowsnest Pass region

Upon completion of the trans-continental railway in 1885, Jurassic-Cretaceous strata in the Rocky Mountain Foothills and Front Ranges became of paramount interest as a readily accessible source of coal to power steam locomotives. Accordingly, many of the early Kootenay investigations were concerned mainly with the delineation, thickness, quantity and quality of the coal seams. Kootenay strata were first described by G.M. Dawson (1886), as part of a regional geological reconnaissance study in southwestern Alberta and southeastern British Columbia encompassing rocks of all geological ages. He named the coal-bearing sequence the "Kootanie series", a name which was later given formal recognition by J.W. Dawson (1886). Selwyn (1892), continued the reconnaissance work of G.M. Dawson by examining and describing other coal seams in the Crowsnest Coal Basin of British Columbia.

The first comprehensive study of Kootenay rocks and their coal resources was made by McEvoy (1901, 1902) in the area now defined as the Fernie Basin (Fig. 1). This work was continued by Leach (1902, 1903, 1912, 1914) who subsequently extended the investigation to include the Crowsnest Coal Field in the Blairmore-Coleman area to the east. Several maps and reports were prepared and in 1911 Leach (1912) revised the name Kootanie to Kootenay and named the succession the Kootenay Formation. Next, Robertson (1909, 1911) reported on Kootenay coals in the Michel Creek and Elk River areas, followed later by MacKenzie (1914) with an investigation of the Kootenay coals in the Blairmore and

Frank area. A synthesis of all published information on the Kootenay and its coal resources was documented by Dowling in 1915 (a, b). Geological investigations were continued in the region by MacKenzie (1916) and Stewart (1916), whose studies included strata of all geological ages. Interest in the Kootenay Formation then shifted to the Blairmore and Coleman areas of Alberta, where Rose (1917, 1918, 1919) began a comprehensive mapping and stratigraphic study of the Kootenay and associated rock formations. Rose (1917) redefined the upper contact of the Kootenay Formation by moving a long recognized conglomerate lithofacies from the Kootenay (present Cadomin Formation) into the overlying Blairmore Formation.

Interest in the Kootenay Formation of the Crowsnest Pass area followed a period of decline during the 1920's with only one report, on the flora of the Kootenay Formation, by Berry (1929). Field investigations were not resumed until MacKay (1931, 1933, 1934) began a geological study of the Kootenay and associated formations in 1931. Hage (1943) and Douglas (1949) provided new data on the distribution of the Kootenay and other formations in the eastern and northern parts of the Crowsnest Pass, while Bell (1946) provided new data on the age and contact relationships of the Kootenay in all areas of Alberta and British Columbia. Geological interest in the Kootenay was continued by Clow and Crockford (1951) in the Carbondale River area of Alberta, and by Newmarch (1953) in the Fernie area to the west. Newmarch (1953) divided the Kootenay into two units, naming the upper the Elk Formation, and retaining the name Kootenay for the lower coal-bearing facies. Norris (1955, 1957, 1958 a, b, 1959 a, b, 1964 a, b) undertook several regional mapping and stratigraphic and structural studies in the Foothills and Front Ranges of southwestern Alberta and southeastern British Columbia. He recognized three distinct rock units in the Kootenay Formation of the Livingstone River and Beehive Mountain areas of Alberta and British Columbia, and later, in 1959, formally proposed new members and a type reference section for the Kootenay Formation at Grassy Mountain. Regional mapping and stratigraphic studies were continued by Price (1962 a, b, 1965) in the area of Fernie and Flathead Valley to the west, areas underlain by a thick succession of Kootenay strata.

Reports on the macroflora and microflora of the Kootenay were prepared by Bell (1956), Rouse (1959), and Pocock (1964), followed by reports on the petrology and depositional environment of Kootenay rocks by Rapson (1964, 1965) and Jansa (1971, 1972). Because of the economic interest in the Kootenay Formation as an important source of coking and thermal coal in the mid to late 1960's, the Crowsnest Pass became an area of renewed interest to major mining companies and governmental agencies. Cameron and Babu (1968), Cameron (1972), and Hacquebard and Donaldson (1974) initiated studies on the petrography and rank of some of the major Kootenay coal seams. Recent work on the Kootenay includes detailed mapping, structural, stratigraphic and sedimentological studies of the Crowsnest Pass area by Pearson and Duff (1975), Pearson (1977), Pearson et al. (1977), Ollerenshaw (1977, 1981), Graham et al. (1977), Gibson (1977, 1979), Pearson and Grieve (1980), Hamblin and Walker (1979), Gibson and Hughes (1981), and Gibson, Hughes and Norris (1983).

Canmore-Cascade and Bow rivers region

The stratigraphy and coal resources of the Kootenay Formation in the Canmore-Cascade and Bow rivers area were briefly documented by Dawson and McConnell (1885) and G.M. Dawson (1886) as part of a regional geological study involving rocks of all ages in the Rocky Mountains and Foothills of southwestern Alberta and southeastern British Columbia. This reconnaissance work was extended by McConnell (1887), who described the coals in the Kootenay of the Bow and Kananaskis rivers area. Next, Poole (1903) documented coal occurrences and provided rank information on the coal at Anthracite, an abandoned town now included in Banff National Park. This work was followed by that of Dowling (1904, 1905, 1907a, b), who prepared geological maps and provided preliminary stratigraphic observations and coal seam information on the Cascade, Costigan, and Palliser coal basins between Bow and Red Deer rivers, and the areas of Mist and Sheep creeks. In the Moose Mountain area, Cairnes (1908, 1914) mapped and defined the Kootenay as a new and distinct formation, and also described contact relationships between the Kootenay and adjacent formations. In addition, he provided detailed information on the coal and associated lithotypes in the area. Malloch (1908), continued to study the geology and coal resources of the Kootenay in the Cascade, Costigan, and Palliser coal basins. A summary of all major coal occurrences in Canada, including the Kootenay coals of the Canmore-Cascade and Bow rivers area, was published by Dowling (1915). Rose (1920) continued to map and describe the Kootenay in the area between Highwood and Livingstone rivers as an extension of his earlier work in the Crowsnest Pass area to the south. This work was then followed by that of Marshall (1922), who described the structure and stratigraphy of the Kootenay and associated formations in the Sheep, Mist, and Storm Creek areas. Dowling (1924) concluded his field research with a study of Kootenay coal quality and structural relationships in the Canmore and Wind Mountain area of the Cascade Coal Basin.

It was not until 1943 that interest was again directed toward the Kootenay Formation. Beach (1943) in the Moose Mountain-Morley area of Alberta, recognized and formally defined a new sandstone member at the base of the Kootenay Formation, naming it the Moose Mountain Member. Regional geology studies involving rocks of all geological ages including the Kootenay and equivalent strata (Nikanassin Formation) were continued by Henderson (1946) in the Tay River and Falls Creek area, Allan and Carr (1947) in the Highwood-Elbow River area, Crockford (1949) in the Ribbon Creek area, Erdman (1950) in the Alexo-Saunders area, and Norris (1957) in the Canmore area. In the region of Mount Head, the southern boundary of the Canmore-Cascade and Bow rivers area, Douglas (1958), as part of a geological mapping, structural and stratigraphic study, divided the Kootenay into two informally defined map units, which correspond to the Elk, and newly defined Mist Mountain Formation and Moose Mountain Member of the redefined Kootenay Group (Gibson, 1979). More recent descriptions, discussions, and/or maps of Kootenay strata in the Canmore-Cascade and Bow rivers area, occur in papers and geological maps by Rapson (1964, 1965), Ollerenshaw (1966, 1968), Price and Ollerenshaw (1970 a, b), Price and Mountjoy (1970, 1971, 1972a, b), Norris (1971), Jansa (1971, 1972), Mountjoy and Price (1974 a, b), Hughes (1975), Gibson (1978, 1979, 1983), Hughes and Cameron (in press), and Ricketts and Sweet (in press).

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STRATIGRAPHY

Introduction

Information on the Jurassic-Cretaceous, Kootenay rock succession of the Rocky Mountain Foothills and Front Ranges of southwestern Alberta and southeastern British Columbia has been documented in varying detail by the writer in five previous preliminary reports (Gibson, 1977a, b, 1978, 1979; Graham et al., 1977). However, only two of these reports discuss the stratigraphy in relative detail. One involves a comprehensive discussion, although preliminary in nature, of the stratigraphy of Kootenay rocks in the Crowsnest Pass area (Gibson, 1977b). This report also includes preliminary observations and information on nomenclature, nomenclatural problems past and present, information on paleoenvironments and depositional history, and a brief discussion of the tectonic significance of conglomerate lithofacies in the Kootenay rock succession. The second report (Gibson, 1979) discussed in detail formal and informal stratigraphic subdivisions recognized by the writer and earlier workers, raised the Kootenay to group status and designated and described three new Jurassic-Cretaceous formations which, in ascending order, are: the Morrissey, Mist Mountain, and Elk (Fig. 2). Furthermore, the report proposed that the Morrissey Formation be subdivided into two members, a lower, Weary Ridge, and an upper, Moose Mountain. In addition, the placement of the base of the Kootenay was returned to its former position, in accordance with the original definition proposed by Cairnes (1908, 1914) and Rose (1917), to include older sandstone strata that had been transferred by some previous workers into the Jurassic Fernie Formation (Gibson, 1979). The new nomenclature and formational boundary changes will be reviewed briefly below.

The following discussion will mainly emphasize the stratigraphy of Kootenay strata in the Foothills and Front Ranges, in the area between an approximate east-west line across the Line Creek, Oldman and Livingstone River area (50°N) and the northern limit of recognition of coal-bearing strata of the Kootenay Group (Fig. 1). However, reference to Kootenay strata in the Crowsnest Pass is necessary, and will be made when comparisons and correlations are documented between the two regions. Furthermore, reference to the Crowsnest Pass area will be necessary when previous observations and conclusions concerning Kootenay strata must be modified or amplified. Each major stratigraphic unit (member, formation and group) will be discussed in terms of its: 1) definition or recognition, 2) type section, 3) lithology and facies variations, 4) contact relationships, 5) age and correlation, and 6) sedimentary structures. In addition, stratigraphic cross-sections, illustrative plates and isopach maps (illustrating unit contacts, lithofacies, lithofacies variations, and thickness trends) are provided for each of the major rock units.

Kootenay Group

Definition

The Kootenay Group (Gibson, 1979) of the Rocky Mountain Foothills and Front Ranges encompasses the stratigraphic interval between the Jurassic Fernie Formation below and the Lower Cretaceous Blairmore Group above (Fig. 2). It attains a maximum thickness of 1100 m, although toward the east in the Alberta Foothills it is erosionally truncated by the overlying strata of the Blairmore Group, thinning to an erosional zero edge (Fig. 4). The Kootenay comprises three formations which, in ascending order, are: the Morrissey, the Mist Mountain, and the Elk (Fig. 2). The Morrissey Formation is subdivided into two members, a lower, Weary Ridge, and an upper, Moose Mountain.

Rocks of the Kootenay Group were originally recognized and included as part of the "Kootanie series" by G.M. Dawson (1886). Later, they were recognized, redefined, and named the Kootenay Formation by Cairnes (1908, 1914), in the Moose Mountain area of Alberta, to include only the strata between the Blairmore Group (former Dakota Formation) and the Fernie Formation. In 1953, Newmarch recognized a threefold subdivision in the Kootenay of the Fernie Basin area of southeastern British Columbia (Fig. 2). He formally separated the upper unit from the former Kootenay Formation, naming it the Elk Formation, while retaining the name Kootenay for the remainder of the succession. In the Coleman-Blairmore area of the Alberta Foothills (Crowsnest Pass), Norris (1959b) recognized a fourfold subdivision of the Kootenay and assigned Grassy Mountain as the type section of the Kootenay Formation and three of its subdivisions (Fig. 2). Because of erosional truncation and/or sedimentary thinning, the Elk Formation does not occur in the Coleman-Blairmore area. Jansa (1972),

[1]Formerly of the Geological Survey of Canada.

in a regional study of the Kootenay in Alberta and British Columbia, recognized the same threefold subdivision as Newmarch (1953) although he considered the Elk only as a member of the Kootenay Formation (Fig. 2). Gibson (1977b, 1979) demonstrated the need to redefine the Kootenay to re-include some additional older strata, and subdivided the succession into three formations, thus necessitating the elevation of the former Kootenay Formation to group status.

Type section

The type section of the former Kootenay Formation at Grassy Mountain, 8 km north of Blairmore, Alberta (Fig. 1) is thin, and because of sedimentary thinning and/or erosional truncation prior to deposition of the overlying Cadomin Formation of the Blairmore Group, it does not contain strata of the Elk Formation (Fig. 5; Sec. 75-1). The Grassy Mountain section does, however, contain the newly defined Mist Mountain and Morrissey formations. The former type section of the Kootenay Formation at Grassy Mountain is no longer acceptable as typical of the Kootenay Group. The section at Grassy Mountain, however, may still serve as the type area for three local members (Fig. 2, Norris, 1959b), which now are included as part of the Mist Mountain Formation.

As noted previously, the Kootenay Group now comprises three formations, each of which has a designated type section and a specific geographic location, thereby eliminating the need for a separate type section for the Kootenay Group. However, in keeping with custom and the practice of designating type sections or type areas for new stratigraphic units, three areas are suggested which contain readily accessible and well exposed strata typical of the Kootenay Group. They are the Highwood Pass-Mist Mountain area (secs. 76-10, 76-11; figs. 3, 7), the Flathead Ridge area of southeastern British Columbia (Sec. 75-6; figs. 3, 5), and the Mount Allan area near Canmore, Alberta (Sec. 76-7; figs. 3, 8). The section at this last area is the thickest and best exposed of the three and contains all facies characteristic of the three Kootenay Group formations. The Mount Allan section is described and discussed in relative detail by Hughes and Cameron (in press). The Highwood Pass-Mist Mountain area contains the type section of the Mist Mountain Formation (Gibson, 1979), a good section of the Morrissey Formation and, immediately along strike to the north of Mist Mountain, a good section of the Elk Formation. This area is the most readily accessible of the three. The Kootenay Group occurs at other localities within the Foothills and Front Ranges, but the Mist Mountain Formation commonly is poorly exposed, or the exposed field section is located within private property, or access is difficult because of remoteness from major roadways.

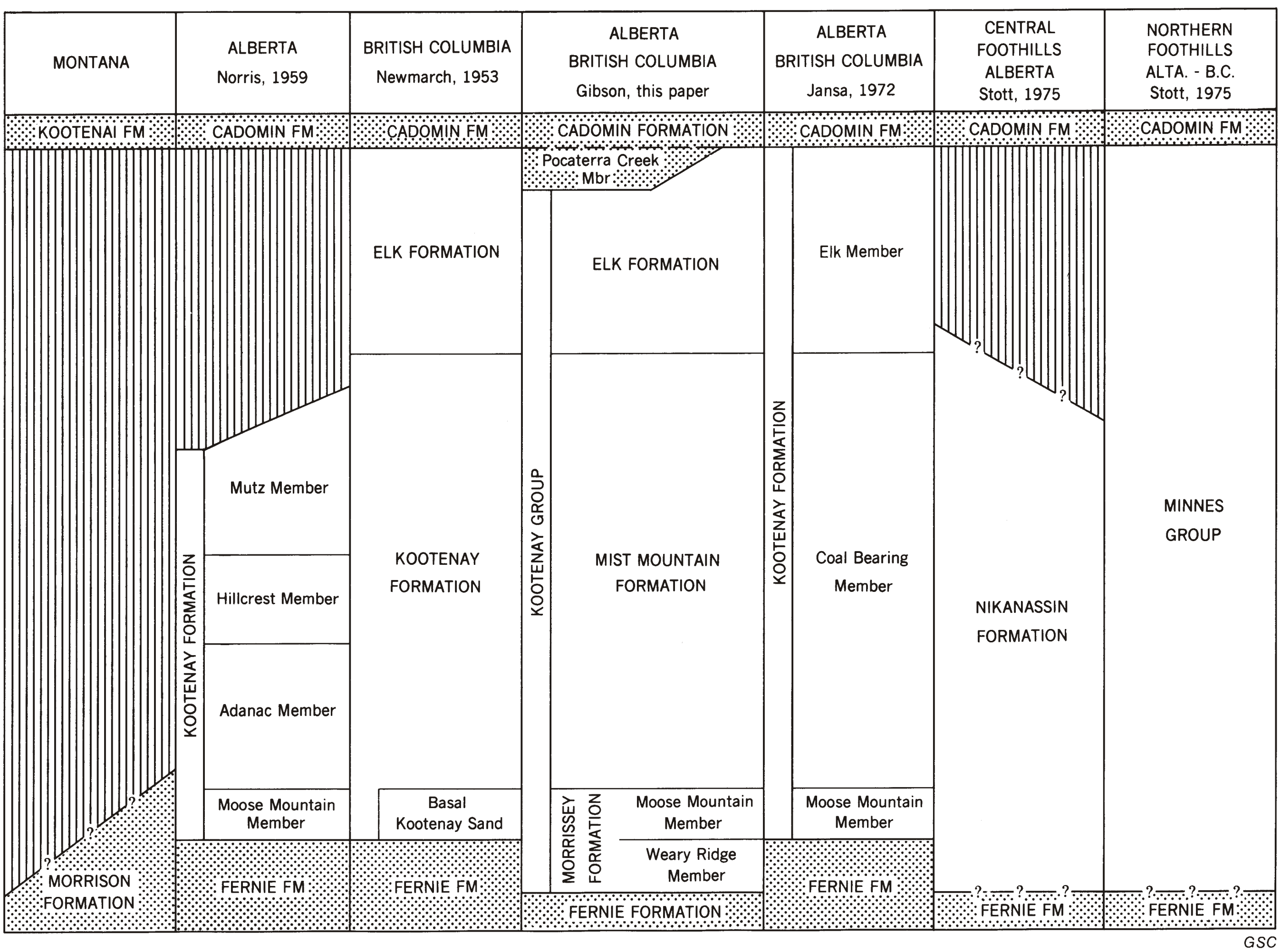

Figure 2. *Nomenclature chart of the members and formations of the Jurassic-Cretaceous Kootenay Group used by the writer in this report, illustrating their relationship to nomenclature used by other workers in the report area and adjacent areas to the north and south.*

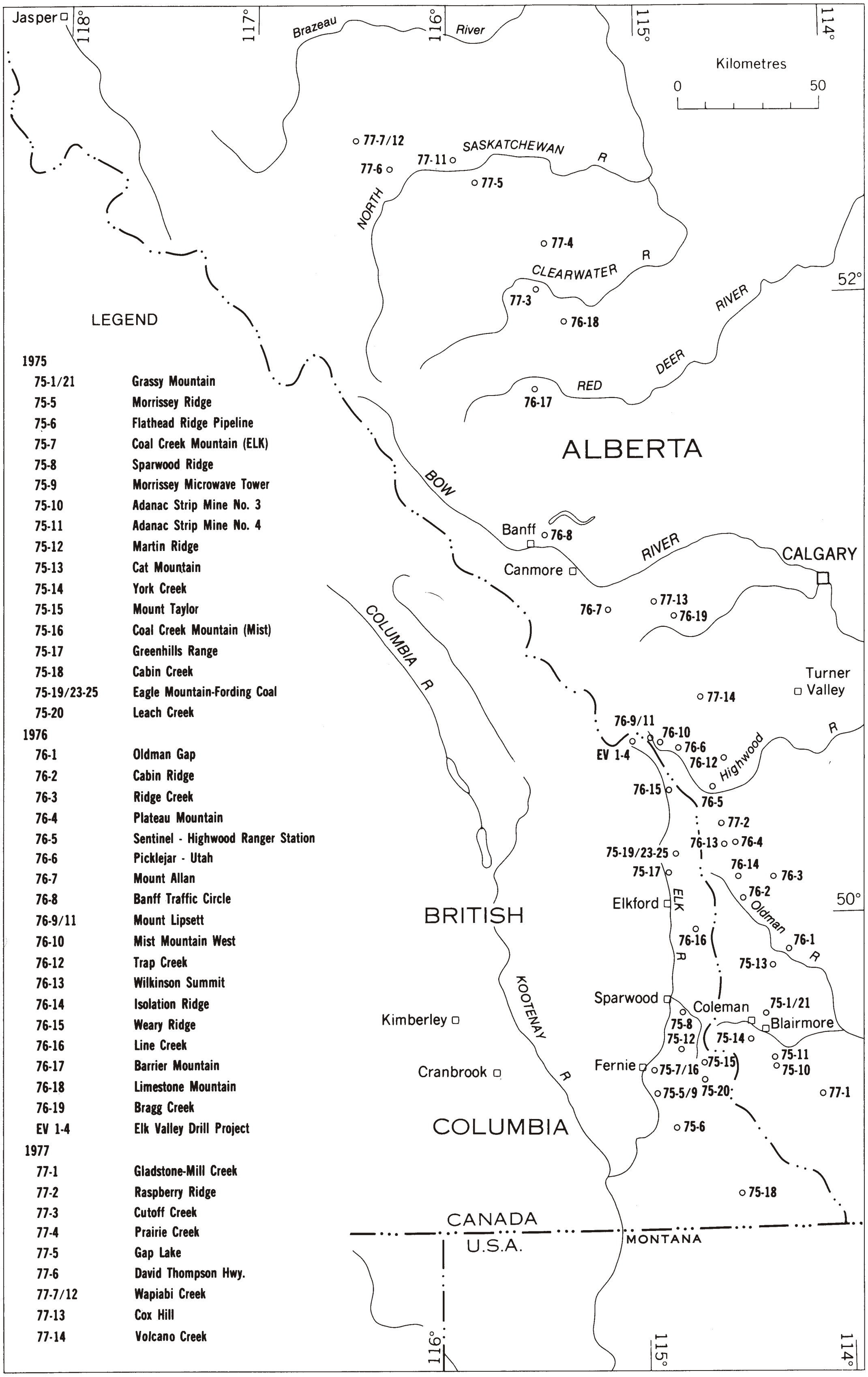

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Figure 3. *Locations and names of measured sections.*

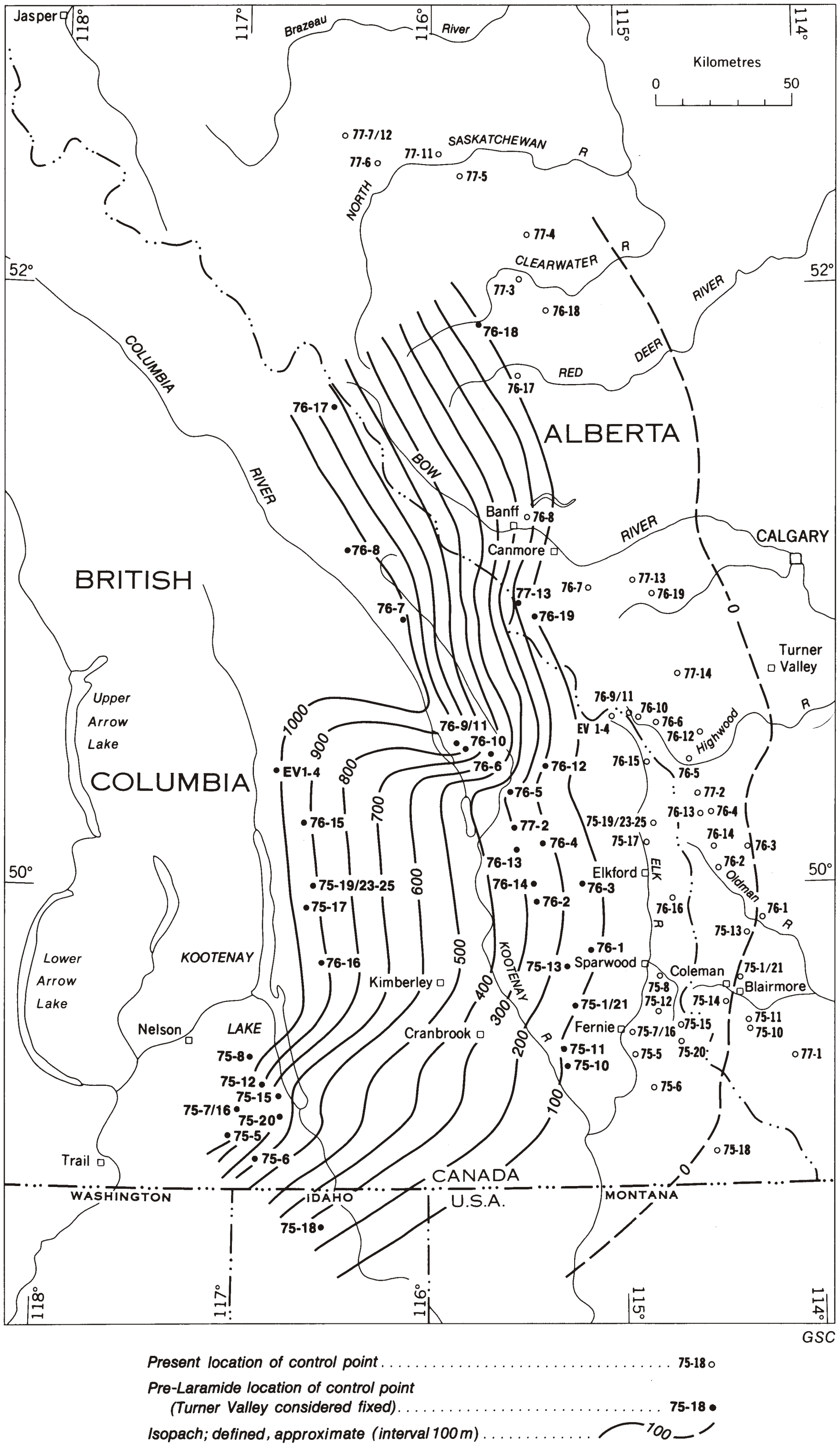


***Figure 4.** Palinspastic isopach map of the Kootenay Group.*

Lithology and facies variations

The Kootenay Group (Gibson, 1979) comprises three formations which, in ascending order, are: the Morrissey – a massive, cliff-forming, predominantly sandstone unit; the Mist Mountain – an interbedded succession of sandstone, siltstone, mudstone, shale, rare conglomerate and economically important thin to thick coal seams; and the Elk – an interbedded sequence of sandstone, siltstone, mudstone, shale, local chert-pebble conglomerate, and thin seams of coal.

Contact relationships

The Kootenay Group conformably overlies interbedded sandstone, siltstone, and shale of the Upper Jurassic Fernie Formation and, in most areas, is disconformably overlain by conglomerate and sandstone of the Lower Cretaceous Cadomin Formation of the Blairmore Group. In some areas, however, it is overlain either disconformably, or in some areas possibly conformably, by sandstone, conglomerate, siltstone, and mudstone of the Pocaterra Creek Member of the Blairmore Group (Gibson, 1977b, 1979; Ricketts and Sweet, in press).

Distribution and thickness

The Kootenay outcrops throughout the Rocky Mountain Foothills and parts of the eastern Front Ranges of southwestern Alberta and southeastern British Columbia, between the North Saskatchewan River to the north and just north of the United States border to the south (Fig. 1). Figure 4 is an isopach map of the Kootenay Group, illustrating thickness trends and the paleogeographic configuration of the strata prior to tectonic movement. The Group attains a maximum measured thickness of 1112 m on Sparwood Ridge near Sparwood, British Columbia (Sec. 75-8; Fig. 5) and thins to a zero edge toward the east.

Age and correlation

The Kootenay Group ranges in age from probable Late Jurassic Portlandian (Frebold, 1957) to probable Early Cretaceous.

Strata of the Kootenay Group grade northward into the mixed marine and nonmarine strata of the Nikanassin Formation in the vicinity of, and north of, North Saskatchewan River, Alberta (Fig. 1). The Nikanassin Formation in turn grades laterally northward into the Minnes Group of west central Alberta (north of Smoky River) and northeastern British Columbia (Stott, 1975). Southward, relationships with equivalent strata in the adjacent United States are uncertain. However, based upon homotaxis, it is suggested that the basal part of the Kootenay Group may be equivalent to part of the upper Morrison Formation (Fig. 2).

Morrissey Formation

Definition

The Morrissey Formation (Gibson, 1979) comprises the stratigraphic interval between the "Passage Beds" of the Jurassic Fernie Formation below and the economically important coal-bearing strata of the Mist Mountain Formation above. In most areas it is subdivided into two members, a lower, Weary Ridge, and an upper, Moose Mountain (figs. 12, 13, 14). However, at two localities north of the Coleman-Blairmore area (secs. 75-13, 76-1, in figs. 3, 5) and in the Foothills area between Limestone Mountain and North Saskatchewan River (Fig. 5), in the northern portion of the study area, the Morrissey Formation cannot be subdivided.

Strata now defined as the Morrissey Formation were first recognized by McEvoy (1902) while mapping the coal deposits of the Fernie area of southeastern British Columbia. These basal strata, because of their resistant weathering, cliff-forming character, served as a prominent lithologic marker defining the base of what is now called the Kootenay Group. Cairnes (1908, 1914), while mapping in the Moose Mountain area west of Calgary, recognized the same marker sandstone and used it similarly to define the base of his Kootenay Formation. In the Crowsnest Pass area of the Alberta Foothills, Rose (1917) likewise defined the base of the Kootenay at the "base of the first heavy bed of sandstone" above the Fernie Formation. It was not until Beach (1943) re-examined and mapped the Moose Mountain and Morley areas west of Calgary – part of the area formerly mapped by Cairnes (1914) – that a stratigraphic problem developed in recognizing the base of strata equivalent to the Morrissey Formation and newly defined Kootenay Group. Beach (1943), like previous workers, recognized the same marker sandstone at the base of the Kootenay Formation. However, at Canyon Creek, near its confluence with Elbow River (for details see Gibson, 1979), Beach (*op. cit.*) indicated the possible occurrence of an erosional contact within the marker sandstone at the base of the Kootenay, and accordingly suggested that the erosion surface may represent an unconformity. This erosion surface corresponds with the contact between the newly defined Moose Mountain and Weary Ridge members of the Morrissey Formation. Because of the erosion surface, Beach (1943) suggested that the sandstone below it be considered part of the Fernie Formation, and the more resistant and better indurated sandstone above the erosion surface be included as part of the Kootenay Formation. The sandstone above the erosion surface he called the Moose Mountain Member. However, elsewhere in the Moose Mountain area, at the original Kootenay reference locality of Cairnes (1914, Sec. 76-19; Fig. 8), Beach included all of the basal marker sandstones as Moose Mountain sandstone, and therefore included strata equivalent to the present Weary Ridge Member as part of the Kootenay Formation.

To the south, in the Highwood River area of the Alberta Foothills, Allan and Carr (1947), as part of a regional mapping program, also noted a possible erosional break within the massive basal sandstone at one locality, and, like Beach (*op. cit.*), assigned the lower sandstone to the Fernie Formation and the upper sandstone above the erosional break to the Kootenay. However, Beach (*op. cit.*) and Allan and Carr (*op. cit.*), and in subsequent years other workers, including Douglas (1958), Newmarch (1953), Norris (1959b), Price (1965) and Frebold (1957), all noted that the contact between the two sandstones was abrupt, although in contrast, the more recent workers actually considered the contact to be conformable. These later workers, all of whom were involved with regional stratigraphic and/or structural mapping programs in the Foothills and Front Ranges of southwestern Alberta and southeastern British Columbia, selected only the upper, more resistant weathering, sandstone of the Morrissey Formation (Moose Mountain Member, figs. 12, 13, 14, 15) as the base of the Kootenay.

Recently, the writer (Gibson, 1977b, 1979) demonstrated the need for returning to the original definition of the Kootenay as outlined by Cairnes (1908, 1914) and Rose (1917), and assigned the contact between the Fernie Formation and the Morrissey Formation/Kootenay Group to the base of the entire massive sandstone lithofacies, and not within it, as had been done by most other workers between 1917 and 1977. For additional details and discussion concerning the contact between the Morrissey and Fernie formations, and the nomenclature, the reader is referred to the earlier papers by Gibson (1977b, 1979).

Type section

The type section of the Morrissey Formation is located on the west side and near the south end of Morrissey Ridge, 7 km north of Morrissey Creek, 16 km southeast of Fernie, British Columbia (Fig. 3; UTM co-ordinates 450757 and 452757; topographic maps NTS 82G/6, Elko, and 82G/7 Upper Flathead Valley). The section is accessible on foot or by trail bike via an old coal exploration road up the west side of Morrissey Ridge, approximately 6.4 km from Morrissey Station. The section has been described in detail by Gibson (1979, p. 198). Other well exposed and readily accessible sections illustrating both members and strata characteristic of the formation are located as follows: on the north side of Coal Creek, immediately east of and adjacent to the town of Fernie (figs. 3, 5; Sec. 75-16; UTM co-ordinates 450867; topographic map NTS 82G/10, Crowsnest); at Weary Ridge in the upper Elk River valley, British Columbia (figs. 3, 13, 14, Sec. 76-15; UTM co-ordinates 507822; topographic map NTS 82J/7W, Mount Head); and at the headwaters of Bragg Creek (figs. 3, 8, 24; Sec. 76-19; UTM co-ordinates 540465; topographic map NTS 82J/15, Bragg Creek). Two additional locations are provided which illustrate the Morrissey Formation as a single undifferentiated formation. They are

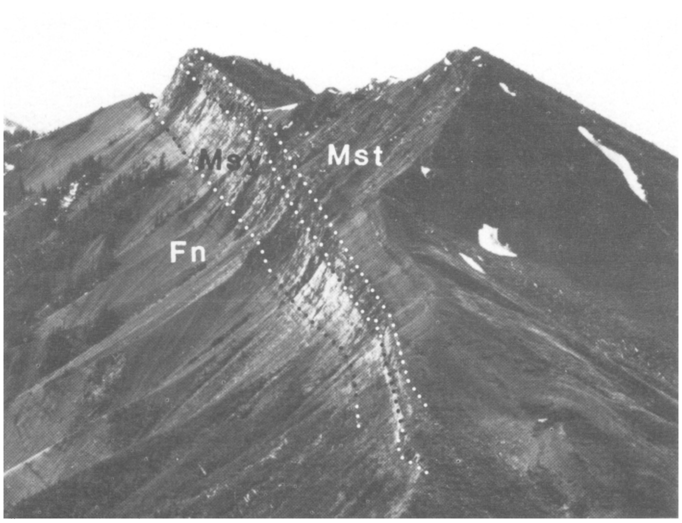


Figure 12. *Contact and lithologic relationships between Fernie, Morrissey and Mist Mountain formations. Note recessive weathering siltstones and shales of Fernie Formation, resistant cliff-forming profile of Morrissey Formation, and recessive weathering character of lower Mist Mountain Formation. Section on south side of Aldridge Creek, south of Weary Ridge. Fernie Formation (Fn); Morrissey Formation (Msy); Mist Mountain Formation (Mst).*

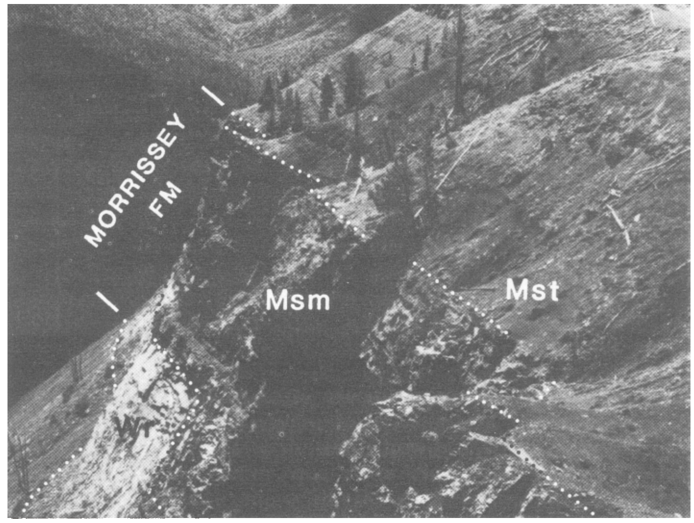


Figure 13. *Massive, cliff-forming sandstones of Morrissey Formation at Weary Ridge (Sec. 76-15). Note prominent colour contrast between Weary Ridge Member below and Moose Mountain Member above. Lower Moose Mountain Member characterized in this area by recessive notch containing dark grey carbonaceous shale and siltstone. Coal seam underlies talus zone at base of Mist Mountain Formation. Weary Ridge Member (Wr); Moose Mountain Member (Msm); Mist Mountain Formation (Mst).*

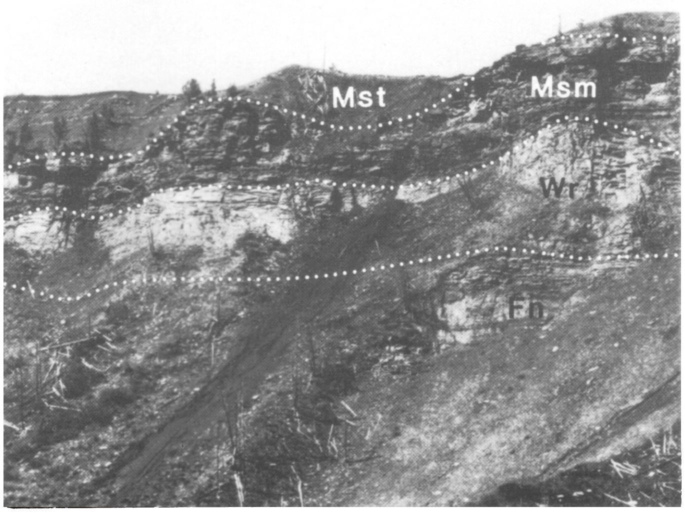


Figure 14. *Contact and lithologic relationships between "Passage beds" of Fernie Formation and Weary Ridge Member of Morrissey Formation. Note interbedded siltstone and shale beds at top of "Passage beds" of Fernie Formation, and thick bedded, massive character of overlying Weary Ridge Member, Weary Ridge (Sec. 76-15). Fernie Formation (Fn); Weary Ridge Member (Wr); Moose Mountain Member (Msm); Mist Mountain Formation (Mst).*

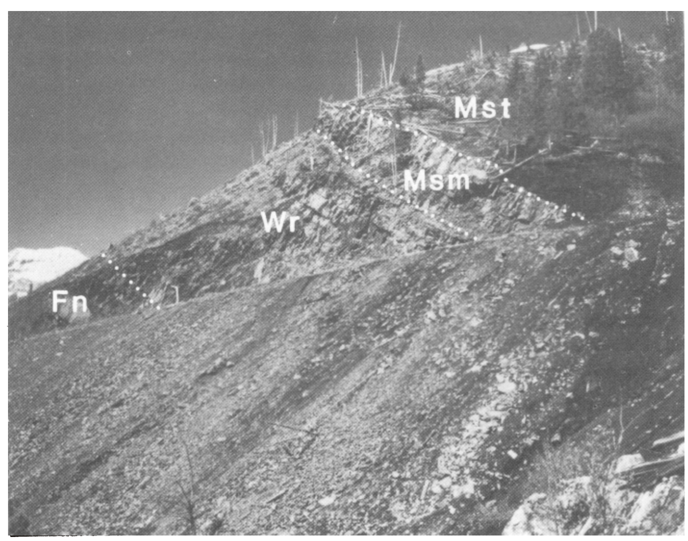


Figure 15. *Flathead Ridge Pipeline (Sec. 75-6), illustrating lithologic and contact relationships between Fernie, Morrissey and Mist Mountain formations. Note thick coal and shale interval at base of Mist Mountain Formation. Fernie Formation (Fn); Morrissey Formation (Msy); Weary Ridge Member (Wr); Moose Mountain Member (Msm); Mist Mountain Formation (Mst).*

Cat Mountain - Pocket Creek (figs. 3, 5; Sec. 75-13; UTM co-ordinates 880225; topographic map NTS 82G/16, Maycroft), and Limestone Mountain (figs. 3, 9; Sec. 76-18; UTM co-ordinates 087527; topographic map NTS 820/14; Limestone Mountain). At the latter locality the Morrissey begins to lose its typical lithologic character and resemble the more siliceous, better indurated sandstones typical of the lower Nikanassin Formation (Gibson, 1978).

Lithology and facies variations

The Morrissey Formaticn comprises a massive, cliff-forming, coarsening-upward sequence of medium dark grey to brownish grey to orange-brown weathering sandstone, with rare interbeds of carbonaceous mudstone, siltstone and coal (figs. 12, 13, 14, 15). The sandstones range from very fine- to coarse-grained, with sporadic lenses and thin beds of very coarse to conglomeratic sandstone. The Morrissey can be divided into two distinct and generally contrasting lithofacies over most of the report area (figs. 12, 13, 14, 15). The lower facies consists of orange-brown weathering, slightly argillaceous and carbonaceous, calcareous sandstone with rare siltstone and mudstone interbeds, and is called the Weary Ridge Member. In contrast, the upper lithofacies consists of medium dark grey to brownish grey weathering, less carbonaceous and argillaceous, more siliceous, better indurated sandstone and rare coal, and is called the Moose Mountain Member.

As noted previously, in some areas the Morrissey Formation cannot be subdivided into the two members because the lithofacies change from one region to another, or because strata of one member are either poorly developed or absent. For example, at Cat Mountain, 24 km north of Blairmore, Alberta, (Sec. 75-13; figs. 3, 5) the distinctive, orange-brown weathering, finer grained sandstone of the lower member is absent, and the Morrissey comprises a medium-grey weathering, well indurated, medium- to coarse-grained, "salt and pepper" sandstone, and a thin (15 cm thick) bed of chert-pebble conglomerate 15 m above the base. At this locality the Morrissey conformably but abruptly overlies interbedded siltstone, sandstone, and shale of the "Passage Beds" of the Fernie Formation. At another locality, near Camp Creek and the Gap on Oldman River, 8 km northeast of Cat Mountain (Sec. 76-1; figs. 3, 5), the Morrissey Formation consists of predominantly medium grained, brownish grey weathering, cliff-forming, quartzose sandstone. However, at this locality the lower 6 to 9 m of the formation contain interbeds of very fine- to fine-grained, slightly carbonaceous and argillaceous sandstone characteristic of the Weary Ridge Member, suggesting the possibility of an interfingering relationship between the sandstones of the two members. It would appear that at these two localities the lower, less resistant, finer grained sandstones characteristic of the Weary Ridge Member are either completely absent in the one case, or interfinger with the coarser grained sandstones of the Moose Mountain Member in the other.

The most conspicuous facies variations displayed by the Morrissey Formation occur in the Alberta Foothills in the northern part of the report area, between Barrier Mountain, Limestone Mountain and the North Saskatchewan River (secs. 76-17, 76-18, 77-5; figs. 3, 9).

At Barrier Mountain (Sec. 76-17; figs. 9, 20) the two members of the Morrissey can still be recognized, although the prominent lithologic break between the predominantly fine grained sandstones of the Weary Ridge Member and the coarser grained sandstones of the Moose Mountain Member is not as distinctive or readily apparent as that found to the south, in the Foothills and Front Ranges of southwestern Alberta and southeastern British Columbia. The fine grained, slightly carbonaceous and argillaceous sandstones of the Weary Ridge Member at Barrier Mountain contain interbeds and thick units of medium grained sandstone, lithotypes which are elsewhere more common to strata of the overlying Moose Mountain Member. Furthermore, at Barrier Mountain, the coarser grained sandstones of the Moose Mountain Member, although still better indurated and more cliff-forming than those of the Weary Ridge Member, contain interbeds and thin intervals of fine- to very fine-grained, carbonaceous and argillaceous sandstone characteristic of the underlying Weary Ridge Member.

At Limestone Mountain, 27 km north of Barrier Mountain, the entire Morrissey consists of fine- to medium-grained, medium bedded, silica cemented, quartzose sandstone. These strata are unlike the sandstones in the formation at Barrier Mountain and other areas of southwestern Alberta and southeastern British Columbia. The Morrissey at this locality cannot be divided into members. Fine grained, quartzose sandstone forms the predominant lithology of the member, however, in contrast to the similarly textured sandstones of the formation to the south, they are more siliceous, less carbonaceous, and thus much better indurated. Medium- to coarse-grained sandstone still comprises a conspicuous component of the total sandstone at Limestone Mountain.

In the vicinity of North Saskatchewan River at Gap Lake (Sec. 77-5; figs. 3, 9), the Morrissey consists of very fine grained, light yellow grey, very siliceous sandstone, with no medium or coarser grained sandstone interbeds. The sandstones are still very well indurated, weather a distinctive orange to buff colour, and continue to display their massive, cliff-forming character. Adjacent to, and north of, North Saskatchewan River, argillaceous and carbonaceous siltstone and shale form conspicuous interbeds within the Morrissey sandstones, such that the formation loses its distinctive cliff-forming character. Consequently, the Morrissey Formation is no longer recognizable as a distinct mappable unit, and is not differentiated from the lower Nikanassin Formation (figs. 11, 21).

Contact relationships

The Morrissey Formation conformably but abruptly overlies interbedded sandstone, siltstone, and mudstone of the "Passage Beds" of the Fernie Formation, and is in turn overlain conformably and abruptly by interbedded siltstone, sandstone, mudstone, coal, and rare conglomerate of the Mist Mountain Formation.

Distribution and thickness

Because of its well indurated and generally cliff-forming character, the Morrissey Formation can be easily recognized and mapped at all outcrop sections in the Rocky Mountain Foothills and eastern Front Ranges of southwestern Alberta and southeastern British Columbia, between the Cabin Creek-Flathead River area near the United States border and North Saskatchewan River (the northern limit of recognition of the Kootenay Group and the Morrissey Formation). The Morrissey ranges in measured thickness from a maximum of 80 m near Mist Mountain and Highwood

Pass (Sec. 76-10; figs. 3, 7), to a minimum of 20 m at two localities, one near Moose Mountain 52 km west of Calgary, and the other at Adanac mine 12 km south of Blairmore (secs. 76-19, 75-10; figs. 3, 8).

Figure 16 is an isopach map of the Morrissey Formation prepared on a palinspastic base, illustrating the distribution and thickness trends in the report area. Visual inspection reveals a general but irregular thinning trend from west to east. The formation ultimately thins to a zero edge along the eastern Foothills of Alberta. In the vicinity of North Saskatchewan River, the Morrissey, in addition to thinning, also grades laterally (by interfingering) into strata of the lower Nikanassin Formation. Numerous thickness irregularities are apparent on the isopach map. They are probably related in part to the regional interfingering nature of the contact with the underlying "Passage Beds" of the Fernie Formation, although locally the contact is conformable and abrupt as previously noted.

Age and correlation

The Morrissey Formation is of probable Late Jurassic Portlandian age, a date based mainly on the identification of a single large ammonite mold found by Newmarch (1953) and identified and described by Frebold (1957). In addition, dinoflagellate cysts have been identified by Pocock (1964) from strata possibly equivalent to the Morrissey Formation. The cysts were assigned a late Jurassic age by Pocock.

A sandstone unit, locally referred to as the "Brown sand", occurs in the subsurface of the Alberta Foothills near Turner Valley. This distinctive sandstone is lithologically similar to parts of the Morrissey Formation, and occurs at a similar stratigraphic level between the Fernie Formation and strata herein defined as the Mist Mountain Formation. However, the exact stratigraphic relationship of the "Brown sand" with the Morrissey Formation is uncertain. It may be correlative with all of the Morrissey Formation, as implied by Hume (1938) and Spivak (1954), or it may be equivalent to only the Moose Mountain Member, as suggested by Beach (1943), or to strata herein defined as the Weary Ridge Member, as suggested by Douglas (1958). The "Brown sand" of the subsurface has been in the past arbitrarily placed in, and considered part of, the Fernie Formation. In keeping with the original definition and recognition of the base of the Kootenay Formation (Cairnes, 1914; Rose, 1917), the writer (Gibson, 1979) would suggest that the "Brown sand" be considered part of the Morrissey Formation.

In the absence of convincing fossil evidence, and based on homotaxial position, the Morrissey Formation is considered to be equivalent to the basal strata of the Nikanassin Formation of west central Alberta, between the North Saskatchewan and Smoky rivers (Fig. 2). As noted in the foregoing discussion, the Morrissey loses its distinctive cliff-forming character in the vicinity of North Saskatchewan River by grading laterally into and interfingering with the basal siltstones, mudstones, and shales of the Nikanassin Formation (Fig. 21). In the Foothills of northeastern British Columbia north of Smoky River, the Morrissey is suggested to be equivalent to part or all of the basal Monteith Formation of the Minnes Group (Stott, 1975). Correlation of the Morrissey with strata south of the Canada-United States border in Montana and Wyoming is uncertain. Lithologic descriptions of the Morrison Formation in parts of Montana by Kauffman (1963), Harris (1966, 1968), Silverman and Harris (1966), Suttner (1966, 1969) and Walker (1974), indicate that the Morrison Formation is thin and lithologically unlike the strata of the Morrissey Formation in Alberta and British Columbia, although in some areas of Montana the upper Morrison contains thin seams of coal. The Morrison Formation is assigned an age ranging from Kimmeridgian to Portlandian (Billings Geological Society, 1966), suggesting that the strata are time equivalent to part of the upper Fernie Formation and possibly the Morrissey Formation of the Kootenay Group. However, lithologic evidence would suggest that strata of the Morrissey and younger overlying formations of the Kootenay Group, such as occur in Alberta and British Columbia, have either not been deposited, have been erosionally removed, or have drastically changed lithofacies south of the Canada-United States border. Either or both of the first two interpretations appear most probable.

Weary Ridge Member

Definition

The Weary Ridge Member is the lower, less resistant orange-brown weathering sandstone member of the recently defined Morrissey Formation, occurring between the Moose Mountain Member above and the "Passage Beds" of the Fernie Formation below (Fig. 2). The writer, as a result of the present investigation and having examined Weary Ridge strata and "Passage Beds" strata in many outcrops throughout southwestern Alberta and southeastern British Columbia, as well as some core, suggests for reasons previously discussed, that strata of the Weary Ridge Member be included as the lowermost sandstone unit of the Kootenay Group and Morrissey Formation, and no longer be considered as part of the marine "Passage Beds" of the Fernie Formation. The re-assignment of the base of the Weary Ridge Member to the Morrissey Formation of the Kootenay Group, in accordance with the earliest interpretations of this stratigraphic interval, means that the basal contact now corresponds with a prominent lithologic break in the sedimentary record, visible both in outcrop and in the subsurface. This will facilitate surface and subsurface recognition of the Kootenay-Fernie lithologic contact.

Type section

The type section is located at the north end of Weary Ridge, between Aldridge and Weary creeks, on the east side of upper Elk River valley, southeastern British Columbia (Fig. 3; UTM co-ordinates 507822; topographic map NTS 82J/7E, Mount Head). The section was illustrated and described by Gibson in 1979 (p. 183-208). Other well exposed and easily accessible sections typical of the member may be examined at Flathead Ridge (Sec. 75-6; figs. 3, 15; UTM co-ordinates 540664; topographic map NTS 82G/7, Upper Flathead); the abandoned Adanac mine south of Blairmore (Sec. 75-10; figs. 3, 19; UTM co-ordinates 875854; topographic map NTS 82G/8W, Beaver Mines); Sentinel-Highwood Ranger Station (Sec. 76-5; figs. 3, 29; UTM co-ordinates 668859; topographic map NTS 82J/7E, Mount Head); and Storm Creek near Mist Mountain (Sec. 76-10, figs. 3, 25; UTM co-ordinates 459024; topographic map NTS 82J/10W, Mount Rae). Many other sections of the Weary Ridge Member are well exposed (see Appendix), but access to them is difficult.

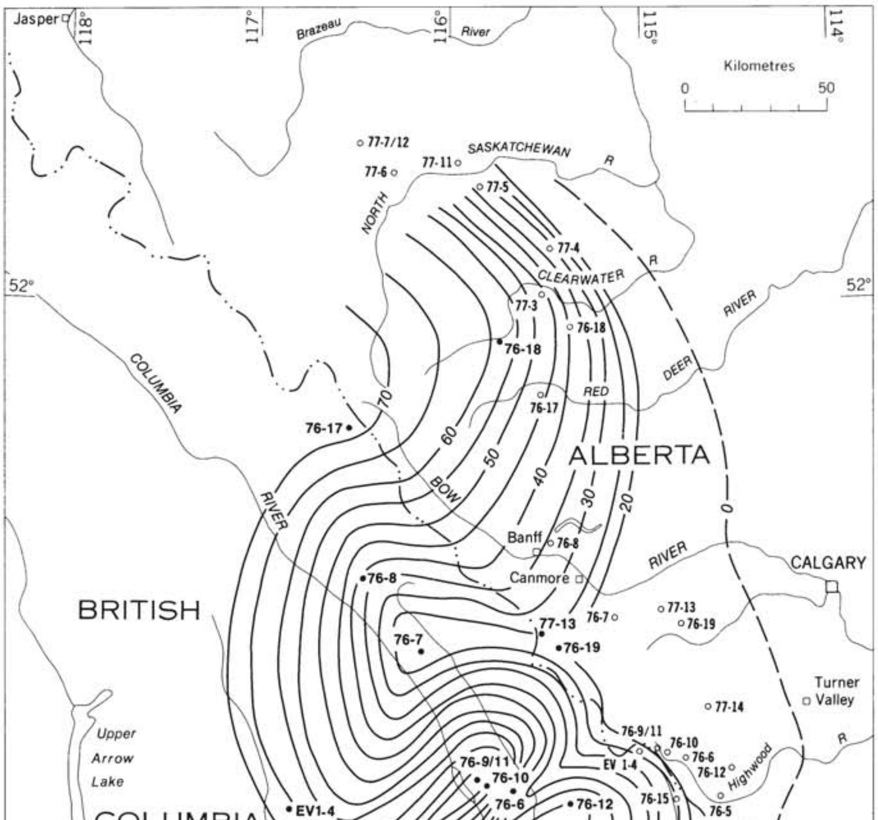


Figure 16. *Palinspastic isopach map of the Morrissey Formation.*

Lithology and facies variations

The Weary Ridge Member consists of medium to medium-dark grey, predominantly fine grained, quartzose sandstone with rare interbeds or thin intervals of dark grey, carbonaceous and argillaceous, very sandy mudstone to siltstone (figs. 13, 14, 19, 20). The sandstone is argillaceous, and slightly carbonaceous, calcareous, dolomitic, and ferruginous at most localities. The ferruginous matter, mainly pyrite and limonite, occurs finely disseminated throughout the member as small, fresh and weathered grains or crystals - some up to 13 mm in diameter. The ferruginous minerals appear to be responsible for the distinct orange-brown to greyish brown weathering colour that is characteristic of the member, and which contrasts with the generally darker grey weathering, less ferruginous, sandstones of the overlying Moose Mountain Member (figs. 13, 14). In addition, because of the content of carbonaceous matter and the argillaceous, ferruginous and carbonate minerals, the sandstones are commonly more porous, less well indurated, and less resistant to weathering than the overlying strata of the Moose Mountain Member. The carbonate minerals, although in very low concentration, form a ubiquitous mineralogical component of the member and, when combined with the weathering character, help to distinguish these sandstones from those of the overlying Moose Mountain Member, which do not contain obvious carbonate minerals. The occurrence of dark grey chert grains and brown, ferruginous minerals in some places imparts a conspicuous salt and pepper texture to the sandstones.

Bedding ranges from medium to thick, and at many localities increases in thickness upwards. Where strata are well exposed, bedding in the upper member is massive, such that individual beds are difficult to discern (figs. 13, 14). Spheroidal weathering is common in many of the thicker beds. At one locality near Mist Mountain (Sec. 76-10; figs. 3, 25), sandstones near the base of the member are platy, occurring as 3 to 5 cm thick plates. The sandstones are predominantly fine grained, but also contain medium grained and rare coarse grained beds. The sandstones are graded at some localities, with the average grain size increasing upwards toward the Moose Mountain Member. However, the upward grain size increase is not systematic and uniform. Rare beds and thin intervals of finer grained sandstone may be found near the top.

Local facies variations in the Weary Ridge Member are rare, with the exception of sporadic siltstone to mudstone interbeds up to 20 m thick, and thin intervals up to 1.5 m thick, observed in the lower half to one third of the member at a few localities. These beds are lenticular and usually grade laterally within a single exposure (30-50 m) into the fine- to very fine-grained sandstones typical of the member. No more than two beds of siltstone and/or mudstone were observed in the member at any one section locality. In most cases only one thin bed was observed. At Greenhills (Sec. 75-17; figs. 3, 6), however, a siltstone-mudstone unit forms an unusually thick (1.5 m) interval, 19.2 m above the base. Another uncommon facies variation of the Weary Ridge Member may be seen at Barrier Mountain (Sec. 76-17; figs. 3, 9, 20), where the member contains medium- to thick-bedded, conspicuous orange-brown weathering, very calcareous, and well indurated, very fine grained sandstone interbeds within the less well indurated sandstones characteristic of this member. These atypical sandstones resemble those found in basal strata of the Nikanassin Formation. Barrier Mountain is, however, the northernmost locality within the study area where Weary Ridge strata can still be recognized as a separate member of the Morrissey Formation. The last unusual facies variation was observed in a core sample from a locality on Cabin Creek (Sec. 75-18; figs. 3, 11) near the United States border. In this core, the lower 15 cm of the member contain well rounded pebbles of dark grey quartz siltstone, up to 1.9 cm in diameter, in a matrix of quartz-chert sandstone.

It should be noted that, at three localities in southeastern British Columbia where the member is well exposed (secs. 75-16, 75-5, and 76-15, in Fig. 3), the Morrissey Formation is cut by thrust faults, which produce a repetition and alternation of lithofacies of both the Weary Ridge and Moose Mountain members. This structure may create the false impression of an interfingering relationship, and may be misinterpreted as a vertical facies variation between the two sandstone members.

Jansa (1972) reported an unusual lithofacies variation in his Moose Mountain Member of the Kootenay Formation (Fig. 2) at the Cascade River bridge-Banff traffic circle locality (Sec. 76-8; Fig. 3) in Banff National Park. The facies identified as Moose Mountain by Jansa (*op. cit.*, p. 3202) and illustrated by Frebold (1962, p. 19) has been misidentified by both authors. The facies in question consist of interbedded sandstone, siltstone and shale of the upper "Passage Beds" of the Fernie Formation, a conclusion recently confirmed by Hamblin and Walker (1979).

Contact relationships

Lower contact. The contact between the Weary Ridge Member and the underlying "Passage Beds" of the Fernie Formation is conformable and abrupt, and is placed at the base of the first continuous occurrence of soft, porous, poorly indurated, orange-brown weathering sandstone, devoid of the interbeds of siltstone, mudstone or shale typical of the upper Fernie Formation (figs. 17, 18, 19, 20). Because of the generally poor induration of the Weary Ridge sandstone, and its resulting recessive weathering nature, the contact with the "Passage Beds" is partly or totally covered in some sections. Strata of the upper "Passage Beds" consist of an interbedded sequence of dark brownish grey to greyish brown weathering, very fine- to fine-grained sandstone, darker grey weathering, argillaceous siltstone, and dark grey carbonaceous mudstone to shale (figs. 17, 20). The mudstone-shale contains a relatively high concentration of comminuted plant debris, which increases upwards within the Fernie Formation. At most localities sandstone forms the predominant lithology of the upper "Passage Beds" with siltstone and mudstone-shale decreasing both in thickness and frequency upwards toward the Weary Ridge Member contact. This makes placement of the Weary Ridge - "Passage Beds" contact easy when the massive, siltstone- mudstone- and shale-free sandstones of the Weary Ridge Member are first encountered. At two localities: Isolation Ridge (Sec. 76-14; figs. 3, 6) and the Sentinel-Highwood Ranger Station (Sec. 76-5; figs. 3, 7, 29), the strata of the upper "Passage Beds" are unusual and do not display an increase in thickness of sandstones vertically toward the Weary Ridge contact. The strata are characterized by an alternation of thin beds of sandstone (5 to 10 cm thick) and thick intervals of argillaceous siltstone and shale, directly overlain by the massive, orange-brown weathering sandstones of the Weary Ridge Member. However, at some localities, i.e. Weary Ridge (Sec. 76-15; Fig. 3); Greenhills (Sec. 75-17; Fig. 3); Grassy Mountain (Sec. 75-1; Fig. 3); and others, thin, lenticular siltstone to mudstone beds were observed several tens of metres above the lower Weary Ridge contact. These thin interbeds resemble the mudstone, siltstone and shale observed in the upper "Passage Beds" of the Fernie Formation. Because of their rare occurrence within the Weary Ridge Member in the report area, they are interpreted as part of the Weary Ridge lithofacies, and the lower contact is still placed at the base of the first vertically continuous sandstone.

These contact criteria, even with the above described anomalies, have proven reliable in consistently assigning the lower contact, in both surface sections and in drill core, at most localities in Alberta and British Columbia where the member is recognized at the base of the Kootenay Group.

Upper contact. The contact with the overlying Moose Mountain Member is conformable and at most localities very abrupt. It is placed at a level where the thicker bedded, argillaceous, ferruginous, commonly finer grained, more recessive, orange-brown to brownish grey weathering sandstones of the Weary Ridge Member are overlain by the commonly thinner bedded, less argillaceous, less ferruginous, but coarser grained, more resistant, darker grey weathering sandstones of the Moose Mountain Member (figs. 13, 14, 20). The contact at most localities is very well defined along a single bedding plane surface. As previously noted, this contact relationship prompted some early workers, including Hume (1938), Beach (1943), and Allan and Carr (1947) to suggest that it represents an erosional surface and the possibility of an unconformity between the two members. In the Sparwood-Fernie area of southeastern British Columbia it occurs at a pronounced textural change within a single thick bed of sandstone. However, at a few localities, i.e. Morrissey Creek (Sec. 75-5; Fig. 3), Flathead Ridge (Sec. 75-6; Fig. 3), Oldman Gap (Sec. 76-1; Fig. 3), Isolation Ridge (Sec. 76-14; Fig. 3) and Barrier Mountain (Sec. 76-17; Fig. 3), the contact between the two members appears to be gradational. The upper 1.5 to 3 m of the Weary Ridge Member at these localities is characterized by an increasing concentration of coarser grained, well indurated sandstone beds more typical of those in the Moose Mountain Member. However, where this gradation of lithofacies occurs the contact is still apparent and corresponds with a textural and major colour change between the two members, at the base of the better indurated, coarser grained sandstone. Because of the interdigitating nature of the Weary Ridge and Moose Mountain lithofacies at Oldman Gap (Sec. 76-1; Fig. 3), it was not possible to define the upper contact of the Weary Ridge Member and, accordingly, the strata are interpreted as part of the undifferentiated Morrissey Formation.

Figure 17. Flathead Ridge Pipeline section (Sec. 75-6), illustrating strata of upper Fernie Formation ("Passage Beds"). Note increasing bed thickness and increase in concentration of sandstone beds from base to top of interval. For location in measured section see Figure 15. Figure 18 is continuation of measured section.

Figure 18. Continuation of measured section illustrated in Figure 15 along Flathead Ridge Pipeline section (Sec. 75-6). Note increase in thickness of beds in upper Fernie Formation ("Passage Beds") as contact with Weary Ridge Member is approached. Scale of exposure and contact between Fernie Formation and Weary Ridge Member shown by assistant at contact. Note resistant cliff-forming nature of overlying Moose Mountain Member. Fernie Formation (Fn); Weary Ridge Member (Wr); Moose Mountain Member (Msm).

Figure 19. Contact and lithologic relationships between Fernie Formation and Weary Ridge Member of Kootenay Group at Adanac Strip Mine (Sec. 75-10). Note thick-bedded and massive character of Weary Ridge sandstones. Assistant on contact. Fernie Formation (Fn); Weary Ridge Member (Wr).

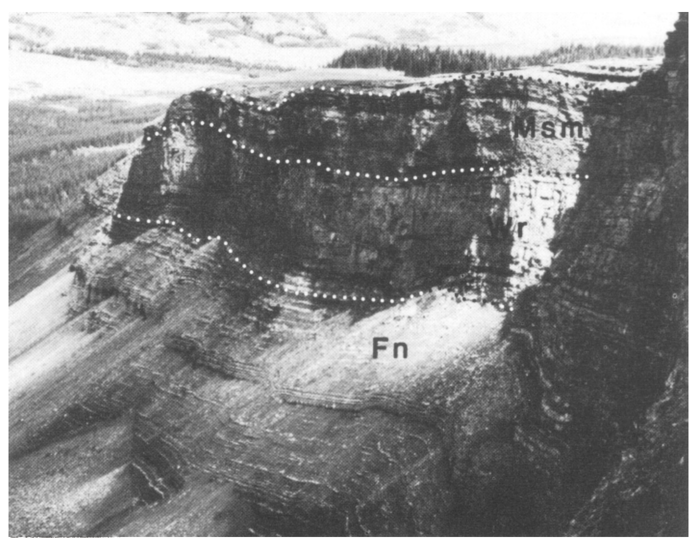


Figure 20. Contact and lithologic relationships between Fernie Formation and Weary Ridge Member at Barrier Mountain (Sec. 76-17). Note gradational Fernie and Weary Ridge contact, and dark grey siltstone-shale unit near top of Moose Mountain Member. Fernie Formation (Fn); Weary Ridge Member (Wr); Moose Mountain Member (Msm).

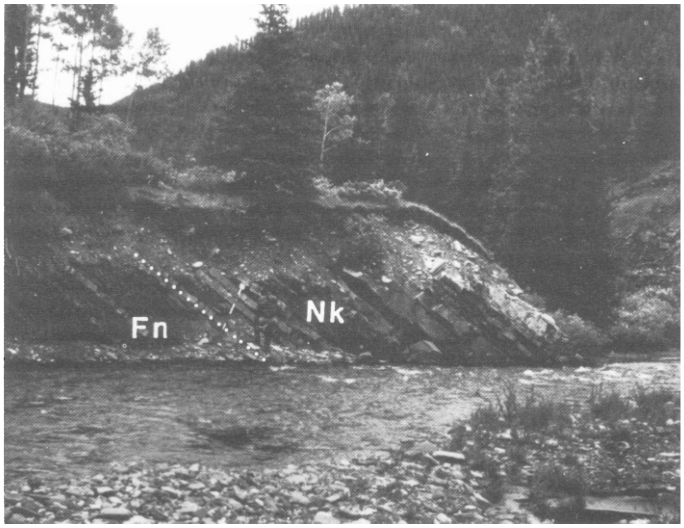


Figure 21. *Contact and lithologic relationships between Fernie and Nikanassin formations, Wapiabi Creek (Sec. 77-7). Note gradational contact and absence of well developed basal sandstone unit. Fernie Formation (Fn); Nikanassin Formation (Nk).*

addition, the upper contact of the Weary Ridge Member in core sections may not be readily apparent without detailed petrographic examination of thin sections and, consequently, the strata may have to be mapped as undifferentiated Morrissey Formation.

Distribution and thickness

The Weary Ridge Member can be recognized as a distinct and separate member of the Morrissey Formation throughout the Rocky Mountain Foothills and Front Ranges of southwestern Alberta and southeastern British Columbia, in the area between Cabin Creek and the upper Flathead River valley (near the United States border) to the Barrier Mountain area near the headwaters of Red Deer River and Banff National Park (Fig. 1). At Barrier Mountain (Sec. 76-17; figs. 3, 20), the Weary Ridge Member, although still recognizable as a distinct facies of the Morrissey Formation, begins to lose its distinctive recessive, orange-brown weathering character found at most localities to the south. At Limestone Mountain, 25 km northeast of Barrier Mountain, the Weary Ridge Member is no longer recognized as a separate member of the Morrissey Formation (Fig. 9).

The Weary Ridge Member ranges in measured thickness from a minimum of 5 m at Grassy Mountain and Mount Allan, near Blairmore and Canmore respectively (figs. 3, 5, 8), to a maximum of 55 m at Greenhills Range near Elkford, British Columbia. The Weary Ridge Member does not display any significant thickness trends. The erosional edge corresponds with that identified for the Morrissey Formation and Kootenay Group as shown by the isopach maps (figs. 4, 16). The general absence of any conspicuous thickness trends is probably related to the regional and local interfingering or gradational nature of the underlying contact with the "Passage Beds" of the Fernie Formation. Because of the criteria used to define the base of the Weary Ridge Member (the absence of interbeds of siltstone, mudstone or shale) and because of interbedding between the sandstone and finer clastics at some localities, placement of the contact may arbitrarily include or exclude significant thicknesses of strata. For example, at Mount Allan (Sec. 76-7; Fig. 3), the upper "Passage Beds" of the Fernie Formation are characterized by thick sandstone beds and sandstone intervals similar in composition to those of the Weary Ridge Member. These sandstones comprise units up to 10 m thick. They are, however, always overlain by thin to thick intervals of siltstone, mudstone or shale, which by definition necessitates placement of the lithofacies into the "Passage Beds" of the Fernie. If, however, the siltstone, mudstone, and shale interbeds were absent due to nondeposition, then the base of the Kootenay Group and Weary Ridge Member would, by definition, be placed lower in the stratigraphic column, to coincide with the base of the first continuous sandstone devoid of siltstone, mudstone or shale interbeds. Conversely, if siltstone, mudstone and shale beds occur higher in the section, these strata would by definition be assigned to the "Passage Beds". For example, at Mount Allan the Weary Ridge Member is 5 m thick, while the "Passage Beds" of the Fernie Formation are in excess of 82 m thick.

Age and correlation

Macrofossils or microfossils are rare in the Weary Ridge Member. Allan and Carr (1947) recovered a sparse fauna of marine pelecypods from 25 feet (7.6 m) above the base of a massive sandstone unit, at the top of the Fernie Formation near the Sentinel-Highwood Ranger Station Section (Sec. 76-5; Fig. 3). This is the sandstone herein defined as the Weary Ridge Member. The fauna, which includes the pelecypods *Oxytoma* cf. *blairmorensis* McLearn, *Modiolus* cf. *frankensis* McLearn, *Astarte* sp., and cf. *Pachyteuthis densus* (Meek), was suggested as indicating a probable Late Jurassic age. In the Fernie area of southeastern British Columbia, the discovery of the large solitary ammonite, *Titanites occidentalis* Frebold, by Newmarch (1953), at the top of strata defined herein as the Morrissey Formation, suggests that the strata of the Weary Ridge Member are also Late Jurassic and probably Portlandian, or possibly slightly older, in age. Pocock (1964), in a palynological study of the Kootenay Formation at Grassy Mountain (Sec. 75-1; Fig. 3), suggested a similar Late Jurassic age. He recovered a microfloral assemblage from the entire Kootenay, including strata at the base of the formation that are probably equivalent to the Weary Ridge Member. Pocock (*op. cit.*) suggested an age for the formation (Mist Mountain and Morrissey formations of this report) of Portlandian to possibly Purbeckian (Late Jurassic). Thus, on the basis of the foregoing meagre paleontological evidence, one can suggest that the Weary Ridge Member is not younger than Late Jurassic and is probably Portlandian in age.

The Weary Ridge Member grades laterally northward, in the vicinity of Limestone Mountain (Sec. 76-18; figs. 3, 9, 10), into well indurated siliceous sandstones of the undifferentiated lower Morrissey Formation and, in the west central Alberta Foothills north of North Saskatchewan River (Fig. 1), the latter passes into interbedded marine sandstone, siltstone, and shale of the lower Nikanassin Formation (figs. 2, 11, 21). Allan and Carr (1947) and Douglas (1958) suggested that sandstone strata at the top of the Fernie Formation, which are defined herein as the Weary Ridge Member and part of the Kootenay Group, correlate with a distinctive subsurface sandstone marker called the "Brown sand", in the subsurface of the eastern Foothills of the Turner Valley area. This subsurface marker sandstone has been arbitrarily placed in the Fernie Formation, but, as previously noted, the correlation is speculative and is not based upon either faunal or convincing lithologic evidence.

Correlation with the Morrison Formation in the Montana area of the United States is problematical. Lithological and faunal data reported in studies of the Morrison Formation by Kauffman (1963), Silverman and Harris (1966), Suttner (1966, 1969), Harris (1968), Walker (1974), and members of the Billings Geological Society (1966), suggest that strata of the upper Morrison Formation, on the basis of age (as young as Portlandian), may possibly correlate with strata of the Weary Ridge Member. There does not, however, appear to be any lithological similarity between the sandstones of the Weary Ridge Member and the interbedded sandstones, siltstones, mudstones, shales and rare coals of the Upper Morrison Formation. Therefore, a lithologic comparison suggests that strata equivalent to the Weary Ridge may have been erosionally removed or may not have been deposited in the Montana area.

Sedimentary structures

The massive, locally cliff-forming but generally covered character of the Weary Ridge Member at many section localities makes sedimentary structures difficult to observe. Furthermore, when they are observed, directional structures are not sufficiently well exposed to provide reliable azimuth values necessary for accurate paleocurrent determinations.

Small- to large-scale festoon and planar-tabular crossbeds (McKee and Weir, 1953) were observed at most localities, although they were most conspicuous and best developed at the thicker westernmost sections. Of the two types of crossbedding, festoon is the most conspicuous. It occurs randomly throughout the section, although it is most evident toward the top of the member. Troughs up to 0.6 m thick by 3.0 to 3.7 m wide were recorded at Mist Mountain (Sec. 76-10; figs. 3, 7). Small- to large-scale, shallow dipping, planar-tabular crossbeds were evident at most localities, although never as conspicuous as the festoon crossbeds. However, because of shallow dips, some of the large planar foresets may have been misinterpreted as simple planar or parallel, compositional and textural laminations. Furthermore, the orange-brown, soft weathering "rind", found on some of the more massive weathering strata of the member, may also have masked additional evidence of shallow dipping, planar crossbeds. In a recent sedimentological study, which included strata of the Weary Ridge Member, Hamblin and Walker (1979) reported planar crossbeds as the predominant sedimentary structure of the member. At many sections, because of the limited nature of the exposure, it was not always possible to tell whether a crossbed was part of a foreset of a unidirectional planar set, or whether it should have been classified as the foreset of one side of a large trough.

Lighter and darker grey, thin to thick, parallel, and rare wavy, textural and compositional laminations, are evident at most locations. They are confined mainly to the thinner bedded strata, but were also observed in the thick, massive bedded sandstone near the top of the member. As noted above, the laminae may in part represent unrecognized shallow dipping planar-tabular foresets.

Rare horizontal burrows or "grazing tracks" (ichnofossils) were found on a few bedding plane surfaces in the lower 7 m of the member at Mist Mountain, near Highwood Pass (Sec. 76-10; figs. 3, 7), and on a talus sample from slightly above the basal contact of the member near Mount Taylor (Sec. 75-15; Fig. 3). At the latter locality, however, it is uncertain whether the sample comes from the lower Weary Ridge Member or from the upper "Passage Beds" of the Fernie Formation. Burrowing and other biogenic structures were absent at other localities where exposures of the member were examined.

Moose Mountain Member

Definition

The Moose Mountain Member is the prominent cliff-forming, well indurated marker sandstone of the lower Kootenay Group, occurring in the Morrissey Formation between the Weary Ridge Member below and the coal-bearing strata of the Mist Mountain Formation above (figs. 12, 13, 14, 15, 22, 23, 24). The recognition, definition and contact controversy concerning the Moose Mountain Member has been reviewed in a preceding section of this report, and in an earlier preliminary paper by the writer (Gibson, 1979), and will not be repeated here. However, it should be noted that recognition of facies and member boundaries of the Moose Mountain Member by the writer, correspond with those of Newmarch (1953), Douglas (1958), Norris (1959b), and Price (1962, 1965), used during earlier local and regional mapping investigations in the Crowsnest Pass and Fernie areas of southwestern Alberta and southeastern British Columbia.

Type section

A type section was never clearly designated or described for the Moose Mountain Member of the former Kootenay Formation, although Beach (1943) designated a type locality for the member in the area of Moose Mountain, 52 km west-southwest of Calgary (figs. 3, 24). Beach (*op. cit.*) did however, suggest a section near the headwaters of Bragg Creek, which had earlier been described by Cairnes (1914), as the best exposed in the Moose Mountain area (Fig. 24). It has been suggested by the writer (Gibson, 1979) that the section referred to by Beach (1943), and described by Cairnes (1914), be designated as the type section of the Moose Mountain Member, and to comprise only the upper 9.1 m of well indurated, resistant, cliff-forming sandstone, overlying 10.7 m of more recessive weathering, orange-brown sandstone (Weary Ridge Member of this report). The section is located on the east flank of Moose Mountain, at the headwaters of Bragg Creek, 2.4 km east-northeast of Moose Mountain Lookout Tower (figs. 8, 24, UTM co-ordinates 540465; topographic map NTS 82J/15, Bragg Creek).

It should be noted that the Moose Mountain Member is generally not well exposed in the type area, nor is the lithology typical of the member elsewhere in Alberta and British Columbia. Supplemental reference sections that are completely exposed, readily accessible, and typical of the facies may be examined at: Morrissey Ridge, the type section of the Morrissey Formation (Fig. 3; UTM co-ordinates 452757; topographic map NTS 82G/7, Upper Flathead Valley); Weary Ridge, the type section of the Weary Ridge Member (figs. 13, 14; UTM co-ordinates 507822; topographic map NTS 82J/7W, Mount Head); the Sentinel-Highwood Ranger Station section near Mount Head

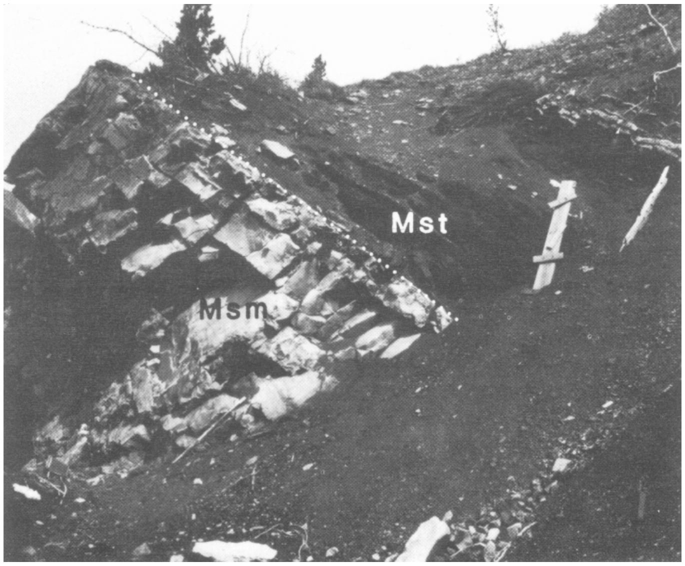


Figure 22. Contact between Moose Mountain Member of Morrissey Formation and Mist Mountain Formation at Line Creek (Sec. 76-16). Note thick coal (3 m) at base of Mist Mountain Formation on sandstone of Moose Mountain Member. Compare with Figure 15. Moose Mountain Member (Msm); Mist Mountain Formation (Mst).

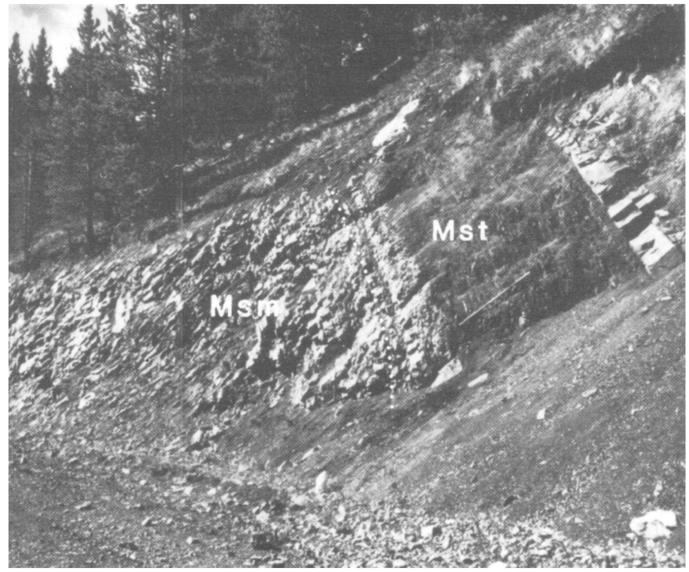


Figure 23. Grassy Mountain section (Sec. 75-1), illustrating strata of Moose Mountain Member and lower Adanac Member of Mist Mountain Formation. Note gradational contact and thick coal seam at base of Mist Mountain Formation. Compare contact relationships with figures 15 and 22. Moose Mountain Member (Msm); Mist Mountain Formation (Mst).

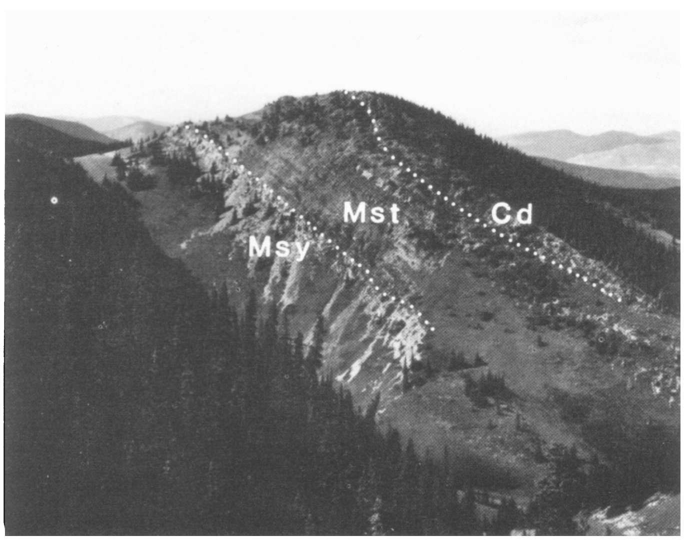


Figure 24. Contact and lithologic relationships between Morrissey, Mist Mountain and Cadomin formations near headwaters of Bragg Creek (Sec. 76-19). Note cliff-forming Morrissey Formation and Moose Mountain Member, and absence of Elk Formation below Cadomin. Morrissey Formation (Msy); Mist Mountain Formation (Mst.)

(figs. 3, 29; UTM co-ordinates 668859; topographic map NTS 82J/7E, Mount Head); and Mist Mountain, the type section of the Mist Mountain Formation (figs. 3, 25; UTM co-ordinates 459024; topographic map NTS 82J/10W, Mount Rae).

Lithology and facies variation

The Moose Mountain Member comprises a cliff-forming, quartz-chert sandstone, with rare beds and thin intervals of mudstone, shale and bituminous coal at some localities. The sandstone ranges from light to medium-dark grey on fresh surfaces to medium grey, greyish brown or buff on weathered or exposed surfaces. In many areas the strata are lichen covered and appear dark grey. The sandstone is predominantly thin to medium bedded (McKee and Weir, 1953), although thick beds were noted at some western sections. The average grain size of the sandstone is medium although beds of fine grained sandstone occur at many localities. At two sections in the report area the sandstone is conglomeratic. For example, at Line Creek (Sec. 76-16; figs. 3, 22), a few lenticular beds of conglomeratic sandstone to pebble conglomerate, up to 0.3 m thick, are randomly distributed throughout the lower half of the member. The conglomeratic lithofacies consists of matrix supported, well-rounded, dark to light grey and greenish grey chert, and light grey to white quartzite pebbles, ranging mainly between 0.6 and 1.3 cm, but up to 2.5 cm, in diameter. At Cat Mountain (Sec. 75-13; figs. 3, 5) a 15 cm thick bed of conglomeratic sandstone was observed at a level 15 m above the base of the member. This sandstone, like that at Line Creek, contains light and dark grey, well rounded chert pebbles, up to 1.3 cm in diameter, in a grain supported matrix of coarse grained sandstone. Rare, medium grey chert pebbles, up to 1.3 cm in diameter, were also noted in a 30 cm thick sandstone at the base of the member at the locality near the Cascade River bridge - Banff traffic circle in Banff National Park (Sec. 76-8; Fig. 3). At some localities fining- and coarsening-upward intervals were noted. Strata of the member at most localities do, however, display a noticeable average grain size increase over those in the underlying Weary Ridge Member.

The sandstone of the Moose Mountain Member mineralogically resembles that of the Weary Ridge Member, although it is less argillaceous, ferruginous, and carbonaceous and does not contain conspicuous carbonate minerals. There is however, at some localities, a noteworthy increase in dark grey to black carbonaceous plant matter in the upper beds of the member. In the coarser grained sandstones, dark grey chert is a prominent mineral component and these sandstones, like some of the sandstone in the Weary Ridge Member, display a "salt and pepper" texture. Because of the lower concentration of carbonaceous and ferruginous components, the sandstones of the Moose Mountain Member are commonly better indurated and more resistant weathering than those of the underlying Weary Ridge Member.

Facies changes are uncommon. However, in some areas of the upper Elk River valley, the Moose Mountain Member contains one or two beds of thin, recessive intervals of dark grey to black carbonaceous mudstone, shale and bituminous coal. At Line Creek (Sec. 76-16; Fig. 3), on the coal property of Crowsnest Resources Limited, the member contains two thin intervals of very dark grey, carbonaceous mudstone and minor coal, 8.5 and 13.5 m below the top of the member (T. Hannah, pers. comm., 1980). The two intervals are 0.76 and 0.4 m thick respectively, and both contain coal and coaly shale ranging in thickness from zero to 0.35 m thick. At Weary Ridge (Sec. 76-15; figs. 3, 13, 14), a similar recessive, dark grey, carbonaceous mudstone unit, up to 0.6 m thick and 11 m below the top of the Moose Mountain Member, was observed, but contains no coal. However, communication with G. Lawrence of Elko Mining Limited (owners of coal licences in the Weary Ridge area), has revealed that, during a coal exploration drilling program in the Weary Ridge area and the region adjacent to and west of Elk River (Fig. 3), an interval was noted at approximately the same stratigraphic level as on Weary Ridge, which locally contains coal and carbonaceous and coaly shale. The coal locally attains a maximum recorded thickness of 0.3 m. In addition, at the Weary Ridge locality, the base of the Moose Mountain Member is characterized by an unusual lithofacies variation not observed elsewhere in the report area. At Weary Ridge, the lower 2 m consists of recessive, dark grey weathering, thin- to medium-bedded siliceous mudstone, and medium-dark grey, medium- to fine-grained, very siliceous, well indurated sandstone (Fig. 13). This recessive unit thins laterally along strike, within a few hundred metres, to a 5 to 8 cm thick unit of dark grey, carbonaceous shale, which eventually disappears along strike in the cliff face. No coal has been observed in this facies. At a locality near Mount Taylor (Sec. 75-15; figs. 3, 5), another recessive weathering mudstone unit, up to 0.8 m thick, is present 10.7 m below the top of the member. Again, the recessive mudstone interval did not contain any obvious coal, although along strike or elsewhere in the immediate area, or in the subsurface, the interval may contain coal in a similar manner to that recorded in the vicinity of Weary Ridge. Other rare, recessive, shale-mudstone beds were recorded: at Grassy Mountain (Sec. 75-1; figs. 3, 5, 23), 4 and 10 m above the base, and 2.5 cm thick; and at Ridge Creek (Sec. 76.3; figs. 3, 6), where a very sandy shale to mudstone unit, 0.9 m thick, occurs 1.2 m below the top of the member. It must be noted that because of the cliff-forming and generally inaccessible character of the Moose Mountain Member, other thin mudstone-shale and possible coal units may have been overlooked. However, as previously noted, and because of the number of field sections examined, the occurrence of these recessive weathering mudstone-shale and coal lithofacies is considered to be uncommon.

The designated type section and type locality of the Moose Mountain Member near the headwaters of Bragg Creek displays another regional facies variation (Fig. 24). At this locality the sandstones of the member are thinner bedded, more siliceous, more carbonaceous and consequently darker grey than those found elsewhere in the report area, with the exception of the sandstones in the northern part of the study area. In the Barrier Mountain-Limestone Mountain area (secs. 76-17, 76-18; figs. 3, 9), the sandstone becomes increasingly more siliceous and better indurated but less carbonaceous than it was to the south in the Fernie, Crowsnest Pass and Highwood Pass areas of southeastern British Columbia and southwestern Alberta. Furthermore, between Limestone Mountain and North Saskatchewan River, all Morrissey sandstones weather a distinctive light orange-brown to buff and can no longer be separated into members, and are, therefore, designated as an undifferentiated unit of the Morrissey Formation (Fig. 9).

As noted previously, the unusual interbedded sandstone, siltstone and shale lithofacies, described by Jansa (1972, p. 3202) and illustrated by Frebold (1962, p. 19) as part of the Moose Mountain Member and basal Kootenay sandstone near the Cascade River bridge - Banff traffic circle section (Sec. 76-8; Fig. 3), is not a facies variation of the Moose Mountain or basal sandstone of the Kootenay, but is a facies of the "Passage Beds" of the Fernie Formation.

Contact relationships

The contact with the overlying Mist Mountain Formation is conformable and generally abrupt in most areas. It is placed at a level where massive, well indurated, resistant, commonly cliff-forming, quartzose sandstone of the Moose Mountain Member contrasts sharply with dark grey, commonly recessive weathering, carbonaceous siltstones, mudstones, shales, and coals of the lowermost Mist Mountain Formation (figs. 12, 13, 14, 15, 22). The contrast in lithofacies is particularly evident in the area of the western Fernie Basin and upper Elk River valley of southeastern British Columbia. As can be seen in figures 12, 13, 14, 15 and 22, sandstone is not an abundant or conspicuous component of the strata in the lowermost Mist Mountain Formation in this area, thus facilitating recognition and placement of the contact. There are, however, a few localities, i.e. Mount Taylor (Sec. 75-15; figs. 3, 5), Grassy Mountain (Sec. 75-1; figs. 3, 5, 23), Mount Allan (Sec. 76-7; figs. 3, 8), and Barrier Mountain (Sec. 76-17; figs. 3, 9), where sandstone does occur as thin to thick interbeds in the lowermost Mist Mountain strata. At these localities the contact is gradational and, accordingly, not as readily apparent as at most other localities where the contact is abrupt. For example, in the Mount Taylor area of southeastern British Columbia (Sec. 75-15; Fig. 5) the Moose Mountain Member is overlain abruptly by 15 m of recessive, partially talus-covered, dark grey weathering, carbonaceous mudstone and siltstone, with rare, scattered, lenses of coal. This recessive, carbonaceous facies is overlain by a massive unit of coarse grained to conglomeratic sandstone, superficially similar to that of the Moose Mountain Member. However, this massive sandstone contains a few, generally talus-covered, intervals of siltstone to mudstone-shale. The contact between the Moose Mountain

Member and Mist Mountain Formation in the Mount Taylor area is placed at the base of the lowermost recessive weathering mudstone or siltstone, and not at the top of the uppermost coarse grained sandstone, or base of the first major coal seam in the Mist Mountain Formation.

A similar sandstone and conglomeratic sandstone succession occurs at the base of the Mist Mountain Formation at Marten Ridge (Sec. 75-12; Fig. 5), 10.5 km northwest of Mount Taylor, and at Tent Mountain, 5 km northeast of Mount Taylor along the Alberta-British Columbia provincial boundary.

At Grassy Mountain, near Blairmore, Alberta (Sec. 75-1; figs. 3, 5, 23), the Moose Mountain sandstone is overlain by 2 m of interbedded, very fine grained sandstone, siltstone, and shale, the latter in beds up to 7.5 cm thick. The interbedded facies is in turn overlain by 3.2 m of coal and rare coaly shale. The contact between the Moose Mountain Member and Mist Mountain Formation at Grassy Mountain is placed at the base of the 2 m thick, interbedded sandstone, siltstone, and shale succession (Fig. 23).

At Mount Allan (Sec. 76-7; figs. 3, 8) near Canmore, Alberta, medium- to fine-grained, siliceous Moose Mountain sandstone is gradationally overlain by 4.3 m of interbedded medium- to fine-grained sandstone, siltstone, and minor shale of the Mist Mountain Formation. This lithofacies is overlain in turn by 30.5 m of dark grey, carbonaceous and argillaceous siltstone, shale, and possible coal. Again, the contact at this locality is gradational and placed at the base of the lowest interbedded sandstone, siltstone, and shale unit.

At the Barrier Mountain locality, near Red Deer River and Banff National Park (Sec. 76-17; figs. 3, 9, 20), the contact between the Moose Mountain Member and Mist Mountain Formation is gradational. The section comprises a prominent cliff-forming exposure. At one locality on the escarpment the Moose Mountain sandstone is overlain by 2.4 m of dark grey to black mudstone-shale. The mudstone-shale unit thickens eastward along the cliff face to 6 m, in a lateral distance of 30.5 m, but thins westward to zero over a few tens of metres by grading into well indurated, medium- to fine-grained sandstone typical of the Moose Mountain Member. The contact at the Barrier Mountain locality is placed at the base of the first occurrence of dark grey carbonaceous mudstone, siltstone, and/or shale, with the overlying sandstone and its sporadic interbeds of dark grey mudstone, some of which are up to 20 cm thick, being considered part of the Mist Mountain Formation. Where the mudstone-shale tongue grades laterally into medium- to fine-grained sandstone, the contact is placed at the top of the sandstone, at a somewhat higher stratigraphic level, to coincide with the last of the massive sandstone and the first occurrence of the dark grey, carbonaceous mudstone to shale.

In areas characterized by a gradational relationship between the Moose Mountain Member and the Mist Mountain Formation, the contact, in addition to the lithofacies change, also coincides with a conspicuous break in the weathering profile. The basal strata of the Mist Mountain Formation invariably weather more recessively than strata of the underlying Moose Mountain Member.

The contact with the underlying Weary Ridge Member is conformable and abrupt as previously noted.

Distribution and thickness

The Moose Mountain Member occurs as a distinct lithofacies of the Morrissey Formation throughout most areas of the Rocky Mountain Foothills and Front Ranges, between the Cabin Creek-Upper Flathead River valley area (near the United States border) to the Barrier Mountain area near the headwaters of Red Deer River and Banff National Park, Alberta (Fig. 1). At Limestone Mountain, 25.7 km northeast of the Barrier Mountain locality, strata of the Moose Mountain Member are not recognized as a separate member of the Morrissey Formation.

The Moose Mountain Member ranges in measured thickness from a minimum of 4 m at the former Adanac strip mine locality south of Blairmore, Alberta (Sec. 75-10; Fig. 3), to a maximum of 36 m near Mist Mountain and Highwood Pass, the type locality of the Mist Mountain Formation (Sec. 76-10; figs. 7, 25). The Moose Mountain Member is 9 m thick at the type section at the headwaters of Bragg Creek (Sec. 76-19; figs. 8, 24). The Moose Mountain, like the underlying Weary Ridge Member, does not display significant thickness trends within the report area, with the exception of thinning to a zero erosional edge toward the east. The thinning trend corresponds to that of the Morrissey Formation and the Kootenay Group (figs. 4, 16). The reason for the absence of consistent thickness trends was documented previously during the discussion of the Weary Ridge Member.

Age and correlation

No identifiable fossils were obtained by the writer from the Moose Mountain Member. However, a large solitary ammonite mold was discovered by Newmarch (1953) on the upper bedding surface of strata herein defined as the Moose Mountain Member at a locality near Fernie. The ammonite was identified by Frebold (1957) as *Titanites occidentalis* Frebold, and assigned a Late Jurassic Portlandian age. Recently, Hamblin and Walker (1979) reported fragments of a large ammonite from strata equivalent to the Moose Mountain Member, at Tent Mountain. They suggested that the fragments "may represent part of the inner whorl of *Titanites*", implying a possible Portlandian age. To date, no other fossils have been reported from the Moose Mountain Member or equivalent strata in the Foothills or Front Ranges of Alberta or British Columbia.

Because of its distinctive cliff-forming character, the Moose Mountain Member is easily correlated throughout most areas of southwestern Alberta and southeastern British Columbia (figs. 5-11). In the Rocky Mountain Foothills between Barrier Mountain and North Saskatchewan River (Fig. 9), however, it is no longer recognized as a separate and distinct member, but grades laterally into undifferentiated strata of the Morrissey Formation. Between North Saskatchewan River and the Athabasca River-Jasper area, the Moose Mountain Member is homotaxially equivalent to the basal, interbedded sandstone, siltstone and shale of the marine Nikanassin Formation (Fig. 21). However, Warren and Stelck (1958) in a study of the Nikanassin-Luscar hiatus, have suggested that strata of the lower Nikanassin Formation are older than the lower strata of the Kootenay Group and, on the basis of the fossil evidence, probably correlate with the "Passage Beds" of the Fernie Formation. Unfortunately, to date, not enough paleontological data have been obtained from the Nikanassin Formation in the Jasper-North Saskatchewan River area, nor from the Kootenay Group in the North Saskatchewan River-Crowsnest Pass-Fernie area, to establish, with any degree of certainty, the true age relationship between these two major lithostratigraphic units. In the Foothills of west central Alberta and northeastern British Columbia north of Smoky River, the Moose Mountain Member is homotaxially equivalent to part of the basal sandstone strata of the Monteith Formation of the Minnes Group (Stott, 1975). Precise age relationships between strata of the two areas again have not been established. Age relationships and correlation with strata in the Foothills and Front Ranges south of the United States border are uncertain. Strata of the upper Morrison Formation of Montana and Wyoming are sufficiently different from those of the Moose Mountain Member in Alberta and British Columbia that any suggested correlations without fossil evidence, or physically tracing outcrops from one area to the next (i.e. across the international border), would be speculative. However, based on the lithological and faunal data reported in studies of the Morrison Formation by Silverman and Harris (1966), Harris (1968), Walker (1974), and others, strata of the Moose Mountain Member may correlate with the uppermost strata of the Morrison Formation in Montana and Wyoming. The Morrison Formation in Montana is suggested to be Kimmeridgian to Portlandian in age (Billings Geological Society, 1966).

Sedimentary structures

Festoon or trough crossbedding forms the most conspicuous sedimentary structure in the Moose Mountain Member. Sets range in size from small to large scale with medium scale the predominant size (McKee and Weir, 1953). The crossbeds do not display any apparent size distribution pattern within the member, although the larger sets are most commonly found in the sandstones of the lower half. The large, and some medium scale crossbeds are characterized by shallow trough axes. Small to medium scale planar-tabular crossbedding was also noted at some localities, commonly occurring immediately above or below the festoon type. Because of the cliff-forming and generally inaccessible nature of the member, difficulties were encountered in determining whether individual crossbeds represented one side or set of a festoon or trough, or whether they represented the inclined foresets of a planar-tabular set. Reliable azimuth values were difficult if not impossible to obtain for use in paleocurrent determinations. Crossbedding was not observed at all localities, being commonly replaced by thin to thick, parallel to slightly wavy, lighter and darker grey laminations, or by massive structureless bedding.

Other structures, although rare in occurrence, include: black, carbonaceous, vertical rootlets, in the uppermost bed of the member adjacent to the Mist Mountain Formation contact; a single small vertical burrow, 1.2 cm in diameter, in the upper 30 cm of the member; and wood molds and casts (see Fig. 46) containing rare, vitreous coal spars (for definition of 'coal spars' see Ferm and Melton, 1977). The molds and casts, although noted at five localities, are usually not found in the sandstones of the Moose Mountain Member nor in the sandstones of the underlying Weary Ridge Member. This feature, along with other compositional criteria, may be used to assist in mapping and differentiating thick bedded, isolated sandstone outcrops in forested or grass- and talus-covered areas. Wood molds and casts are most commonly found in, or restricted to, the major channel sandstones of the overlying Mist Mountain and Elk formations (Fig. 46). When observed in the Moose Mountain Member the wood molds and casts mostly occur near or adjacent to the contact with the coal-bearing Mist Mountain Formation. However, at one locality they were observed near the centre of the member, immediately above thin beds of coal and coaly shale.

Mist Mountain Formation

Definition

The recently defined Mist Mountain Formation (Gibson, 1979) occupies the stratigraphic interval between the Morrissey Formation below and the Elk Formation above (figs. 2, 25, 29, 32, 33). However, in the area of the eastern part of the Alberta Foothills the Elk is absent and the Mist Mountain Formation is unconformably overlain by the Cadomin Formation of the Blairmore Group (figs. 2, 27).

Strata equivalent to the Mist Mountain Formation were first recognized and defined as a separate lithostratigraphic unit (Cairns, 1914, Rose, 1917) by Newmarch (1953), while mapping in the Fernie area of southeastern British Columbia. Newmarch (*op. cit.*) divided the original Kootenay Formation into two mappable units or formations, an upper, which he called the Elk, and a lower, for which he retained the name Kootenay (Fig. 2). The Kootenay unit also included an additional facies which is herein called the Moose Mountain Member. Douglas (1958), while mapping in the Mount Head-Oldman River area of Alberta, recognized a similar two-fold division of the Kootenay Formation. He informally designated these units Map Unit-A for the lower and Map Unit-B for the upper. Map Unit-A included strata equivalent to the Mist Mountain Formation and Moose Mountain Member of this report. Later Norris (1959b) subdivided the Kootenay Formation into four members while mapping in the Coleman-Blairmore-Crowsnest Pass area of Alberta (Fig. 2). These members were, in ascending order, Moose Mountain, Adanac, Hillcrest, and Mutz. Grassy Mountain (Sec. 75-1; figs. 3, 5) was designated as the type section for the three upper members, and for the Kootenay Formation. The three upper members, Adanac, Hillcrest and Mutz, are equivalent to the Mist Mountain Formation. Jansa (1972), in a study of Kootenay strata in Alberta and British Columbia, recognized the same major lithostratigraphic divisions as Newmarch (1953), although he considered each division, including the "Basal Kootenay Sand" only as members of the former Kootenay Formation (Fig. 2). Strata equivalent to the Mist Mountain Formation were informally called the "Coal-bearing member". The writer, during a regional stratigraphic study of Kootenay rocks in Alberta and British Columbia, redefined the base of the Kootenay as previously noted, and formally proposed and named two new formations to coincide with the divisional boundaries of Newmarch (1953) and Jansa (1972), with minor modifications (Fig. 2). The two new formations were, in ascending order, Morrissey and Mist Mountain, overlain by the long recognized Elk Formation. The three new and local members recognized by Norris (1959b) in the Crowsnest Pass area of Alberta, although easily recognized and mappable in the immediate and adjacent areas of Grassy Mountain, Coleman and Blairmore, cannot be recognized or extended with any degree of confidence beyond the Grassy Mountain-Crowsnest Pass area of southwestern Alberta. These members will not be described in this report. The interested reader is referred to the report by Norris (1959b) for lithological details and contact relationships.

Type section

The type section of the Mist Mountain Formation is well exposed, readily accessible, and located along a western spur of Mist Mountain, on the east side of and above Storm Creek, 6.4 km south of Highwood Pass on the Coleman-Kananaskis Lakes-Seebe forestry trunk road (Fig. 25; UTM co-ordinates 459024; topographic map NTS 82J/10W, Mount Rae). The section has been described by Gibson (1979). Other complete and well exposed reference sections, illustrating facies typical of the formation, may be examined at the following localities: Grassy Mountain, the type section of the former Kootenay Formation (figs. 5, 23, 27; UTM co-ordinates 868061; topographic map NTS 82G/9, Blairmore); Flathead Ridge pipeline section, on the southwest margin of the Fernie Basin (figs. 5, 31; UTM co-ordinates 540664; topographic map NTS 82G/7, Upper Flathead); Mount Allan, a thick and very well exposed section near Canmore, Alberta (Fig. 8; UTM co-ordinates 269495; topographic map NTS 82J/14E, Evans-Thomas Creek); and Limestone Mountain, a well exposed but thin section of the Mist Mountain Formation near the northern and eastern limits of recognition of the Kootenay Formation (Fig. 9; UTM co-ordinates 087527; topographic map NTS 82O/14, Limestone Mountain). All of the above supplementary sections are accessible by foot, trail bike, or four-wheel drive vehicle. In many areas, strata of the Mist Mountain Formation are generally poorly exposed (talus and/or grass and tree covered), and characterized by sporadic, resistant weathering ribs of sandstone (figs. 29, 32, 33). Accordingly, complete or nearly complete natural exposures of the formation are difficult to find. Good Mist Mountain sections are, however, available in core, and in fresh exposures made by bulldozers. These sections and core are located on, or belong to, coal exploration companies, from whom access permission generally must be obtained.

Lithology and facies variations

The economically important, coal-bearing Mist Mountain Formation comprises a relatively thick, interstratified sequence of predominantly nonmarine siltstone, sandstone, mudstone, shale, and thin to thick seams of low- to high-volatile bituminous coal to semianthracite (Fig. 5). Chert-pebble conglomerate and conglomeratic sandstone form conspicuous interbeds in the area of the Fernie Basin of southeastern British Columbia. Thin beds of silty, carbonaceous limestone were noted on Flathead Ridge, and rare beds or "tonsteins" of light brown to buff claystone were observed in the upper Elk River valley.

Siltstone appears to be the predominant lithotype of the Mist Mountain Formation. However, the grain size of the siltstone is such that some of the strata classified in the field as sandy siltstone, may, upon detailed size analysis, be classified as very fine grained sandstone. The siltstone is medium dark to dark grey, depending on the concentration of comminuted vegetal matter, and predominantly thin- to medium-bedded although, locally, it may display shaly to flaggy weathering. It is composed of quartz, lesser amounts of chert, carbonate minerals and rare feldspar. A variable concentration of small to large or comminuted vegetal fragments or phytoclasts characterize many of the finer grained siltstones, especially those near or adjacent to coal seams or coaly mudstone or shale. The closer the proximity of the siltstones to coal seams the higher the concentration of phytoclasts, which in many instances have been altered to form thin lenses and lenticles of coal. The siltstone commonly weathers a characteristic medium to dark grey, although some beds, containing carbonaceous mudstone or shale, weather a distinctive orange brown to yellow-orange. These beds are commonly siliceous, very calcareous, ferruginous (limonitic), and characteristically are very well indurated. Two unusual siltstone beds were noted at Plateau Mountain (Sec. 76-4; Fig. 3) and Mount Allan (Sec. 76-7; Fig. 3). On fresh surface these siltstones are dark grey and very carbonaceous, with a relatively high concentration of fragmented plant debris, and display a high degree of silicification. These siltstones weather an unusual but distinctive light grey, and resemble similar light grey weathering, silicified siltstones in the overlying Elk Formation. Most siltstone is interbedded and/or interlaminated with very fine grained sandstone, commonly forming resistant-recessive weathering alternations. Siltstone also occurs thinly interbedded with dark grey, carbonaceous mudstone and shale.

Sandstone comprises the most conspicuous, and probably the second most common, rock type in the Mist Mountain Formation. It is conspicuous because of its resistant, commonly cliff- or ledge-forming character within the many grass- and tree-covered intervals (figs. 25, 26, 31). The sandstone ranges from very fine- to coarse-grained and is conglomeratic in part, with the most common size ranging between fine- to very fine-grained sand. The latter size range is found in the sandstones interbedded with the carbonaceous and argillaceous siltstone previously discussed. Most sandstone is medium to medium-light grey, rarely dark grey, weathering medium grey, brownish grey, light grey and buff; the colours being notably lighter than those of the associated siltstones. The sandstone is composed of angular to well rounded grains of quartz and chert, lithic grains of silicified-shale, siltstone, and quartzite or quartz sandstone, limestone and dolostone, and rare grains of feldspar and collophane. The concentration of chert in the sandstone invariably increases with increasing grain size. Cements consist mainly of silica and less commonly of calcite, dolomite, and clay minerals. The sandstone is moderately to well sorted, and generally well indurated, although some coarser grained sandstones may display a porous, "salt and pepper" appearance; a feature attributable to the presence of poorly indurated, yellow-brown, limonitic, sandstone-siltstone detrital grains, and dark grey chert grains.

The most prominent sandstones are the resistant, cliff-forming, medium- to thick-bedded units typically found as lenticular "ribs" or ledges along the side of many mountain ridges in the Fernie Basin area of southeastern British Columbia; but also found, although less commonly, elsewhere in the report area (figs. 25, 31, 32). These cliff-forming sandstones range from medium- to coarse-grained, but, in the Fernie area, may contain thin to thick lenses and beds of chert-pebble conglomerate and conglomeratic sandstone. These coarser grained sandstones, most of which are interpreted as channel facies, vary considerably in thickness within local areas, pinching and swelling along strike on the same ridge or, in some areas, grading laterally into interbedded mudstone and siltstone. The coarse grained sandstone commonly fines upward, and is capped by ripple or ripple drift laminated, coarse siltstone to very fine grained sandstone, which is in turn overlain, at some localities, by mudstone and/or coal. Some inversely graded beds were also noted at a few localities, while at others graded bedding of either type was not apparent.

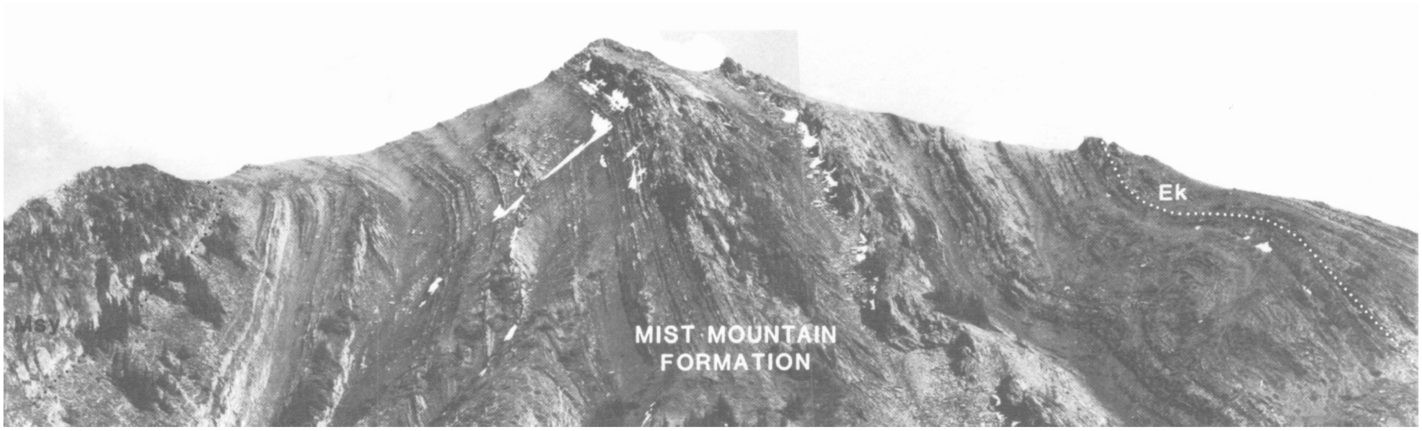


Figure 25. *Type section of Mist Mountain Formation near Mist Mountain (Sec. 76-10), illustrating contact and lithologic relationships between Morrissey, Mist Mountain and Elk formations. Note sparse development of fluvial channels. Coal seams occur within many recessive talus-covered intervals. Morrissey Formation (Msy); Elk Formation (Ek).*

Figure 26. *Mist Mountain strata, illustrating alternation of resistant-recessive bedding. Note large channel sandstone facies at top and smaller channel sandstone in centre. Same locality as Figure 25.*

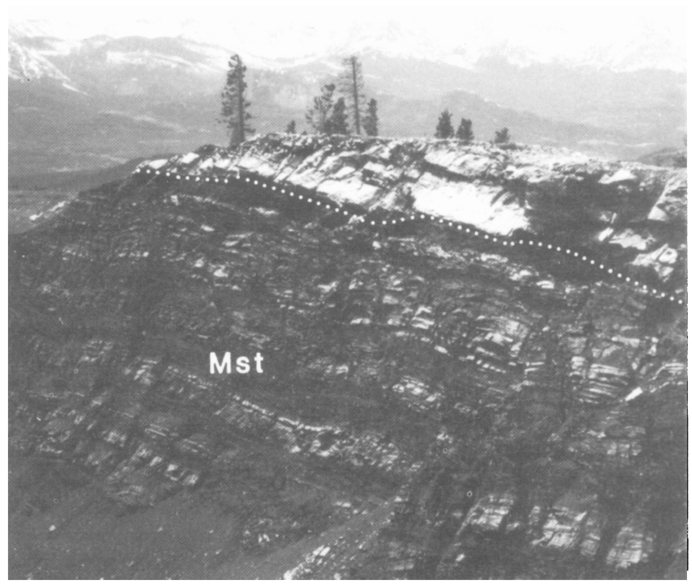


Figure 27. *Contact and lithologic relationships between Mist Mountain (Mutz Member) and Cadomin formations. Note sharp unconformable contact between Cadomin and Mist Mountain strata. Elk Formation absent at this locality. Grassy Mountain (Sec. 75-1). Mist Mountain Formation (Mst); Cadomin Formation (Cd).*

Many of the coarse grained, channel sandstones are characterized, at or near their base, by a thin band of well rounded, light and dark grey chert pebbles, averaging 0.5 to 1 cm in diameter; or, at some localities, by angular, dark grey siltstone to mudstone rip-up clasts – some up to 7.6 cm in diameter. In addition, many of the coarse grained sandstones contain wood molds and casts (Fig. 46), and some contain well preserved, vitreous coal spars, small to large scale trough crossbedding, rare planar crossbedding, and climbing ripple or ripple drift lamination. Many of the medium- to coarse-grained sandstones contain black, carbonaceous plant fragments and comminuted vegetal matter, concentrated in laminations or along parting planes, or, more commonly, disseminated throughout the rock. The finer grained sandstones of the Mist Mountain Formation, associated or interbedded with siltstones or mudstones (Fig. 27), usually contain a conspicuously greater concentration of carbonaceous vegetal matter than the coarser grained sandstones, and consequently are much darker grey. The concentration of vegetal matter in all sandstones of the Mist Mountain Formation contrasts with that found in sandstones in the underlying Morrissey Formation, where such vegetal matter concentrations are rare. Most of the finer grained sandstones are medium- to thin-bedded.

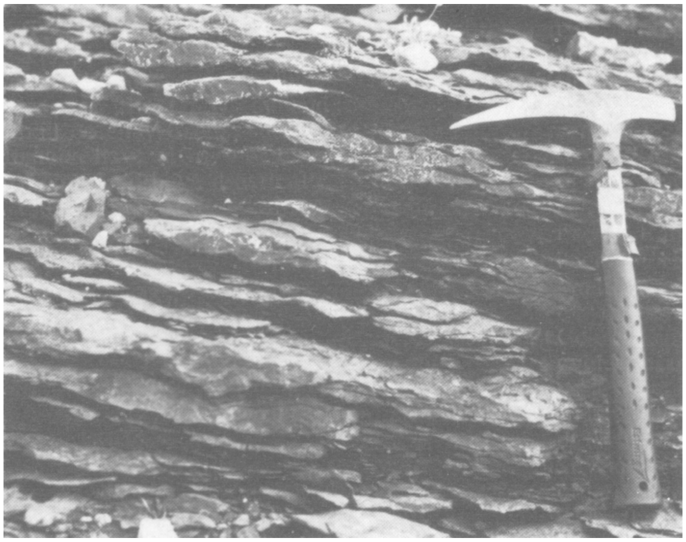


Figure 28. Unusual nodular-like sandstones (ripple laminated) characteristic of Mist Mountain Formation at Limestone Mountain (Sec. 76-18).

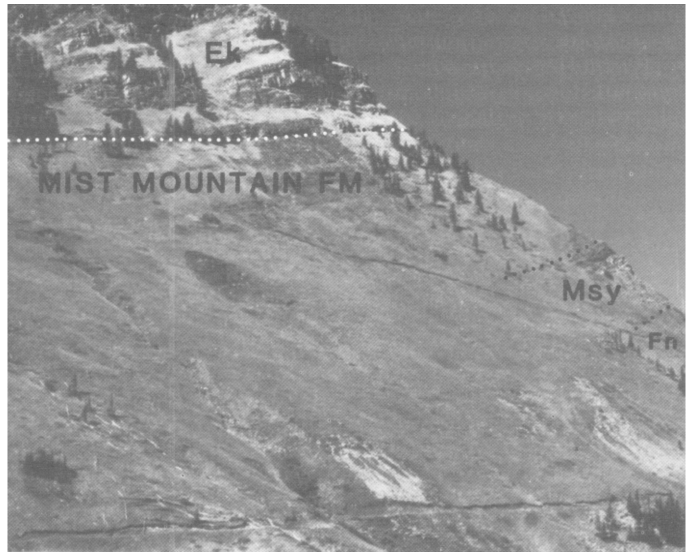


Figure 29. Contact and lithologic relationships between Morrissey, Mist Mountain and Elk formations. Note typical recessive weathering and talus-covered interval of Mist Mountain Formation and absence of fluvial channel sandstones. Sentinel-Highwood Ranger Station (Sec. 76-5). Morrissey Formation (Msy); Elk Formation (Ek).

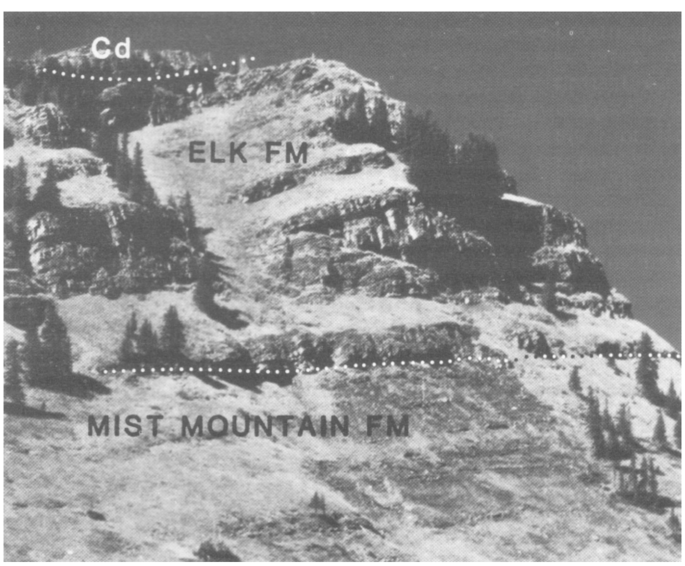


Figure 30. Measured section near Sentinel-Highwood Ranger Station (Sec. 76-5), illustrating massive, coarse grained to conglomeratic sandstone channels. Photo is close-up of Figure 29. Cadomin Formation (Cd).

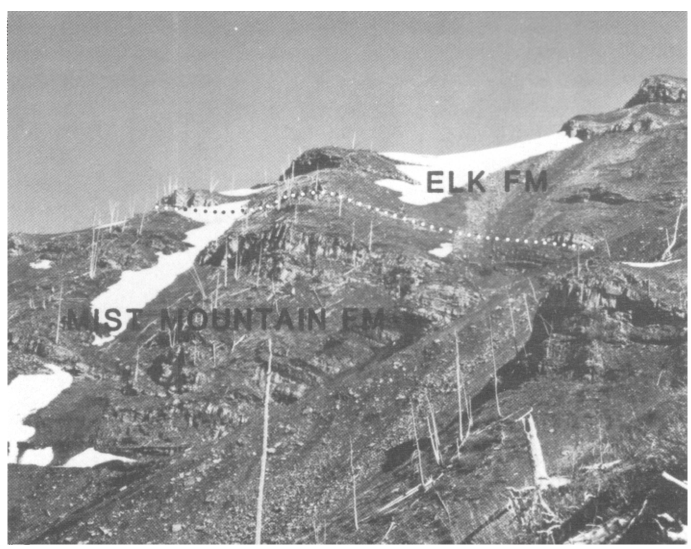


Figure 31. Sandstone channel facies of Mist Mountain and Elk formations along Flathead Ridge Pipeline (Sec. 75-6). Note lenticular nature, sporadic development of fluvial channels, and gradational contact between the two formations.

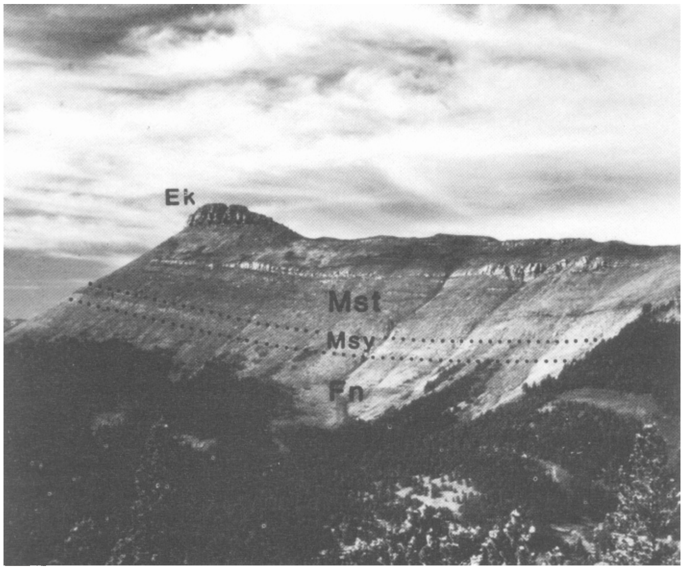


Figure 32. *Contact and lithologic relationships between Fernie, Morrissey, Mist Mountain and Elk formations. Note single, resistant, cliff-forming, lenticular, channel sandstone in Mist Mountain Formation, and typical cliff-forming character of Elk Formation. Cabin Ridge area (Sec. 76-2). Fernie Formation (Fn); Morrissey Formation (Msy); Mist Mountain Formation (Mst); Elk Formation (Ek).*

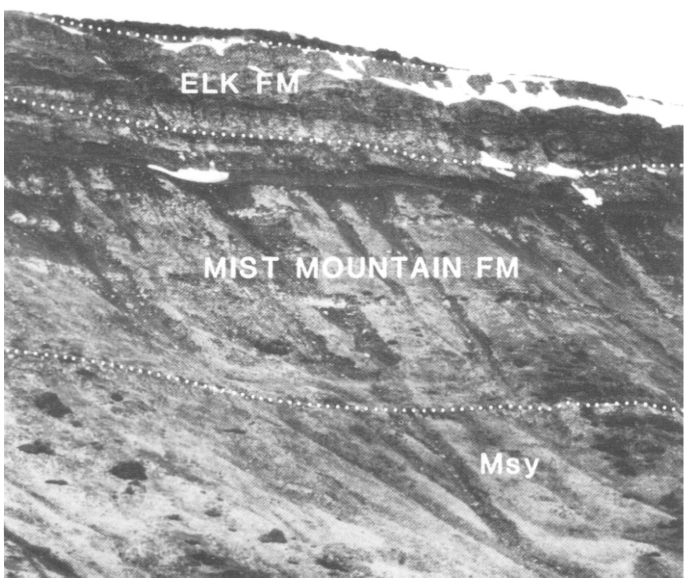


Figure 33. *Contact and lithologic relationships between Morrissey, Mist Mountain, Elk, and Cadomin formations at Isolation Ridge (Sec. 76-14). Note cliff-forming strata and abrupt contact between Elk and Mist Mountain formations. Morrissey Formation (Msy); Cadomin Formation (Cd).*

Conspicuous beds of conglomerate and conglomeratic sandstone occur associated with, or within, the coarse grained sandstones in the area of the Fernie Basin (Sec. 75-16; Fig. 5), and at a locality on Cabin Creek near the United States border (Sec. 75-18; Fig. 11). They have not been recognized elsewhere in the Foothills or Front Ranges of Alberta in the Mist Mountain Formation, except for the chert-pebble, channel "lag" deposits at or near the base of some major channel sandstones. The conglomerate is thin- to thick-bedded, commonly lenticular, occurring in units up to 1 m thick (Sec. 75-16; Fig. 5). It consists of poorly sorted, well rounded pebbles of light and dark grey chert, less commonly white and pink quartzite, and rare, green chert and angular clasts of dark grey mudstone or siltstone. Pebbles are up to 3.8 cm in diameter, and generally average 0.6 to 1 cm. Most of the conglomerate is matrix supported, with the matrix consisting of medium- to coarse-grained, calcareous to dolomitic, quartz-chert sandstone. Cement consists predominantly of silica overgrowths. Some of the conglomerate contains wood molds and casts, coal spars, and large- and small-scale crossbedding. The conglomeratic lithofacies is sporadic in occurrence and distribution, and cannot reliably be used to correlate the strata between areas or even from one section to another. Compositionally, the conglomerate and conglomeratic sandstone of the Mist Mountain Formation resemble those found in the overlying Elk Formation, thereby necessitating caution in assigning a lithologic contact between the two formations.

Mudstone and/or shale comprise the last of the major rock types in the Mist Mountain Formation (exclusive of coal which will be discussed under a separate heading). Unfortunately, because of the many covered intervals in the Mist Mountain Formation, exposures of mudstone-shale are limited, thus making observations of its lithological attributes difficult. It must be noted, however, that some of the strata classified as mudstone or shale may, upon detailed size analysis, be reclassified as carbonaceous and/or argillaceous siltstone, or silty carbonaceous claystone, depending on the concentration of silt- or clay-sized grains. At localities where mudstone-shale is well exposed, or where it has been examined in core (Sec. E.V.1-4; Fig. 7), the pelitic facies is medium-dark to dark grey, weathering dark grey to dark brownish grey. It is commonly very carbonaceous and/or argillaceous, very quartzose (45 to 97%) and, in addition, may contain small amounts of calcite, dolomite, anhydrite and feldspar. Clay minerals, determined by X-ray analysis, consist mainly of illite, kaolinite-chlorite, plus other mixed layer, silicate clay minerals.

Three noteworthy mudstone-shale lithotypes have been recognized in the formation. The most common and most obvious is very silty to sandy and very carbonaceous – commonly containing a high concentration of comminuted and fragmented vegetal matter. This pelitic variety commonly contains the coarser fraction as parallel to wavy, light grey, sand-silt laminations and, if adjacent to a coal seam, may contain lenses of coal. It is some of these very silty to sandy mudstones-shales which, upon detailed size analysis, may be classified as very carbonaceous-argillaceous siltstone. Another relatively common type of mudstone-shale found in the Mist Mountain Formation is typified by a distinct subconchoidal fracture. It is dark grey to black, with a high concentration of clay minerals, and commonly lacks conspicuous vegetal matter. This facies may contain orange-brown, ferruginous (ironstone) nodules, concretions, and fine lenticular laminations. The nodules or concretions are commonly ovoid in shape, and have been observed up to 30 cm in diameter. Some core samples of this lithofacies contain thin lenses and lenticular laminae of pyrite up to 1.3 cm thick. Other samples have yielded small pelecypods, ostracodes, esthyriids, chara, and miospores. At two field localities in the eastern Foothills of southwestern Alberta (Oldman River Gap, Sec. 76-1; and Trap Creek, Sec. 76-12; figs. 3, 10), an unusual, black to dark grey shale, with well developed fissility, was found in contact with the overlying Cadomin Formation. The shale is very siliceous and brittle, and at one locality contains small cubes and microaggregates of pyrite. At Trap Creek, palynomorphs were recovered from one sample.

Throughout the area of study the mudstone-shale lithofacies in contact with, but below, major or minor coal seams, does not contain evidence of rootlets or rootlet zones - a characteristic one might expect below coal seams. However, mudstone-shale immediately overlying coal seams commonly contains vertical rootlets in addition to an abundance of coal lenticles. Most mudstones and shales occur interbedded with coal, or alternatively with the very carbonaceous, fine grained siltstones.

Another unusual lithotype, which texturally is related to the mudstone-shale facies, was encountered in two drill cores and one field exposure in the upper Elk River valley of southeastern British Columbia (secs. E.V.1-4, 75-17; figs. 6, 7). In boreholes E.V.2 and E.V.3 (Fig. 7), two pale yellowish brown, claystone beds, up to 6 cm thick, occur in a dark grey, very carbonaceous, coaly mudstone and coal unit. X-ray diffraction and chemical analyses of samples from these beds indicate a mineral composition of 75 per cent kaolinite and 25 per cent quartz for one sample, and 100 per cent kaolinite for the other. At Greenhills (Sec. 75-17; Fig. 6), near the town of Elkford, a similar light grey to buff claystone was encountered 583 m above the base of the Mist Mountain Formation, in a 1.9 m thick seam of coal. These light grey to buff claystones are interpreted to be "tonsteins", which sometimes can be used to correlate coal seams between different areas. However, in the present study they have mainly gone unnoticed, either because they are not common or because the strata or coal seams in which they occur are generally talus or grass covered.

Dense, dark grey, silty, quartzose, carbonaceous limestone is the last of the observed rock types in the Mist Mountain Formation. It was noted on Flathead Ridge (Sec. 75-6; Fig. 5) as two thin beds, each up to 10 cm thick, 182 and 201 m respectively above the base of the formation. Like the "tonstein" units in the upper Elk River valley, the limestones may be more common, but have been overlooked because of poor exposure, or perhaps may have been incorrectly classified as a facies of dark grey, carbonaceous mudstone.

Facies variations in the Mist Mountain Formation are illustrated in the columnar cross-sections of figures 5 to 11. As can be seen in the cross-sections, vertical changes within the formation are not readily apparent. However, lateral facies changes are common between closely spaced sections, such that correlation of individual rock types, including coal seams, has proven difficult. The most conspicuous lateral changes are readily displayed by the coarse grained sandstones, conglomeratic sandstones and the chert-pebble conglomerates. The last two lithotypes occur as thin to thick lenses and thin to medium interbeds associated with the coarser grained sandstones in the Fernie Basin area of southeastern British Columbia. They extend from the Cabin Creek area, near the United States border (Sec. 75-18; Fig. 11), in the south, to the Sparwood Ridge area in the north, and from the Fernie, Morrissey and Flathead ridges in the west, to Mount Taylor, and Michel and Marten ridges in the east (Fig. 3). Beyond this area the conglomeratic facies is absent, having graded laterally into medium- to coarse-grained sandstone, or into units of interbedded sandstone, siltstone and mudstone.

In addition to the reduction and eventual disappearance of the conglomeratic facies north and east of the Fernie Basin, the associated, massive, commonly cliff-forming, medium- to coarse-grained, channel sandstone facies also displays a similar reduction in occurrence and lateral distribution (figs. 5, 11). For example, major channel sandstone units are common in the Fernie Basin area, but show a conspicuous decrease toward the east into the Coleman-Blairmore area of the Crowsnest Pass (Fig. 5). There, only one or, possibly, two major, resistant weathering, coarser grained channel sandstone units are evident (Fig. 32). Northward from the Fernie Basin area, at Mist Mountain (Sec. 76-10; figs. 7, 25), Mount Allan (Sec. 76-7; Fig. 8), and Barrier Mountain (Sec. 76-17; Fig. 9), major channel sandstone units are again few in number, and the Mist Mountain Formation consists predominantly of overbank, floodplain, and coal lithofacies. Locally, however, along some ridges in the Fernie Basin area these prominent cliff-forming, coarse grained sandstones can be observed to pinch and swell laterally or, alternatively, can be seen to grade laterally into, or interdigitate with, finer grained, thinner bedded sandstones, siltstones, mudstones, and shales (Sec. 75-6; figs. 5, 31).

As noted earlier, the interdigitation of units makes correlation between sections – even closely spaced sections – difficult when using only major sandstone or conglomerate units. This difficulty is apparent in Figure 5 by examining strata of the Hillcrest Member (Fig. 2) of the former Kootenay Formation (now part of the Mist Mountain Formation). The Hillcrest Member in the Coleman-Blairmore area of Alberta is overlain and underlain by prominent marker coal seams, which can be locally correlated in that part of the Crowsnest Pass. At Grassy Mountain (Sec. 75-1; Fig. 5) the type section of the Hillcrest Member (Norris, 1959b), the strata consist of interbedded, very fine- to fine-grained sandstone, siltstone, mudstone and shale. At York Creek (Sec. 75-14; Fig. 3), 12.8 km to the southwest, the Hillcrest comprises a thick bedded, medium- to fine-grained, crossbedded, channel sandstone, devoid of conspicuous interbeds of mudstone, siltstone or shale. At the former Adanac strip mine locality (secs. 75-10, 75-11; Fig. 5) south of Blairmore, the Hillcrest Member is composed of thin beds of sandstone, siltstone and shale, with rare thin seams of coal (Norris, 1959b). Northward, beyond the Grassy Mountain area, facies changes are such that the two marker coal seams above and below the Hillcrest Member disappear, and sandstone is not a conspicuous component of the Hillcrest. Strata of the Hillcrest Member can no longer be recognized with any degree of certainty.

Another important lateral facies change occurs in the Mount Taylor, Marten Ridge and possibly Tent Mountain areas on the eastern side of the Fernie Basin. In this area the basal Mist Mountain Formation is characterized by a massive, thick, cliff-forming facies of conglomeratic and coarse grained sandstone with minor beds of recessive weathering siltstone and shale. The massive sandstones (Sec. 75-15; Fig. 5) attain unit thicknesses up to 34 m, and occur immediately above the massive, cliff-forming sandstones of the underlying Morrissey Formation. These massive sandstones do not occur on the western margin of the Fernie Basin, in the Crowsnest Pass area to the east, or in adjacent areas to the north and south. The equivalent stratigraphic interval is occupied by interbedded sandstone, siltstone, mudstone and shale. In the Sparwood Ridge area (Fig. 5) the interval is occupied by an economically important thick seam of coal, locally known as the Balmer or Number 10 Seam.

Sandstones in the Mist Mountain Formation of the Barrier Mountain, Limestone Mountain, and Gap Lake areas to the north (secs. 76-17, 76-18, 77-5; figs. 3, 9) illustrate facies variations from one area to another. In the area between Barrier Mountain and Limestone Mountain the relatively thin bedded, ledge-forming, basal sandstones of the Mist Mountain Formation are medium- to fine-grained and characterized by an abundance of vertical and horizontal burrow structures. Between Limestone Mountain (Sec. 76-18; figs. 3, 9) and the Gap Lake area (Sec. 77-5; figs. 3, 9), the basal sandstones change colour and texture, grading laterally from medium- to fine-grained sandstone, to sandstone which is fine- to very fine-grained, very siliceous, well indurated, and weathers a distinctive orange-buff colour. These characteristics suggest a different depositional environment for these sandstones. In addition, the finer grained sandstones of this area do not contain the same concentration of burrow structures as found in the basal Mist Mountain Formation of the Barrier Mountain-Limestone Mountain area.

Contact relationships

In most areas of the eastern Front Ranges and western Foothills, the coal-bearing Mist Mountain Formation is conformably and abruptly overlain by the Elk Formation (figs. 29, 30, 32, 33). The contact is of the interfingering type (figs. 5-11), and is placed at the base of the first major sandstone or conglomerate above the uppermost major coal seam in the Mist Mountain Formation. This contact assignment, in many areas, corresponds to a prominent break in weathering profile between the two formations, particularly at localities in the western Foothills area of Alberta (figs. 29, 30, 32, 33).

In the Fernie Basin area of the western Front Ranges, the base of the Elk Formation is commonly characterized by thick, massive, cliff-forming conglomeratic sandstone, chert-pebble conglomerate, or very coarse grained sandstone, which abruptly overlie the more recessive weathering, interbedded siltstone, finer grained sandstone, mudstone, shale or coal of the Mist Mountain Formation (figs. 5, 11). For example, at the type section of the Elk Formation on Coal Creek (Sec. 75-7-16; figs. 3, 5), the contact is very conspicuous, and is placed at the base of a thick, chert-pebble conglomerate and conglomeratic sandstone unit (Fig. 5) containing well rounded chert pebbles and cobbles up to 15 cm in diameter, although averaging 2.5 to 7.6 cm. In contrast, on Sparwood (Sec. 75-8; figs. 3, 5) and Flathead ridges (Sec. 75-6; figs. 3, 5, 31), the conglomeratic lithofacies at the base of the Elk is not developed, and the contact is placed at the base of the first major, medium- to coarse-grained sandstone above the uppermost coal seam in the Mist Mountain Formation. At Flathead Ridge, however, the contact between the two formations may not at first glance be readily apparent. Along the west side of the ridge a prominent topographic break is apparent, as shown by a series of resistant weathering channel sandstone units, which stand in sharp contrast to the recessive weathering, mainly talus covered strata of the underlying Mist Mountain Formation (Fig. 31). However, examination of bulldozed exposures which transect the ridge, indicates that the lowest of the massive, cliff-forming sandstone units is still part of the Mist Mountain Formation (Fig. 31). As can be seen in Section 75-6, Figure 5, a 1.3 m thick seam of coal occurs 44 m stratigraphically above the base of the lowest marker sandstone. By definition, the contact between the Mist Mountain and Elk formations should be placed at the base of the first major sandstone above this coal seam, at the level illustrated in Figure 5. Because of the lenticular nature of these thick, cliff-forming sandstones, and the local thinning and thickening of some major coal seams, placement of the contact between the two formations may vary slightly from one area to the next. However, by adopting the criteria cited above, placement of the contact between the two formations will be relatively consistent, both in outcrop and in the subsurface, as demonstrated by the formational thickness trends of the Mist Mountain and Elk formations in the isopach maps of figures 5 to 11.

In the upper Elk River valley north of Sparwood, the Elk Formation is generally poorly exposed, or has been partially removed by Pleistocene or Recent erosion, and contact relationships between the Elk and Mist Mountain formations are not always apparent. However, at Eagle Mountain (Sec. 75-19; Fig. 6) the contact between the two formations is well exposed in a bulldozed excavation on property of Fording Coal Limited. At this locality, the contact coincides with the base of a thick, massive, cliff-forming sandstone overlying a thick coal seam, locally known as the No. 15 Seam. In borehole E.V.3 (Fig. 7) near Elk Pass, the contact between the Mist Mountain and Elk formations is placed, as shown, 1.86 m below the top of the borehole. In this area, a few coal seams, in excess of 60 cm thick, occur above this stratigraphic level. One may wish to include these as part of the Mist Mountain Formation. However, thickness and lithologic comparisons between the two formations, in areas to the south and east, suggest that the contact, as selected, is the best choice available. As can be seen in Figure 7, massive or prominent sandstone units are not common in the lower Elk Formation of this area.

In the western part of the Foothills of Alberta, the contact between the Elk and Mist Mountain formations is easily recognized and coincides with a prominent physiographic break in the Kootenay Group, a feature first recognized by Douglas (1958). In this area, the base of the Elk is characterized by a thick, massive, generally cliff-forming, coarse grained sandstone with occasional "floating", well rounded pebbles of chert and quartzite. This facies contrasts sharply with the more recessive weathering siltstones, finer grained sandstones, and shales of the underlying Mist Mountain Formation. This feature is well illustrated at Isolation Ridge (Sec. 76-14; figs. 3, 6, 33), Plateau Mountain (Sec. 76-4; figs. 3, 10), Wilkinson Creek summit (Sec. 76-13; figs. 3, 6), and most notably near Mount Head (Sec. 76-5; figs. 3, 7, 29, 30). At the section near Wilkinson Creek summit (Sec. 76-13; Fig. 6), the basal Elk Formation is characterized by three major, cliff-forming, channel sandstone lithofacies, with no apparent major seams of coal between or above the sandstones. In the absence of recognizable coal, the Mist Mountain-Elk formational contact is placed at the base of the lowest massive sandstone as shown. This contact placement results in an unusually thin interval for the Mist Mountain Formation, and a correspondingly thick section of the Elk Formation, when compared with adjacent field sections in the same region. At Mount Allan, in the eastern Front Ranges near Canmore, Alberta (Sec. 76-7; figs. 3, 8, 50), the contact between the Mist Mountain and Elk formations varies from one location on the mountain to the next. For example, near the southeast end of the mountain, it is placed at the base of the prominent sandstone illustrated in figures 8 and 50. Immediately along strike to the northwest, however, the massive sandstone grades laterally into a lithofacies of interbedded sandstone, siltstone, and shale, which at this northwest locality is still cliff-forming, in marked contrast to the interbedded, very fine grained sandstone, siltstone, shale, and thin to thick seams of coal below. In the absence of the massive sandstone, the contact between the two formations at this location is placed at the base of the topographically prominent, cliff-forming, interbedded sandstone and siltstone lithofacies.

In the eastern Foothills, the Elk Formation thins, or has been erosionally truncated, and the Mist Mountain Formation is unconformably overlain by the Cadomin Formation of the Blairmore Group (figs. 3, 5, 27). The contact is readily apparent and is placed at the base of massive, cliff-forming, light- to medium-grey weathering sandstone and conglomerate, characteristic of the lower Cadomin Formation, which contrasts sharply with the more recessive, commonly talus and grass covered, interbedded siltstone, mudstone, shale, sandstone and coal interval of the Mist Mountain Formation. In exposures of the easternmost Foothills, in the subsurface east of Blairmore, and in the Turner Valley area of Alberta, the Cadomin consists of a different facies, comprising medium- to coarse-grained sandstone with, locally, sporadic pockets or lenses of chert-pebble conglomerate. Consequently, at isolated sandstone exposures in this area, care must be exercised in placing the contact between the two formations, because some of the Cadomin sandstones may lithologically resemble the channel sandstones found locally in the Mist Mountain Formation.

The contact between the Mist Mountain Formation and the underlying Moose Mountain Member of the Morrissey Formation is conformable and abrupt as previously discussed.

Distribution and thickness

Because of the economically important coal seams in the Mist Mountain Formation its distribution within the Rocky Mountain Foothills and Front Ranges is well known. It has been recognized from the Cabin Creek area of the upper Flathead River valley, near the United States border, to North Saskatchewan River, where it changes facies and loses its characteristic coal-bearing property. Accordingly, it has been given another formational name, the Nikanassin (figs. 2, 34). In the Foothills, Mist Mountain strata are restricted mainly to exposures west of a line extending parallel to the structural strike of the region from the Beaver Mines-Mill Creek area in the south to the Limestone Mountain-Gap Lake area in the north. Strata equivalent to the Mist Mountain Formation have been reported from the subsurface of the Turner Valley area (Hume, 1938), but not from the subsurface east of Tay River-Fall Creek and the southern Brazeau Range area of west central Alberta. Because of major thrust faulting, strata of the Mist Mountain Formation do not outcrop west of such geographic-topographic features as Elk River valley, Kananaskis Range, Cascade Mountain and the Ram Range.

The Mist Mountain Formation ranges in measured thickness from a minimum of 25 m at Limestone Mountain, in the western Foothills near Clearwater River (Sec. 76-18; figs. 3, 9), to a maximum of 665 m in the Greenhills Range of the eastern Front Ranges near Elkford, British Columbia (Sec. 75-17; figs. 3, 6). At the type section, near Highwood Pass and Mist Mountain, the formation is 380 m thick (figs. 6, 25).

Figure 35 is an isopach map of the Mist Mountain Formation prepared on a palinspastically restored base, and illustrates thickness trends and formation distribution prior to Laramide deformation. Visual inspection reveals a general west to east reduction in thickness, ultimately thinning to a zero edge along the eastern part of the Alberta Foothills. In the vicinity of North Saskatchewan River, the Mist Mountain Formation grades laterally into strata of the Nikanassin Formation (Gibson, 1978). The prominent thickness irregularity depicted in Figure 35 appears to be mainly the result of an unusually thin development of the Mist Mountain Formation in the vicinity of Wilkinson Creek summit (Sec. 76-13; figs. 3, 6).

Age and correlation

The Mist Mountain Formation ranges in probable age from Late Jurassic to Early Cretaceous. Unfortunately, the microfaunal, microfloral and megafloral collections obtained to date from the Mist Mountain, or strata equivalent to the Mist Mountain, have not been sufficiently time sensitive to date the strata with any degree of precision. Bell (1956), in a study of the megaflora from strata equivalent to the Mist Mountain and part of the Elk Formation, considered the age to be Early Cretaceous, Neocomian-Barremian. However, many of the genera were also common to strata in the overlying Blairmore Group. As previously noted, Frebold (1957) identified a large ammonite mold from the Moose Mountain Member of the underlying Morrissey Formation and interpreted it to be Portlandian in age, thus providing a lower age limit for the Mist Mountain Formation. Microfloral studies by Rouse (1959) and Pocock (1964) on samples from the Kootenay Formation (Mist Mountain Formation of this report), in the Fernie and Grassy Mountain areas of British Columbia and Alberta respectively, suggested a Jurassic age for the formation. However, Pocock (*op. cit.*) suggested that the Kootenay (Mist Mountain Formation) may include strata of Early Cretaceous age in some other areas.

A number of samples of mudstone and shale from the Mist Mountain Formation were submitted to A.R. Sweet (microflora) and J.H. Wall (microfauna), of the Geological Survey of Canada, for palynological and microfaunal analysis (appendices 3, 4), with the anticipation that perhaps new information might be obtained to assist in more precisely dating the formation. Some of the results from the Crowsnest Pass area were documented in an earlier preliminary report (Gibson, 1977b). Unfortunately, most palynological samples provided little information useful for dating the strata, either because the degree of carbonization (rank) was so high that preservation was poor, or the population contained only long ranging species. Those samples which did contain species of possible biostratigraphic significance, suggest that at least the upper part of the Mist Mountain Formation may be of Early Cretaceous age. For example, at Marten Ridge (Sec. 75-12; figs. 3, 5), one sample from 337.1 m above the base of the measured section, yielded *Schizosporis reticulatus*, *Contignisporites glebulentus* and *Trilobosporites* cf. *T. apiverrucatus*. Based mainly on the presence of *Schizosporis reticulatus* a probable Early Cretaceous age is interpreted for this sample. At a locality on Cabin Creek (Sec. 75-18; figs. 3, 11), miospores were identified from a level 229.5 m above the base of the formation, and included such species as *Schizosporis reticulatus*, *Januasporites reticularis*, *Formisporis dailyi* and *Cooksonites* sp. These species, according to Sweet, suggest a Cretaceous age. At Greenhills (Sec. 75-17; figs. 3, 6), near Elkford in the upper Elk River valley, miospores were identified from a shale outcropping 4.5 m below the contact with the Elk Formation, and included (see Appendix 6 for complete list) *Taurocusporites* sp. cf. *T. segmentatus*, *Verrucosisporites asymmetricus*, and *Distaltriangulisporites irregularis*. These species may also indicate an Early Cretaceous age (Sweet, pers. comm., 1982). At a level 152.4 m below the Elk Formation contact at the same locality, a sample yielded an excellent recovery of miospores, among which *Schizosporis reticulatus* was identified, again suggesting, according to Sweet, that the sample may possibly be Early Cretaceous in age. At Trap Creek (Sec. 76-12; figs. 3, 10) in the eastern part of the Foothills, one sample from the Mist Mountain Formation yielded several specimens of *Cicatricosisporites australiensis*, suggestive of, but not conclusive evidence for, an Early Cretaceous age.

Although many samples were submitted for microfossil analysis, few have yielded any specimens useful in age dating. Most specimens were barren of microfossil material, a feature possibly related to the fact that strata of the formation are mainly nonmarine. In the Elk River-Fernie Basin area, one or more primitive protistids - possibly "thecamoebians" – were recovered from a core sample from Section 75-23; (figs. 3, 6). At Greenhills, 91.4 m above the Morrissey Formation contact, the charophyte ?*Sphaerochara* sp. was identified by Wall and suggested to have a Jurassic-Cretaceous age. In the upper Elk River valley, in borehole E.V. 2 (figs. 3, 7), two indeterminate ostracode carapaces and a partial, pyritized specimen of ?*Cyzicus* sp., a brachiopod, were recovered. At Marten Ridge (Sec. 75-12; figs. 3, 5), on the east margin of the Fernie Basin, the ostracode *Darwinula leguminella* Forbes was recovered from a sample from 267.6 m above the base of the measured section. An age ranging from Jurassic to Cretaceous was suggested by Wall (pers. comm.). At Barrier Mountain (Sec. 76-17; figs. 3, 9), some sections to the north, and from north of the North Saskatchewan River, foraminifera were recovered from some mudstone and shale samples. These specimens, although few in number, were of the simple agglutinated type, and included *Ammodiscus* or *Trochamminoides* sp., and *Ammodiscus* sp. cf. *A. southeyensis* (Wall). On the basis of the latter specimen and its similarity to *Ammodiscus southeyensis*, found in Saskatchewan and generally regarded as Bathonian, Wall (pers. comm.) suggests that the specimen collected from the Mist Mountain Formation at Barrier Mountain may be of questionable Jurassic age.

It can thus be seen that the age of the Mist Mountain Formation, based on the collections of the writer and upon evidence provided by other workers, is still uncertain, but would appear to range from Late Jurassic to Early Cretaceous.

Strata of the Mist Mountain Formation are homotaxially equivalent to the predominantly marine to brackish water, interbedded sandstone, siltstone and shale of the Nikanassin Formation in the North Saskatchewan River-Smoky River area of the Alberta Foothills (figs. 2, 34). As noted and discussed previously, however, age relationships between the two formations have not been clearly defined. In the Foothills of west central Alberta and northeastern British Columbia, between the Smoky and Peace rivers, the Mist Mountain is considered homotaxial with the Monteith and, possibly, part of the Beattie Peaks and Gorman Creek formations of the Minnes Group (Stott, 1975, 1981). Again, definite age relationships between the formations in the two areas have not been established. Correlation with strata south of the United States border is uncertain, as previously noted. It would appear that there is no stratigraphic equivalent of the Mist Mountain in the Montana area. Strata equivalent to the Mist Mountain Formation have probably been erosionally truncated or were never deposited. The Morrison Formation in Montana, although coal-bearing in part, does not resemble the Mist Mountain Formation lithologically. Morrison strata have been interpreted to be no younger than Kimmeridgian or Portlandian. Evidence in support of a sedimentary thinning or erosional truncation is provided in Figure 35, an isopach map of the Mist Mountain Formation, which shows the isopach lines swinging toward the southwest and west in the Montana-Idaho area, demonstrating a marked thinning of the formation toward the south and southeast, immediately south of the Canada-United States border.

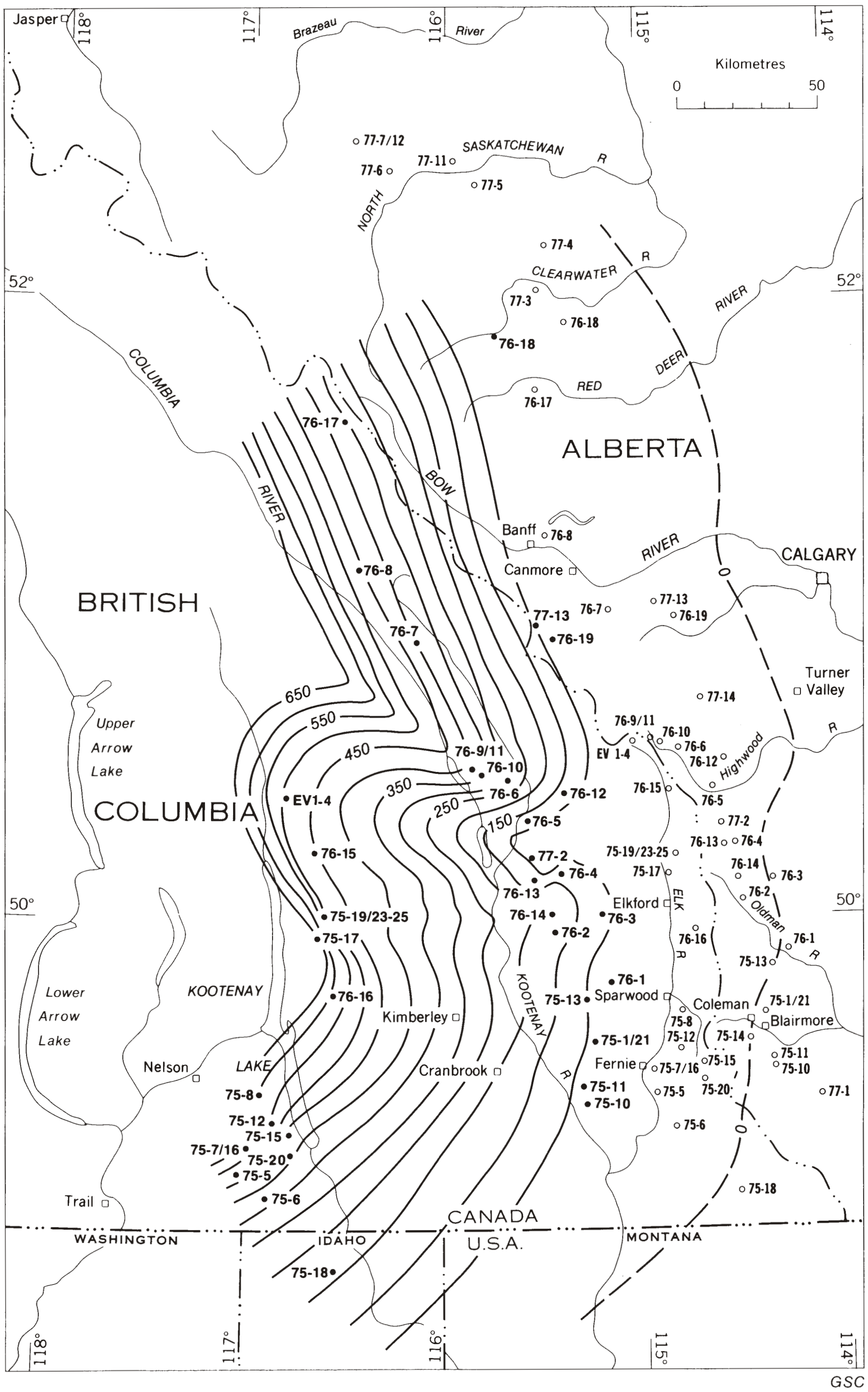
Figure 34. *Nikanassin Formation on Wapiabi Creek (Sec. 77-7). Note resistant-recessive weathering strata, and small sandstone dyke underlying massive sandstone facies at upper right of photo.*

Sedimentary structures

Primary sedimentary structures are common in the Mist Mountain Formation. They consist predominantly of small-to large-scale festoon and, less commonly, planar-tabular crossbedding, current, wave-ripple and ripple-drift laminations and minor flaser bedding. Festoon crossbedding is the most conspicuous of the large structures, mainly occurring in the coarser grained, cliff-forming, channel sandstone lithofacies (figs. 36, 37). Troughs are generally shallow, although they have been observed up to 1.5 m deep. They commonly average 30 to 60 cm deep, depending on the thickness of the sandstone unit. Crossbedding size in the Mist Mountain Formation appears to be related to the grain size of the host rock. The coarser the grains of the host rock, the larger the scale of the crossbedding, whereas, in contrast, the finer the grains of the host rock the smaller the scale of the crossbedding. This feature is well illustrated in most fining-upward channel sandstone units. Planar-tabular crossbedding is not common in the formation and, where observed, it consists of shallow to moderately dipping, small- to medium-scale foresets in a medium- to fine-grained sandstone. Current, wave-ripple, and climbing-ripple laminations occur in the finer grained sandstones and coarser grained sandy siltstones, particularly those in the resistant-recessive weathering sandstone-siltstone facies previously described. Ripple-drift or climbing-ripple laminations also occur in the uppermost metre of the thicker bedded, cliff-forming, channel sandstones of the formation (see Fig. 58). Flaser bedding was noted only in core samples of dark grey mudstone and siltstone (Fig. 38). The structure may be more common in field exposures, but has gone unrecognized because of talus and vegetation cover.

Convolute or distorted laminations were noted in core of the fine grained sandstones, sandy siltstones, and mudstones (figs. 38, 39), from the upper Elk River valley and the Grassy Mountain area. Convolute laminations were recorded at Line Creek (Sec. 76-16; Fig. 3), occupying the lower 30 cm of a bed of very fine grained sandstone (figs. 40, 41). The convolute zone grades vertically into a 15 cm thick zone of parallel laminated sandstone, which is in turn overlain by a thin interval of climbing-ripple laminations. Small scale load casts were observed at the base of some thick, ledge-forming, channel sandstones, particularly those where the sandstone is underlain by a recessive weathering unit of mudstone or shale. Small but rare, sand-filled, deformed syneresis cracks (Donovan and Foster, 1972) were observed in carbonaceous siltstone-mudstone core samples from the upper Elk River valley (Loc. E.V. 1-4; Fig. 42).

Vertical and horizontal burrow structures, although present, are not common in outcrop in the southern Crowsnest Pass part of the report area (Gibson, 1977b). They are, however, more abundant in core samples (fig. 38). Burrow structures are very common and conspicuous in the Barrier Mountain-Limestone Mountain area, the area of North Saskatchewan River, and in the area of Bragg Creek, occurring in the sandstones and shales of the lower part of the formation. Burrows are up to 2.5 cm in diameter and average 1.3 to 1.9 cm (figs. 43, 44, 45). At Limestone Mountain, the base of the formation is characterized by a mudstone-shale unit containing a profusion of light grey, sand-filled, horizontal and vertical burrows (Fig. 45). Vertical rootlets characterize mudstone-siltstone facies overlying coal seams. Fine- to coarse-grained, parallel to wavy, light and dark grey laminations are found in varying abundance throughout the strata of the formation, particularly in the very fine grained sandstones and siltstones. The last noteworthy sedimentary structure consists of large and small wood molds and casts, a structure confined mainly to the base of many of the cliff-forming sandstones and conglomeratic sandstones of the formation (figs. 46, 47). The molds and casts are flattened to lenticular in shape and range in width up to 20 cm. They are straight or curved, display growth or bark patterns in part, and some are characterized by thin "rinds" of coal. Wood molds and casts are also common in the channel sandstones of the overlying Elk Formation but are rare in the sandstones of the Morrissey Formation.



Present location of control point . . . . 75-18 ○

Pre-Laramide location of control point (Turner Valley considered fixed) . . . . 75-18 ●

Isopach; defined, approximate (interval 50m) 50

Figure 35. *Palinspastic isopach map of the Mist Mountain Formation.*

Elk Formation

Definition

The Elk Formation comprises the stratigraphic interval between the coal-bearing Mist Mountain Formation below, and the massive, generally cliff-forming Cadomin Formation, or Pocaterra Creek Member of the Blairmore Group, above (figs. 2, 5, 30, 33, 48, 50, 51). Strata equivalent to the Elk Formation were first recognized by McEvoy (1902) in the Fernie area of southeastern British Columbia and were called the "Elk conglomerates", a lithologic unit which probably also included strata equivalent to the Cadomin Formation and Pocaterra Creek Member of the Blairmore Group. Many years later, Newmarch (1953), while working in the same area as McEvoy, designated part of the "Elk conglomerates" (excluding the Cadomin Formation) as a new and separate unit of the Kootenay rock succession, naming it the Elk Formation, the name adopted in this report (Fig. 2). However, Crabb (1957), in a brief report on the geology of the Fernie area, interpreted the Elk facies of Newmarch as a member of the overlying Blairmore Group, an interpretation which has not been accepted by later workers involved with studying or mapping Blairmore or Kootenay strata. In the Mount Head area of the Alberta Foothills, Douglas (1958) recognized a two-fold division in the Kootenay Formation and informally named the upper, "Map-unit B", and the lower, "Map-unit A". The upper unit is herein correlated with the Elk Formation of the Fernie area. A similar two-fold lithologic division in the Kootenay was observed by Norris (1958a) in the Livingstone River map area of the Alberta Foothills. However, Norris (*op. cit.*) did not map the two facies as separate units of the Kootenay. Jansa (1972) undertook a regional sedimentological study of the Kootenay Formation in Alberta and British Columbia, and disagreed with Newmarch (1953) raising the Elk to formational status. Jansa suggested instead that it should be considered as only a member of the Kootenay Formation. The writer, in a preliminary paper on Kootenay stratigraphy in the Crowsnest Pass area, tentatively adopted the nomenclatural proposal of Jansa and considered the Elk lithofacies as a member of the Kootenay Formation (Gibson, 1977b). It can be demonstrated, as a result of the present investigation by the writer (which involves Kootenay strata in all areas of Alberta and British Columbia), that the Elk strata have regional significance, and can be easily recognized and mapped in most areas, in both the surface and the subsurface. The Elk should, therefore, be defined as a formation (Gibson, 1979), as earlier proposed by Newmarch (1953).

Type section

The type section of the Elk Formation has been defined and described by Newmarch (1953). It is located east of the town of Fernie on the north side of Coal Creek, midway up the ridge opposite the now abandoned Elk River coal preparation plant (See Sec. 75-7, this paper, and Fig. 48; UTM co-ordinates 458842; topographic map NTS 82G/7, Upper Flathead Valley). Unfortunately, the type section contains some thick, covered intervals and access is difficult. A supplemental, or reference, section is herein proposed. This section is better exposed, more readily accessible, and illustrates all lithofacies typical of the formation. It is located south of Coal Creek, along strike from the type section, on the west side of Morrissey Ridge below the Morrissey microwave relay tower (Sec. 75-9; Fig. 49; UTM co-ordinates 450778, topographic map NTS 82G/7, Upper Flathead Valley). The section may be reached by four-wheel drive vehicle, on foot, or by trail bike, via a private "use at your own risk" service road up the east side of Morrissey Ridge. Other accessible and well exposed sections of the Elk may be seen near Plateau Mountain (Sec. 76-4; Fig. 10; UTM co-ordinates 733660, topographic map NTS 82J/2E, Fording River); Highwood-Sentinel Ranger Station near Mount Head (Sec. 76-5; figs. 7, 30; UTM co-ordinates 662865, topographic map NTS 82J/7E); and near Mount Lipsett and Highwood Pass (Sec. 76-11; figs. 7, 51; UTM co-ordinates 446031, topographic map NTS 82J/10W, Mount Rae). As in the case of the Mist Mountain Formation, other sections exist that illustrate facies typical of the formation. Many of these sections are either located on the private property of mining companies, or access is difficult because of relatively long distances to walk, or, in some cases, access involves some steep slopes and/or strenuous rock climbing.

Lithology and facies variations

The Elk Formation comprises a westward thickening, commonly cliff-forming sequence of interbedded sandstone, siltstone, mudstone, shale, conglomerate, and thin seams of coal (figs. 5-11). The strata lithologically and mineralogically resemble those in the underlying Mist Mountain Formation, with the following differences. Sandstones of the Elk are generally more numerous, laterally more extensive, commonly coarser grained, thicker bedded, and more resistant to weathering (figs. 29, 30, 48). In addition, coal seams in the Elk are much thinner, less common, and appear to be of no commercial value (figs. 5, 11).

The most conspicuous and probably most abundant lithotype of the Elk Formation is sandstone, which forms most of the massive cliffs on many of the major mountains and mountain ridges in the report area (figs. 30, 32, 33, 48, 49, 50). These sandstones are thick bedded, with beds up to 2.5 m thick, and consist of detrital components ranging in size from medium- to coarse-grained sand to small cobbles. The cobbles comprise well rounded, light and dark grey chert, and white quartzite clasts in a medium- to coarse-grained sandstone matrix. The sandstones are medium grey to yellow grey on fresh surface, and weather light to medium grey, dull brownish grey and buff. Mineralogically, they are composed of subrounded to angular grains of quartz, chert, lithic rock fragments, and carbonate grains, cemented by silica and less abundant calcite and/or dolomite. The concentration of chert and other detrital lithic grains increases as the average grain size increases. Because of the dark grey colour of many of the grains of chert, the sandstone may be described as a "salt and pepper" sandstone.

Many of the thicker sandstones fine upward. Some coarsen upward, while others display no grading at all. Most of the coarser grained sandstones display an abrupt erosional base with the underlying finer grained lithofacies. Many of these sandstones contain scattered, angular, rip-up clasts, usually of dark grey mudstone or siltstone. At one locality (Sec. 76-5; figs. 3, 6), pyrite nodules up to 5 cm in diameter were observed in the thick bedded sandstones near the top of the formation.

Sandstone also occurs as thin beds and as thin to thick, very fine grained laminations interbedded and interlaminated with the darker grey weathering siltstones. This facies is dark to medium-dark grey, calcareous and/or dolomitic in part, and contains a variable concentration of disseminated vegetal matter.

Another sandstone related lithotype in the Elk is chert-pebble or cobble conglomerate. It is characteristic of the formation only in the Fernie area of southeastern British Columbia and at Mount Allan (Sec. 76-7; figs. 3, 8) near Canmore, Alberta. In the Fernie area its occurrence has been partly responsible for the initial recognition and naming of the formation as a separate and major lithologic unit,

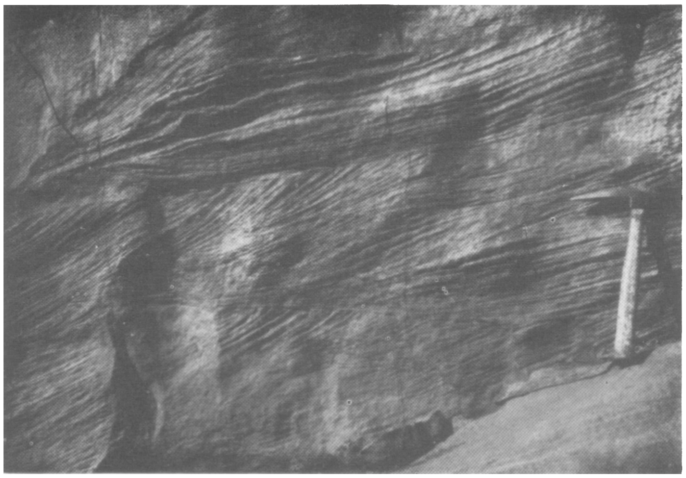


Figure 36. *Medium scale, festoon crossbedding in fluvial channel sandstone of Mist Mountain Formation, Sparwood Ridge.*

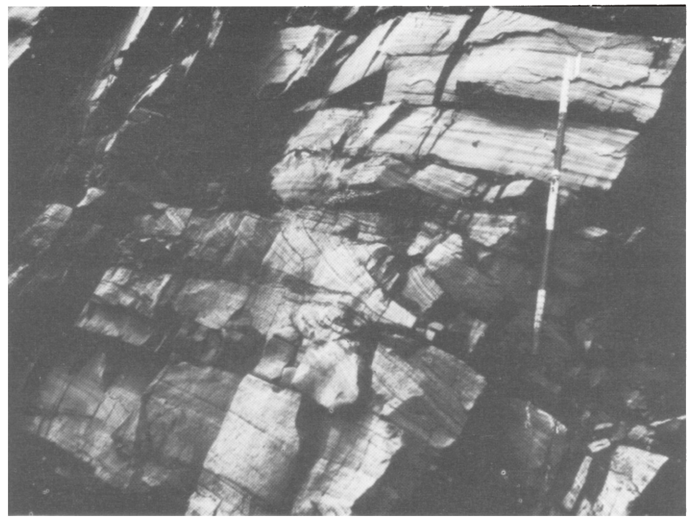


Figure 37. *Medium to large scale, festoon crossbedding in large fluvial channel sandstone of Mist Mountain Formation at Flathead Ridge Pipeline section (Sec. 75-6). Jacob's staff in feet.*

Figure 38. *Distorted sandstone and siltstone laminations. Note small, horizontal, sand-filled burrow and dark grey mudstone flasers in sandstone laminations. Fording River (Sec. 75-24), Mist Mountain Formation.*

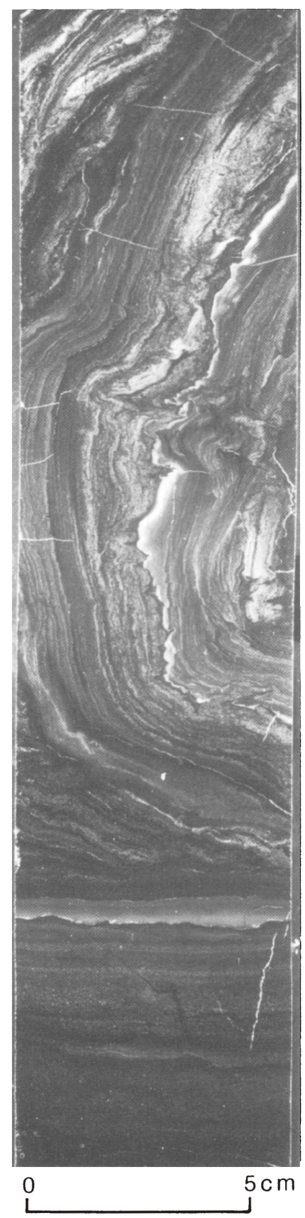


Figure 39. *Contorted laminations, Mist Mountain Formation, Elk River valley. Bar scale 5 cm.*

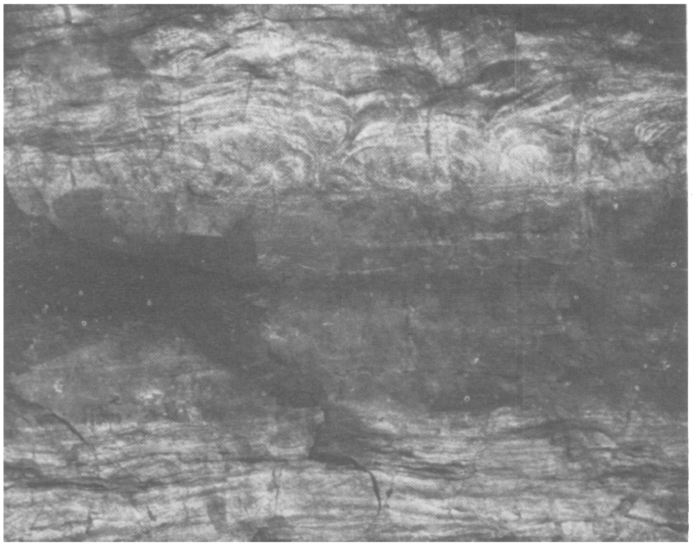


Figure 40. Vertical succession of lithologies and associated sedimentary structures, typical of floodplain depositional environment. Pen 13.6 cm long.

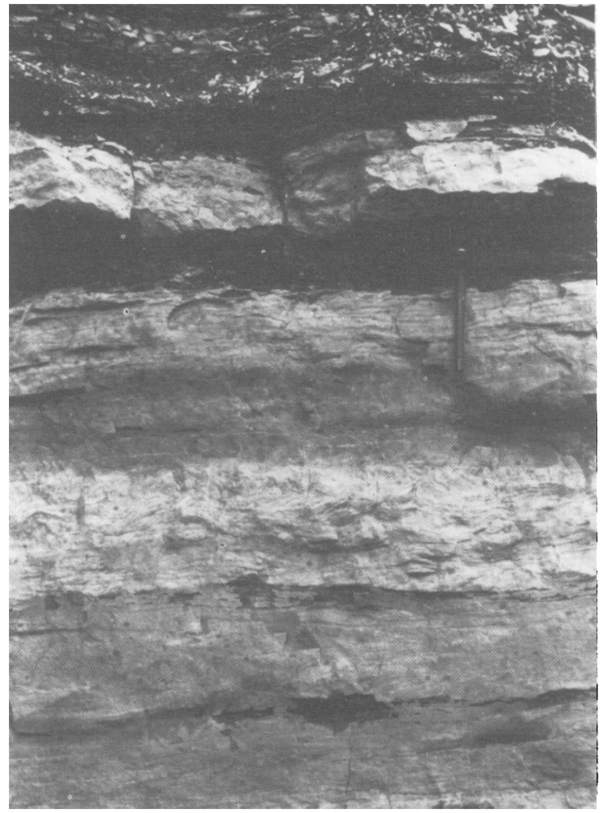


Figure 41. Close-up view of part of Figure 40 illustrating convolute bedding, overlying thin unit of finely laminated siltstone. Siltstone overlies an interval of ripple laminated to climbing ripple laminated sandstone. Mist Mountain Formation, Line Creek (Sec. 76-16).

Figure 42. Small, sand-filled, deformed syneresis cracks in carbonaceous siltstone-mudstone of the Mist Mountain Formation, upper Elk River valley (Sec. E.V.1-4). Bar scale 2 cm.

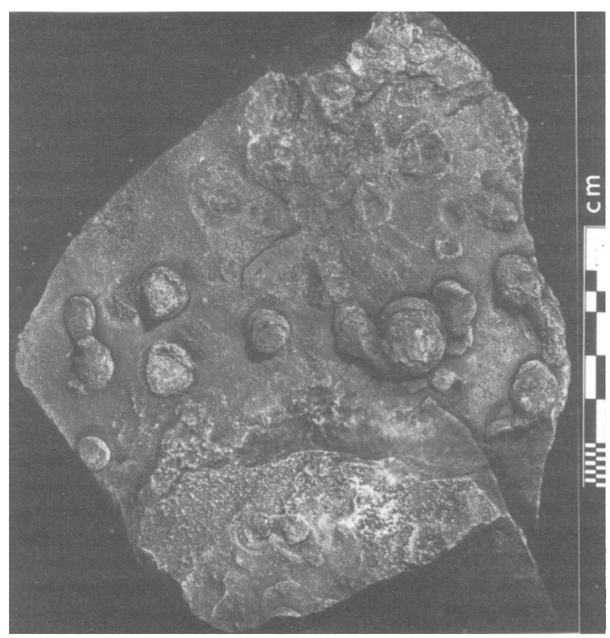


Figure 43. Vertical burrows from basal sandstone facies of Mist Mountain Formation at Limestone Mountain (Sec. 76-18). Note unusual collar or ribbing.

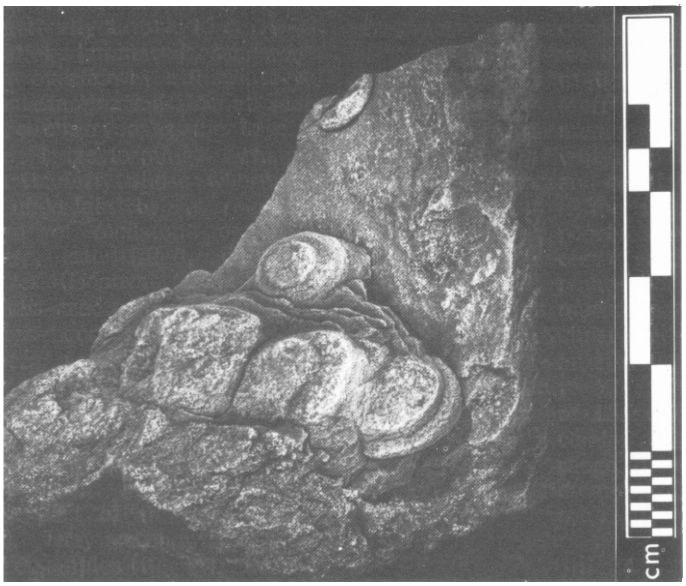


Figure 44. Close-up view illustrating details of sand-filled burrows from basal sandstone of Mist Mountain Formation at Limestone Mountain (Sec. 76-18).

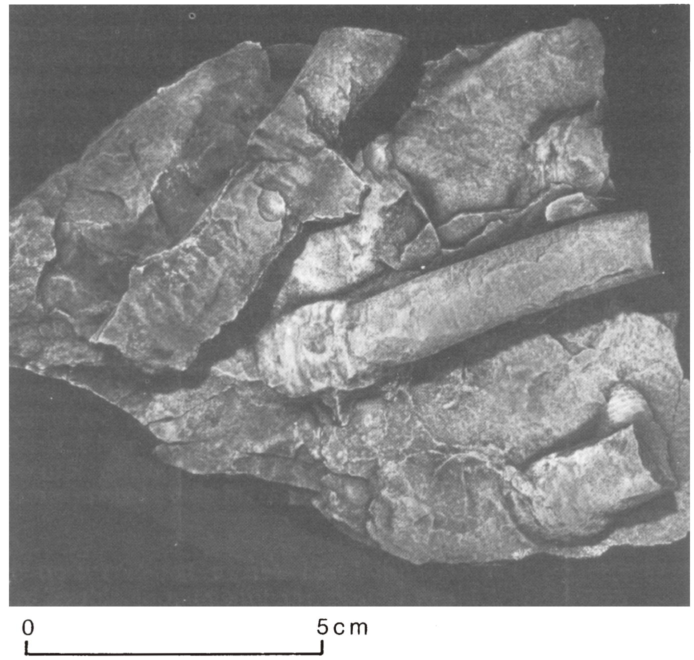


Figure 45. Horizontal, sand-filled burrows in carbonaceous siltstone of basal Mist Mountain Formation at Limestone Mountain (Sec. 76-18). Compare with Figures 43 and 44.

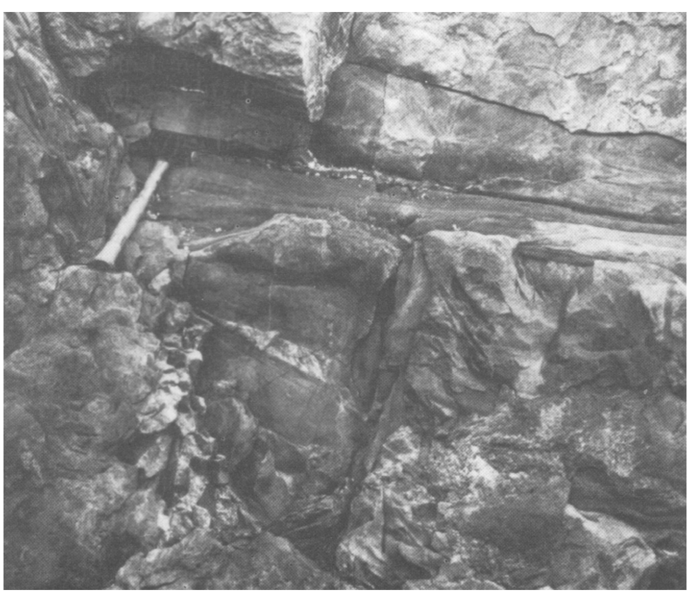


Figure 46. Wood molds and casts in basal fluvial channel sandstone, Mist Mountain Formation (Sec. 76-10).

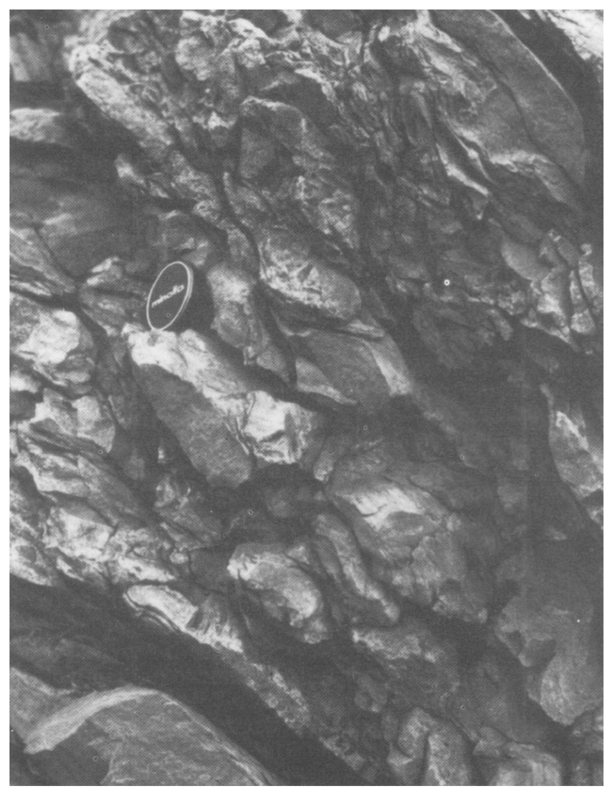


Figure 47. Wood molds and casts, and vitreous coal spars in channel sandstone of Mist Mountain Formation, Cabin Ridge (Sec. 76-2).

distinct from the underlying coal-bearing strata of the Mist Mountain Formation (McEvoy, 1902; Newmarch, 1953). The conglomerate is most abundant and best exposed along the western margin of the basin at Coal Creek, the type locality of the Elk Formation, and along strike toward the south on Morrissey Ridge (figs. 5, 11). The conglomerate occurs as medium to thick beds or as thin to thick lenses interstratified with the massive, thick bedded, coarse grained sandstones and conglomeratic sandstones characteristic of the formation in the area (Fig. 5). It consists of well rounded, commonly poorly sorted, pebbles and cobbles of light and dark grey chert, green chert or silicified tuff, light and dark grey and pink quartzite, and laminated, silicified siltstone and mudstone, in a matrix of medium- to coarse-grained quartz-chert sandstone (Fig. 52). In the Coal Creek-Morrissey Ridge area of the Fernie Basin, pebble sizes range mainly from 2.5 to 5.0 cm in diameter, although maximum cobble diameters of 15.2 cm were observed at Coal Creek. Away from the Coal Creek-Morrissey Ridge area, the average pebble size-range decreases conspicuously to 0.6 to 1.2 cm or less in diameter and maximum pebble diameters in excess of 2.5 cm are rare.

Another lithotype common to the Elk Formation is siltstone. It occurs as thin to medium beds or thin to thick laminations, interbedded and interlaminated with very fine grained sandstone, or as thin beds and laminations interbedded or interlaminated with mudstone or shale. Lithologically and mineralogically, it resembles the siltstones in the underlying Mist Mountain Formation. The siltstone is medium to dark grey, weathering the same or rare orange-brown. It is very carbonaceous and/or argillaceous, sandy in part, and contains a variable concentration of vegetal matter or phytoclasts, the concentration of which usually increases toward coal seams. In addition, the siltstone may be very calcareous or dolomitic, such that, one may in some occurrences classify it as silty limestone or silty dolostone. Such occurrences, however, are considered rare.

One unusual variety of siltstone is common in the upper third of the formation. It consists of dark grey, commonly sandy, very siliceous, carbonaceous and/or argillaceous, thin to medium beds of siltstone up to 30 cm thick, which weather a very distinctive light to light-medium grey. They have been observed throughout the report area, although their abundance and concentration appear to increase toward the southwest and the area of the Fernie Basin. The siltstone is very siliceous for the most part, and well indurated. It occurs as thin beds beneath thin coal seams or very carbonaceous, coaly mudstone. In the Fernie area the siltstone is distinguished by a relatively high concentration of macerated phytoclasts and commonly an unusual content of elongate, rod-like "needles" of vitreous coal (figs. 53, 54, 55). These unusual "needles" were first recorded by Newmarch (1953) and later interpreted to be of algal origin; an interpretation based on coal petrography, geochemical evidence and chemical analysis (Kalkreuth, 1982; L.R. Snowdon, pers. comm.). In the Fernie area these light grey weathering siltstones generally occur with an unusual type of coal locally known as "needle coal"; consequently, the siltstones have informally been referred to as "needle siltstones" (Gibson, 1977b), even though in other areas of Alberta and British Columbia they may not contain the vitreous coal "needles". Some "needle siltstones", when overlain by thin coal seams or very carbonaceous, coaly mudstone or shale, may display vertical rootlets, suggesting that they may represent seat earths or ganisters.

Mudstone and shale comprise the last of the major lithofacies in the Elk. Although inconspicuous in most field sections, because of vegetation and talus cover, they form a common lithologic component of the formation, occurring

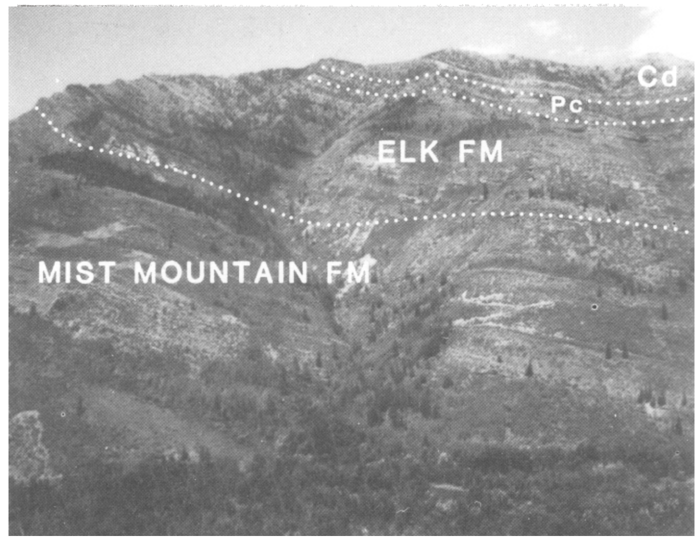


Figure 48. *Type section of Elk Formation, north side of Coal Creek (Sec. 75-7). Note resistant channel sandstone and conglomerate units in Elk, and typical generally covered character of Mist Mountain Formation. Pocaterra Creek Member (Pc); Cadomin Formation (Cd).*

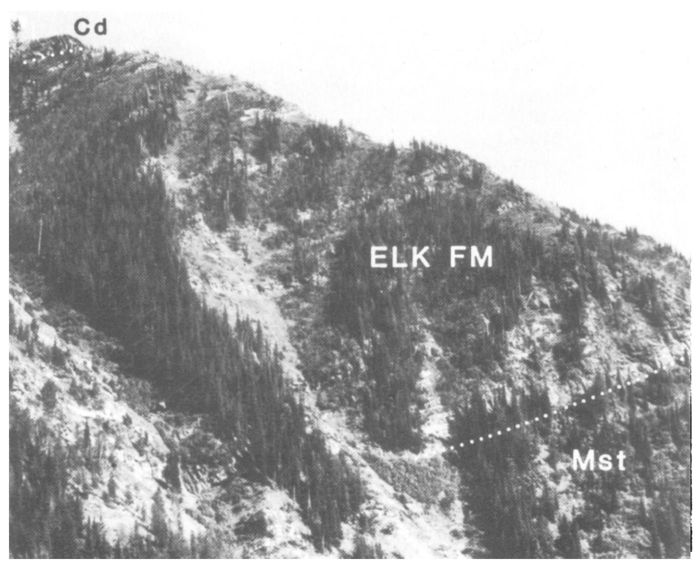


Figure 49. *Elk Formation at Morrissey Microwave Tower section (Sec. 75-9), illustrating massive, channel facies of conglomerate and coarse grained sandstone typical of the formation in Fernie Basin area. Mist Mountain Formation (Mst); Cadomin Formation (Cd).*

most commonly as thin beds or wavy to parallel laminations, interbedded or interlaminated with carbonaceous siltstones or thin coal intervals. The mudstone-shale is dark grey to black, very carbonaceous and/or argillaceous and, like many of the siltstones, contains a variable concentration of phytoclasts. At some localities, i.e. Eagle Mountain (Sec. 75-19; figs. 3, 6), the mudstone displays a conspicuous subconchoidal fracture and a strong degree of fissility, depending on exposure, with little to no obvious macroscopic vegetal matter. In addition, some of the mudstone contains fresh water pelecypods, gastropods, ostracodes, and esthyriids. Ochre or orange-brown weathering ironstone nodules, concretions, and rare pyrite laminations also occur. Another more unusual mudstone-shale lithofacies occurs near the contact with the overlying Cadomin Formation of the Blairmore Group, at two localities in the Alberta Foothills (secs. 76-11, 76-13; Fig. 3). Here, the lithofacies is dark grey but is unusually siliceous, displaying a strong platy fissility. A similar type of mudstone-shale was noted in strata of the underlying Mist Mountain Formation, again near the Cadomin Formation contact (Sec. 76-1; Fig. 3).

Facies variations are common in the Elk Formation and are illustrated by the cross-sections in figures 5 to 11. One excellent example of a vertical facies change, although not illustrated in the figures, is the occurrence of "needle coal" in the Fernie area. This coal, like the "needle siltstone", is restricted mainly to the upper third of the formation.

The lateral facies variations in the Elk make correlation of lithotypes between closely spaced sections difficult (figs. 5-11). This is well illustrated by the chert-pebble conglomerates at the type locality on Coal Creek, and on Morrissey Ridge (secs. 75-7, 75-9; Fig. 5). As can be seen in Figure 5, the conglomerate is laterally discontinuous both locally and regionally, becoming less abundant away from the Coal Creek-Morrissey Ridge area. At Sparwood Ridge (Sec. 75-8; Fig. 5), 22.5 km northeast along strike from Coal Creek, only two conglomerate units were recorded in the formation, one thin lenticular bed at the base and another 8.5 m-thick unit 390 m above the base. South of Coal Creek and Morrissey Ridge, at Flathead Ridge (Sec. 75-6; Fig. 5), the southernmost exposure of the Elk Formation examined by the writer in the report area, individual pebble conglomerate beds were not observed, although lenses and pockets of conglomeratic sandstone were found in some of the thicker, ledge-forming sandstones. At Mount Taylor (Sec. 75-15; Fig. 5), on the eastern margin of the Fernie Basin, only rare beds of pebble conglomerate and conglomeratic sandstone were found, near the base and top of the formation. In the Alberta Foothills east of the Fernie Basin, pebble conglomerate, as a distinct and separate lithofacies, is rare to absent in the Elk. However, at Mount Allan, Cabin and Isolation ridges, and the Plateau Mountain area (secs. 76-7, 76-2, 76-14, 76-4; figs. 6, 8, 10), sporadic, thin to thick lenses occur singly or as units within the thick sandstone facies near the base of the formation. Here, the conglomerate consists of well rounded pebbles of chert, quartzite, and silicified mudstone, up to 2.5 cm in diameter although averaging only 1.3 cm, in a matrix of coarse grained sandstone. At other localities in the Alberta Foothills, well rounded but smaller chert and quartzite pebbles and granules occur sporadically distributed in the basal part of some of the thicker sandstone beds. These beds would be classed texturally as conglomeratic sandstones.

Another lateral facies variation may be demonstrated by the conspicuous increase in concentration and thickness of major sandstone units from west to east, between the eastern margin of the Fernie Basin and the eastern limit of the Elk Formation (figs. 6, 7). This change corresponds with a proportionate decrease in siltstone concentration.

The last noteworthy lithofacies change is shown by the coal seams in the cross-sections of figures 5 to 11. As shown, the coal seams decrease both in thickness and, generally, in number from west to east in many sections between the Front Ranges of British Columbia and the eastern part of the Foothills of Alberta. Coal was not observed in the Elk at three localities in the Alberta Foothills. It should be noted that some of these facies variations may be attributable in part to a reduction in stratigraphic thickness of the Elk Formation, because of pre-Blairmore erosion or sedimentary thinning, and may not all be related to changes in the depositional environment.

Contact relationships

In most areas, the Elk Formation is disconformably overlain by the Cadomin Formation of the Blairmore Group (figs. 5, 6, 30, 33). The contact is placed where darker grey weathering, carbonaceous and/or argillaceous siltstones, mudstones, shales and sandstones of the Elk, are abruptly overlain, at an erosion surface, by medium to lighter grey weathering, massive, thick bedded, cliff-forming, chert-pebble conglomerate, coarse grained sandstone, and conglomeratic sandstone of the Cadomin Formation. However, in some areas of the western Foothills and eastern Front Ranges, strata of the Cadomin or basal Blairmore Group differ lithologically from equivalent Cadomin strata found toward the east. The Cadomin Formation in the western region consists not only of thick, massive, chert-pebble conglomerate and coarse grained sandstone, but also of recessive weathering, partly talus covered intervals of olive-grey, buff, to reddish-brown siltstone and mudstone, and fine- to medium-grained, buff to light grey, quartzose sandstone. In addition, the Cadomin or basal Blairmore strata may be further subdivided into two units. At some of these western localities, including: Sparwood, Fernie, and Marten ridges; the area adjacent to and west of Highwood Pass; and the area of Mount Allan near Canmore, Alberta (Fig. 3); the Cadomin or basal Blairmore strata may be further subdivided into two units. The lower unit is composed of light grey, very well indurated quartz sandstone, olive-grey, reddish-brown, and dark grey siltstone, and light- to medium-grey quartz and chert pebble conglomerate and conglomeratic sandstone. This lower unit is identified as the Pocaterra Creek Member (Gibson, 1977b). The upper unit, composed of thick bedded conglomerate and conglomeratic, light- to medium- grey weathering sandstone, comprises the main facies of the Cadomin Formation (figs. 48, 50, 51).

The Pocaterra Creek Member was first recorded and described by Allan and Carr (1947) in the Highwood-Elbow River area of Alberta. This unusual lithofacies overlies apparently eroded strata of the Elk Formation, although in some areas, including the Sparwood, (Sec. 75-8) and Fernie (Sec. 75-7) ridges, and Mount Allen (Sec. 76-7), the contact between the two units is abrupt, but may be conformable. The strata of the Pocaterra Creek Member are unlike those of the Elk Formation because of a conspicuous lack of carbonaceous matter, the occurrence of light grey quartz sandstones, and the presence of "red beds" and olive-grey weathering siltstones in the former. Additional work will be required to resolve the lithologic relationships between the Cadomin Formation and the Pocaterra Creek Member of the lower Blairmore Group, in the area of the western Foothills and eastern Front Ranges of southwestern Alberta and southeastern British Columbia. For additonal information on the Cadomin Formation and the Pocaterra Creek Member, the interested reader is referred to reports by Allan and Carr (1947), Rapson (1964), McLean (1977), and Ricketts and Sweet (in press).

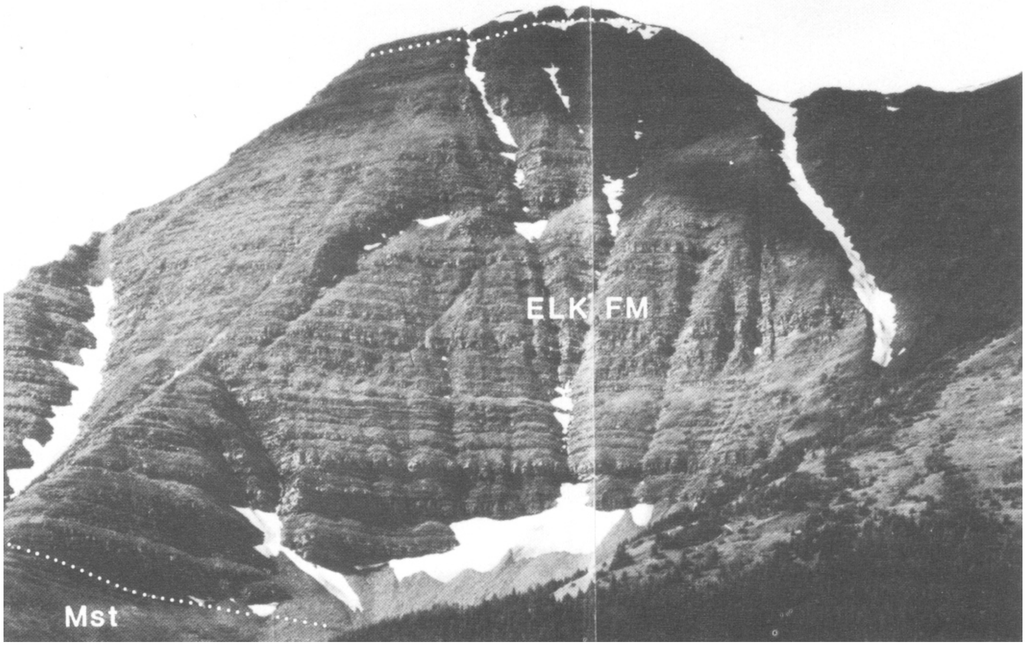


Figure 50. Contact and lithologic relationships of Elk and Mist Mountain formations and Pocaterra Creek Member of Cadomin Formation at Mount Allan (Sec. 76-7). Mist Mountain Formation (Mst); Pocaterra Creek Member (Pc).

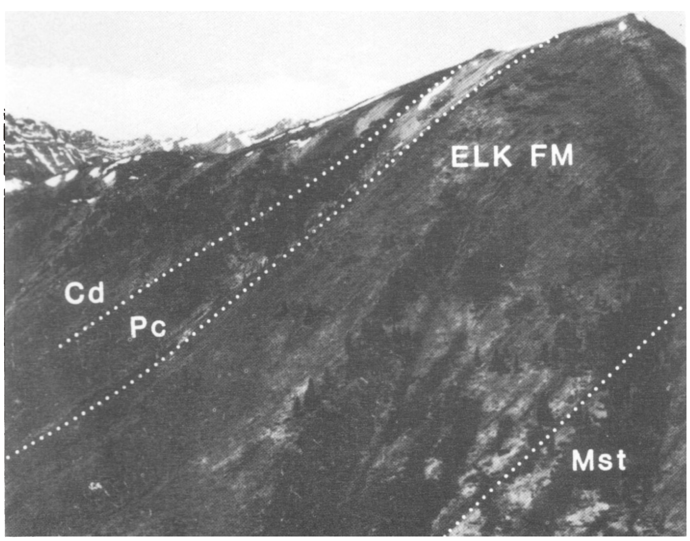


Figure 51. Contact and lithologic relationships between Elk Formation and Pocaterra Creek Member and Cadomin Formation at Mount Lipsett (Sec. 76-9). Mist Mountain Formation (Mst); Pocaterra Creek Member (Pc); Cadomin Formation (Cd).

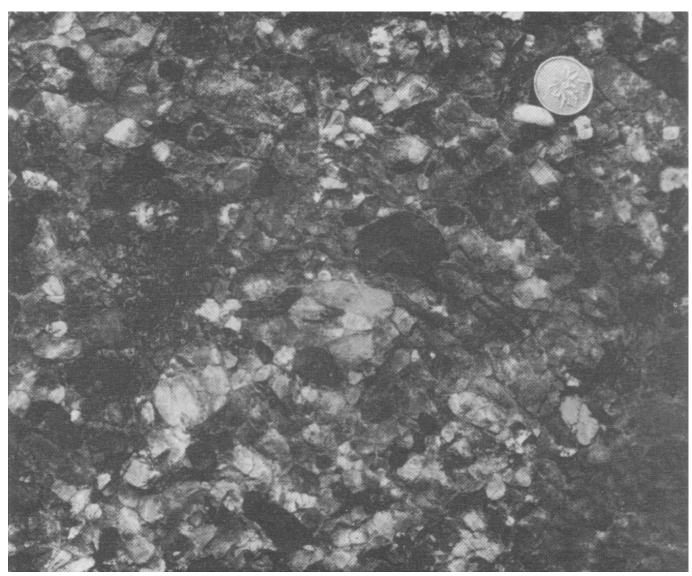


Figure 52. Chert-pebble conglomerate of Elk Formation, western margin of Fernie Basin (Sec. 75-9). Pebbles consist predominantly of light and dark grey chert, dark grey silicified argillite and siltstone, and light grey and pink orthoquartzitic sandstone.

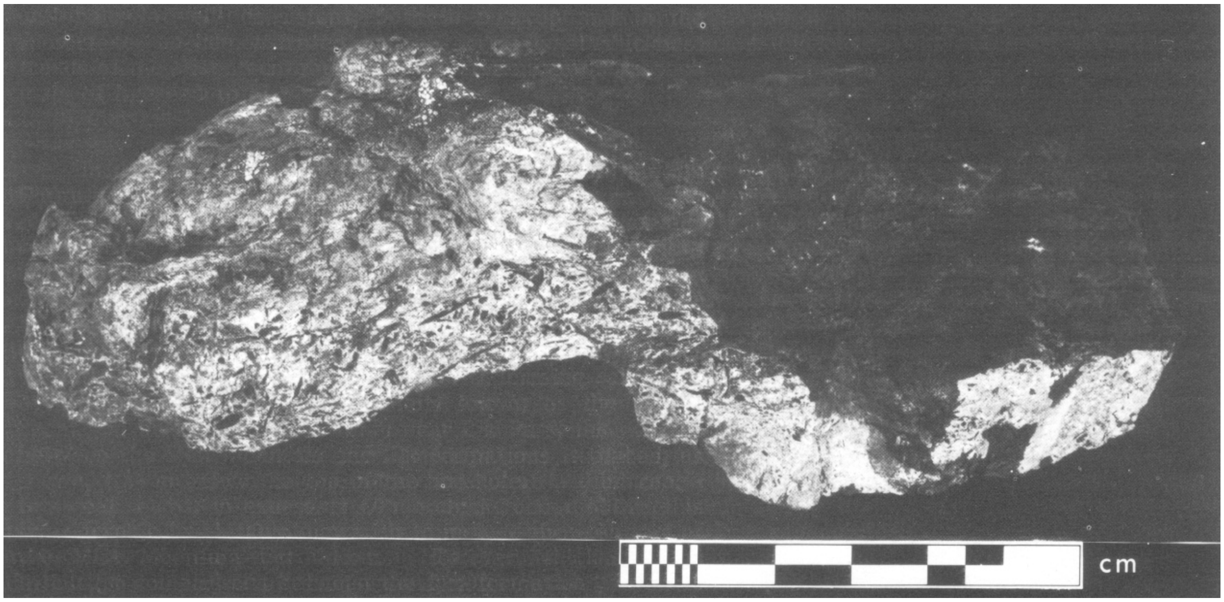


Figure 53. *"Needle Siltstone" from upper Elk Formation (Sec. 75-9). Note black, coalified, algal "needles", and tonal contrast between dark grey on fresh surface and light grey on weathered surface.*

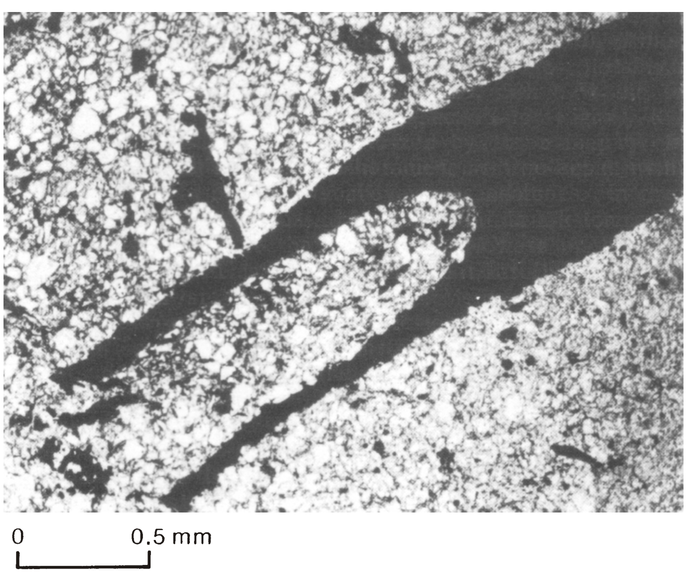


Figure 54. *Photomicrograph of "Needle Siltstone", illustrating hollow centre of some algal "needles". Note concentration of quartz, and matrix and cement of quartz and chert permeated and stained by black organic carbonaceous matter. Sparwood Ridge (Sec. 75-8). Bar scale 0.5 mm.*

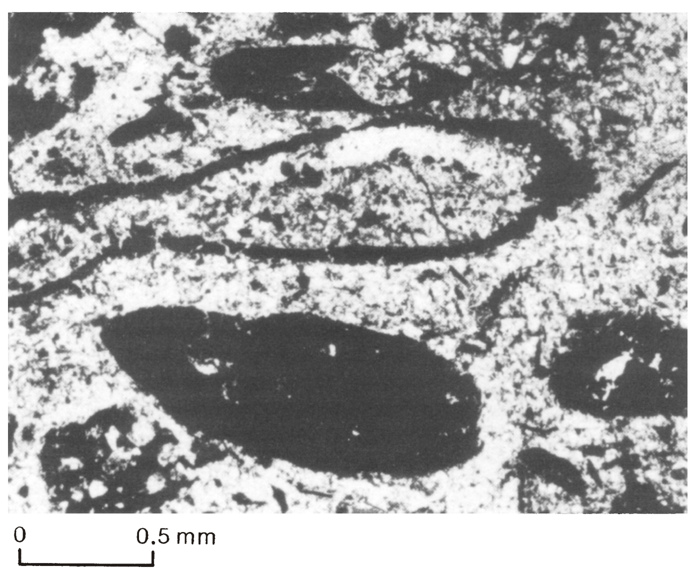
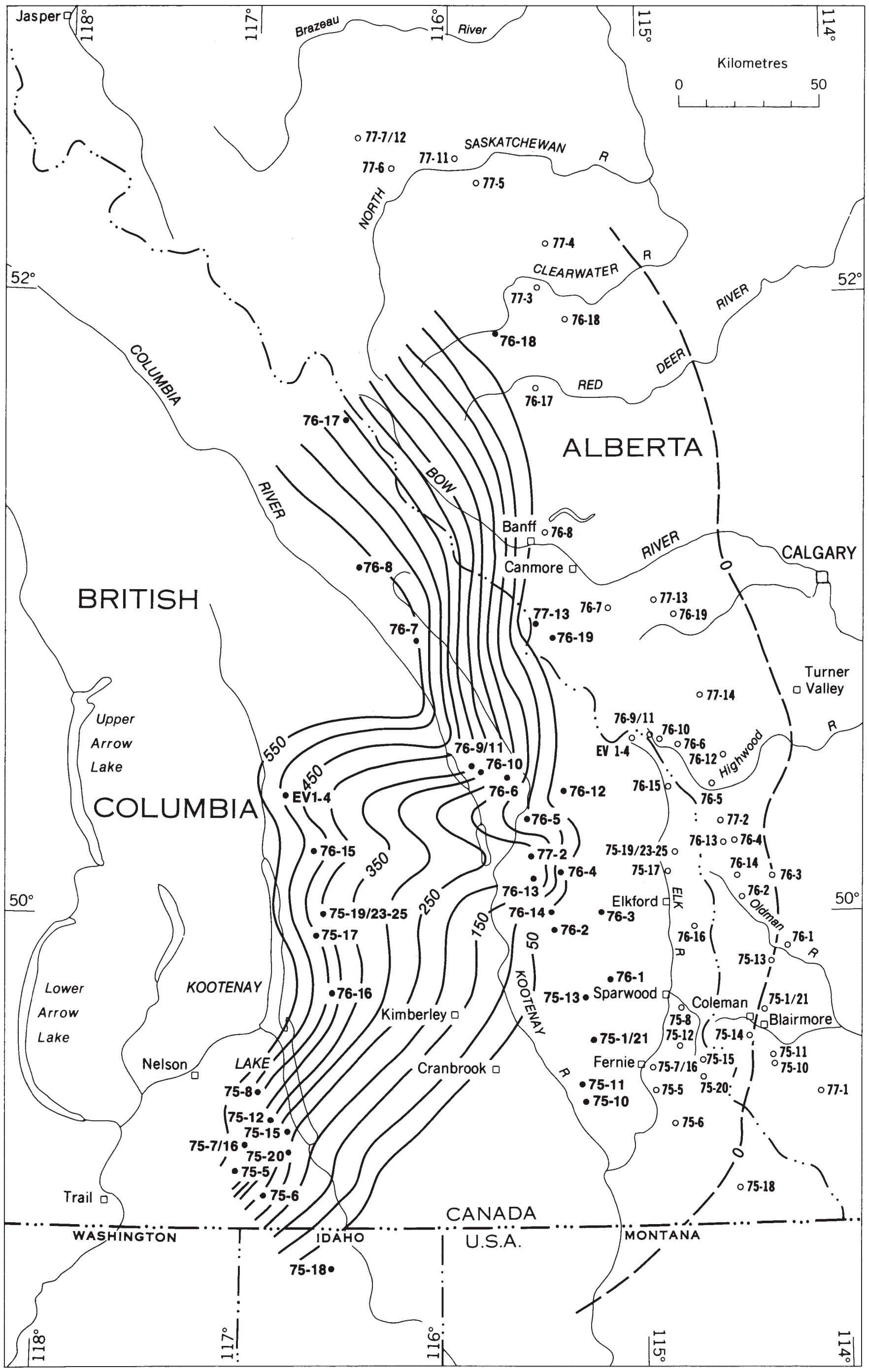


Figure 55. *Photomicrograph of "Needle Siltstone", illustrating hollow and solid algal "needles" in matrix and cement of quartz and chert. Morrissey Microwave Tower (Sec. 75-9). Bar scale 0.5 mm.*

The contact between the Elk Formation and the underlying Mist Mountain Formation is gradational and conformable, as previously described.



Present location of control point .... 75-18 o

Pre-Laramide location of control point (Turner Valley considered fixed) .... 75-18 •

Isopach; defined, approximate (interval 50m) 50

Figure 56. *Palinspastic isopach map of the Elk Formation.*

Distribution and thickness

The Elk Formation has a more restricted areal distribution in the report area than the other members and formations of the Kootenay Group. The Elk has been recognized in outcrop as far south as Flathead Ridge, along the southern margin of the Fernie Basin (Fig. 1), and can easily be traced along the western margin of the Basin and along the east side of Elk River valley to the area of Elk Pass and Kananaskis Lakes. The formation is well exposed at Mount Allan (Sec. 76-7; figs. 8, 50), near Canmore, although in this area it begins to lose its distinctive lithologic character and superficially resembles strata of the Mist Mountain Formation. The northern limit of recognition for the Elk is at Barrier Mountain (Sec. 76-17; figs. 3, 9). The existence of the Elk Formation north of Barrier Mountain is not certain, because exposure is poor and access is difficult. Thickness trends illustrated in Figure 56 are drawn, however, to infer a continuation of the formation along strike from Barrier Mountain at least to North Saskatchewan River, the northern limit of the Kootenay Group and northern terminus of the report area (Gibson, 1978).

In the eastern Front Ranges, and western and central Foothills, the Elk forms a distinctive, generally cliff-forming, easily recognized lithofacies. It extends along a line from Mount Taylor and Tent Mountain on the east margin of the Fernie Basin, then swings northeastward, through such areas as Cabin Ridge (Sec. 76-2; Fig. 6), Plateau Mountain (Sec. 76-4; Fig. 10), Sentinel-Highwood Ranger Station (Sec. 76-5; figs. 7, 29, 30) and Mount Lipsett (Sec. 76-11; figs. 7, 51). Elk strata have not been observed east of this line, because of removal by pre-Blairmore erosion and/or sedimentary thinning away from the postulated sediment source area to the west.

The Elk ranges in measured thickness from a maximum of 590 m at Mount Allan (Sec. 76-7; figs. 8, 50), to a minimum of 28 m at Cabin Ridge (Sec. 76-2; Fig. 6), 38.4 km north of Coleman, Alberta. The thickness of the formation at its type section on Coal Creek (Sec. 75-7; figs. 5, 48) was recorded by the writer as 462.6 m, while the thickness at the supplemental reference section on Morrissey Ridge (Sec. 75-9; Figs. 5, 49) was recorded as 522 m. Figure 56 is an isopach map of the Elk Formation prepared on a palinspastically restored base, showing the thickness trends and distribution of the formation in the report area. It can readily be seen that the formation thins toward the east and southeast to a zero erosional edge. Toward the north, in the vicinity of North Saskatchewan River, the Elk grades laterally into strata of the Nikanassin Formation. The conspicuous isopach irregularity illustrated in Figure 56 is a result of a thick development of the Elk Formation near Wilkinson Creek summit (Sec. 76-13; Fig. 6).

Age and correlation

Unfortunately, the microfaunal, macrofaunal, microfloral and megafloral content of the Elk Formation has not been sufficiently time sensitive to date the strata with any degree of precision. Bell (1956), in a megafloral study of the Kootenay Formation, which included strata equivalent to the Elk Formation of this report, considered the age of the Kootenay to be Neocomian-Barremian.

Samples of mudstone, siltstone, and shale from the Elk Formation were submitted to A.R. Sweet and J.H. Wall of the Geological Survey for palynological and microfaunal analysis respectively (Appendix 4), with the hope of obtaining information for more accurately dating the Elk strata, and also to aid in the interpretation of the depositional environment. Unfortunately, samples submitted for microfaunal analysis proved to be barren, a result probably related to the nonmarine, alluvial plain depositional environment postulated for the Elk strata. Fortunately, however, some of the samples processed for the microfloral content provided some information on a possible age for the Elk strata. For example, at Barrier Mountain (Sec. 76-17; Fig. 9), near the northern terminus of the study area (Fig. 1), one sample, collected from 177 m above the base of the Elk Formation, yielded one specimen of *Schizosporis reticulatus*, which Sweet suggested to be of probable Early Cretaceous age. At the Sentinel-Highwood River Ranger Station locality (Sec. 76-5; Fig. 7), a generalized assemblage of miospores was obtained from a sample taken 52 m above the base of the Elk Formation, but gave no confirmation of a Cretaceous age. However, another sample collected from 38 m above the first contained miospores that included *Aequitriradites spinulosus*, which, according to Sweet, is known only from the Cretaceous.

The most useful and significant palynomorphs were obtained from a sample collected at Eagle Mountain (Sec. 75-19; Fig. 6), 20 km northeast of Elkford. From this sample, *Cicatricosisporites australiensis*, *Dictyortriletes southeyensis*, and *Acanthotriletes levidensis* were identified by Sweet, who suggested that, because of their joint presence in the sample, the microflora is of possible Early Cretaceous, Neocomian, age. Other possible Early Cretaceous ages were suggested for samples from Morrissey Ridge (Sec. 75-5; Fig. 5), where a fragment of *Cicatricosisporites* sp. was identified among other species, and from Sparwood Ridge (Sec. 75-8; Fig. 5) (collected from near the base of the Elk Formation), which yielded *Cicatricosisporites australiensis* and other species.

It should be noted that, at Sparwood Ridge, *Schizosporis reticulatus* and *S. parvus* were collected from strata of the Pocaterra Creek Member of the Blairmore Group. They too were assigned a probable Early Cretaceous age by Sweet. However, none of the forms recovered from the Pocaterra Creek Member suggested an age younger than Neocomian.

All other microfloral collections from the Elk were assigned an age ranging between Jurassic and Cretaceous, or were considered as indeterminate or undiagnostic for any age assignment.

Pelecypods, ostracodes, and rare esthyriids have been collected from the Elk Formation by Pearson and Duff (1975). However, these fossils also were not diagnostic enough for precise age determinations.

It is apparent that the age of the Elk, like that of the underlying Mist Mountain, is still in doubt. Enough evidence has been obtained from microfloral collections to suggest that the Elk Formation, especially the strata in the thicker western sections, may be mainly Early Cretaceous in age, but may be as old as Late Jurassic in some of the thinner eastern sections, such as the Sentinel-Highwood River Ranger Station locality (Sec. 76-5; Fig. 7).

Correlation of the Elk Formation with strata north and south of the report area is uncertain. Between Barrier Mountain (Sec. 76-17; Fig. 3) and North Saskatchewan River the Elk Formation thins (figs. 9, 11) because of pre-Blairmore erosion and/or normal sedimentary thinning. At Wapiabi Creek (Sec. 77-7-12; Fig. 11), the Nikanassin Formation – the lithologic equivalent of the Morrissey, Mist Mountain and possibly part of the Elk – is 444 m thick, which is much less than the total thickness of the Kootenay Group at Barrier Mountain (Sec. 76-17; Fig. 11). It would appear, therefore, that the stratigraphic equivalent of the Elk Formation in the Wapiabi Creek area has thinned greatly, or has been totally removed by pre-Blairmore erosion. To the north, in the Athabasca-Smoky River area of Alberta, the Nikanassin Formation thickens, and Elk strata may correlate lithologically with part of the upper Nikanassin Formation. In the northern Foothills of Alberta and British Columbia, the Nikanassin grades laterally into the thick clastic succession of the Minnes Group (Stott, 1975). The Elk Formation is assumed to correlate lithologically with part of the Minnes Group. In the absence of adequate paleontological data for the Elk Formation, age relationships between the Elk and equivalent strata in other areas to the north must remain uncertain or speculative. Similarly, correlation between the Elk Formation and strata in the Montana and Wyoming areas, south of the Canada-United States border, has not been established. It is suggested, however, that strata equivalent to the Elk are not present because of pre-Kootenay erosion and/or nondeposition.

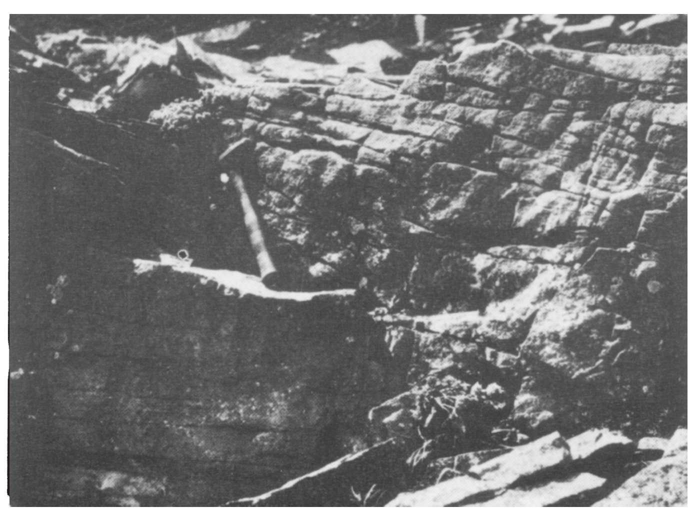


Figure 57. *Medium scale, festoon crossbedding in fluvial channel sandstone of Elk Formation.*

Sedimentary structures

Sedimentary structures in the Elk are similar to those in the underlying Mist Mountain Formation, being most conspicuous in the fine- to medium-grained sandstones and coarser grained siltstones. The structures consist of small-to large-scale festoon and, less commonly, small- to medium-scale, planar-tabular crossbedding (see figs. 57, 58); wave and current ripple, climbing ripple and ripple drift laminations; distorted or contorted laminations; loadcasts; and rare flaser bedding in the finer grained sandstones and siltstones. The flaser bedding is most conspicuous in core samples (Fig. 38). Wood molds and casts (see figs. 46, 47), some with coal spars and coaly "rinds", also occur in the basal and upper parts of some of the thicker, coarser grained sandstone units. Burrow structures, although present in the finer grained sandstones, are generally not evident in outcrop. However, core samples from the upper Elk River valley and Barrier Mountain areas reveal both vertical and horizontal burrows, some of which are up to 1.3 cm in diameter, in many of the finer grained sandstones and coarser grained siltstones. The recognition of burrows in core samples suggests, therefore, that burrowing in the Elk may in fact be more common than previously noted, but has gone unrecognized because of weathering and poor exposure. The mudstones, shales, and other pelitic rocks in the Elk contain wavy to lenticular bedding and laminations; small, vertical, sand-filled burrows, commonly less than 0.6 cm in diameter; contorted or distorted bedding and laminations; and rare, poorly preserved, ripple laminations.

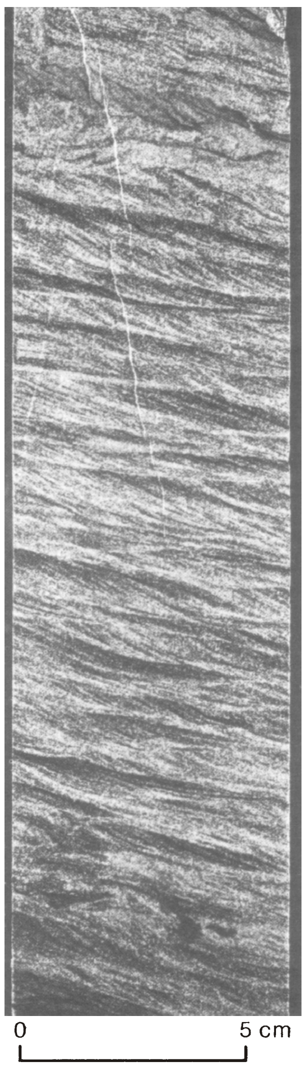


Figure 58. *Climbing ripple laminations, Elk Formation, Elk River valley. Bar scale 5 cm.*

OCCURRENCE AND DISTRIBUTION OF COAL IN THE KOOTENAY GROUP

Coal has long been recognized as an economically important component of the Kootenay rock succession in Alberta and British Columbia. Its distribution, chemical and petrographic properties, important mining statistics, and parameters, have been documented in varying detail in many previous reports by other workers; particularly those involved with the study of coal in the Crowsnest Pass and Fernie areas and, to a lesser degree, the coals of the Cascade River basin near Canmore and Banff National Park. The following discussion will only repeat parts of this information here, where necessary, but will document and illustrate, through a series of stratigraphic cross-sections, the occurrence and distribution of coal seams in the Kootenay Group throughout most of the important coal-bearing areas (figs. 5-11). Each formation will be considered separately, with information provided on correlation of seams, areas or stratigraphic intervals of maximum and minimum seam development, rank of coal to be expected and, where important, an estimate of the volatile matter content of the coal – a value determined from the mean maximum reflectance of the maceral vitrinite in samples analysed by A.R. Cameron and P.A. Hacquebard of the Geological Survey, and P.R. Gunther formerly of that organization. It is hoped that this information, when combined with the detailed chemical and petrographic information provided for Kootenay coals from local areas by other workers, will assist the reader in obtaining a better appreciation of the economic potential of the Kootenay rock succession, particularly the Mist Mountain Formation, in all areas of Alberta and British Columbia where the strata have not been studied in detail.

Reflectance, volatile matter and rank data obtained from Kootenay Group coal samples used in this study are included in the appendix.

Morrissey Formation

Coal in the Morrissey Formation is rare. It has been found only in the Moose Mountain Member at Line Creek (Sec. 76-16; Fig. 3) and in the area of Weary Ridge in the upper Elk River valley (Fig. 3).

At Line Creek, two thin, coal-bearing units of dark grey, carbonaceous mudstone were recorded 8.5 and 13.5 m below the top of the formation respectively, in a massive, thick, cliff-forming sandstone. The upper unit, 70 cm thick, contains a thin (up to 35 cm thick) seam of medium volatile, bituminous coal, with a volatile matter content of 24 per cent[1]. The upper coal-mudstone-shale interval varies in thickness within the Line Creek area from 10 to 76 cm. The lower coal-bearing unit is 40 cm thick, although it ranges in thickness in the area from 20 to 64 cm. The coal occurs as thin lenses and lenticles throughout mudstone and shale in the units. Petrographic analysis by A.R. Cameron of the Geological Survey indicates a volatile matter concentration of 27.5 per cent, a value based upon a mean maximum reflectance of 1.16. The coal in both units is dull to vitreous in lustre and in places is sheared and crushed. It is overlain and underlain by dark grey, very carbonaceous mudstone and shale, with the entire lithofacies overlain and underlain by well indurated, medium- to coarse-grained sandstone.

At Weary Ridge, 52 km northwest of Line Creek, a similar, dark grey, very carbonaceous mudstone and shale lithofacies, up to 60 cm thick, was observed 11 m below the top of the Morrissey Formation. At this locality the unit does not contain coal. A personal communication from Mr. G. Lawrence, of Elko Mining Company Limited, however, indicates that, during an intensive coal drilling exploration program in the Weary Ridge area, a thin coal and coaly shale unit was penetrated in the Morrissey Formation, at approximately the same stratigraphic level below the top of the formation as that noted by the writer in outcrop. The maximum thickness of the coal recorded by Elko Mining Company was 30 cm. No coal, coaly shale or mudstone intervals were observed by the writer, in the Morrissey Formation in the area between Line Creek and Weary Ridge. This area includes the economically important Westar Mining Limited's Greenhills coal leases and the open-pit mine of Fording Coal Limited.

At Mount Taylor, on the eastern margin of the Fernie Basin (Sec. 75-15; Fig. 5), another thin mudstone-shale unit, up to 80 cm thick, was noted 10.7 m below the top of the Morrissey Formation, in the massive, cliff-forming sandstone of the Moose Mountain Member. However, at this locality, no coal was observed in the unit.

Because of their rare occurrence and thin development, the coal seams in the Moose Mountain Member of the Morrissey Formation are not deemed to be of sufficient thickness or quantity to be worth economic exploitation. In most parts of the report area, the Morrissey Formation and Moose Mountain Member do not even contain recessive zones of mudstone or shale, with the exceptions noted above. It is possible, however, that rare, thin, coaly beds may be present in the formation in some other areas, but have gone undetected because of the cliff-forming and generally inaccessible nature of the Morrissey strata.

Mist Mountain Formation

Examination of the cross-sections in figures 5 to 11 readily demonstrates the economic importance of the Mist Mountain Formation as a major source of coal in the report area. Many seams are thick – up to 18 m – and some near the base of the formation are laterally extensive regionally (figs. 15, 22). Figure 5 is a stratigraphic cross-section linking the more important field sections of the Fernie Basin area on the west with some of the important field sections in the Alberta Foothills of the Coleman-Blairmore area to the east. One can readily see the vertical and lateral distribution and thickness trends of the coals in the area, and their relationships with overlying and underlying strata. Currently, most coal production comes from Westar Mining Limited's mines at Sparwood, British Columbia. In this area, most exploitation and development involves the lowest major seam, locally known as the Balmer or No. 10 Seam. The seam is designated as the first major (thick) seam above the top of the Morrissey Formation (e.g. Sec. 75-8; Fig. 5). It can be traced and correlated throughout most areas of the Fernie Basin and adjacent areas to the north and east. The coal of the Mist Mountain Formation in this area ranges in rank from predominantly medium volatile bituminous to, less commonly, high- and low-volatile bituminous. The volatile matter content ranges from a high of 33 per cent to a low of 20.7 per cent. Most coal from the area is exported to foreign markets where it is used to make coke, however, some coal from the Fernie Basin is used domestically and internationally in the generation of electricity. As shown in the cross-sections, coal is most abundant in the northern part of the basin (secs. 75-8, 75-12; Fig. 5), and decreases in concentration toward the south and east sides of the basin (as shown by sections 75-6, and 75-15; Fig. 5) and toward the Alberta Foothills. However, in some of the southern and eastern areas, the seams are reduced in number in the formation but are generally thicker, as shown by the lowest seam on Morrissey Ridge. This seam is 28.6 m thick, although it does contain shale partings. Furthermore, it can also be seen from the figure that large covered intervals are present in some sections. It is possible that these intervals may be underlain in part or in whole by additional seams of coal.

It should be noted that local thickening of seams in some areas may be a result of in-seam faulting and consequent repetition.

In the Foothills of the Coleman-Blairmore area, four seams have been of economic interest in the past, but only the two thick, conspicuous seams, illustrated in field section 75-1 on Grassy Mountain, seem to have potential for future development. They are locally referred to as the No. 2 and No. 4 (lower) seams. They can be correlated throughout most of the Coleman-Blairmore area but, as shown in Figure 5, the thickness of the seams is highly variable within the region.

With the exception of the examples noted above, and the prominent, major coal seam opposite the 670.6 m level in Figure 5, correlation of most major coal seams in the Mist Mountain Formation, in the area bounded by Figure 5, is difficult, even between closely spaced sections. The 670.6 m level seam appears to be locally correlatable, at least to the area around Morrissey Ridge. Beyond this region, correlation is less certain because the seam appears to thin and disappear or, alternatively, occurs at a lower stratigraphic level in the Mist Mountain Formation. Also apparent in Figure 5 is a noticeable reduction in thickness of the Mist Mountain Formation from west to east, accompanied by a proportional reduction in the number of coal seams.

North of the Fernie Basin-Coleman and Blairmore areas is another economically important coal producing region, which is illustrated by the stratigraphic cross-section in Figure 6. The cross-section links the important field sections of the Greenhills Range near Elkford, British Columbia, and the open-pit mine area of Fording Coal Limited, with field sections in the Alberta Foothills to the east, north of

[1]Per cent volatile matter determined from mean maximum reflectance (Ro), according to method of Stach et al. (1975).

Coleman and Blairmore. It is apparent, by comparing figures 5 and 6, that there is a noticeable increase in the number and average thickness of the coal seams in the Greenhills Range (Sec. 75-17) and Fording Coal Mine areas (secs. 75-23, 75-24), over those along strike to the south in the Fernie Basin. Up to 40 seams were recorded in the Greenhills Range-Elkford area, although only 15 or 16 appear to be of sufficient thickness and quality to be of economic interest. Seams in this area are up to 16.8 m thick (Sec. 75-17), with the volatile matter content ranging from a low of 24 per cent to a high of 36 per cent, indicating a range in coal rank from medium volatile bituminous to high volatile bituminous. This range in rank represents a slightly lower range than is found to the south in the coals of the Fernie Basin area. Coal samples from the Alberta Foothills to the east display a slight increase in rank over those to the west and are classed mainly as medium volatile bituminous.

The coal in the Mist Mountain Formation is commonly bright and vitreous in lustre and has generally been tectonically sheared and crushed. An unusual and rare type of coal, characterized by a dull resinous lustre resembling that of cannel coal, was observed as thin seams in some western section exposures and in core samples from the upper third of the Mist Mountain Formation. One sample was characterized by a high concentration of the macerals semifusinite and fusinite, as well as mineral matter. The sample, classified as "Splint Coal", had a volatile matter content of 29 per cent. Again, by examining Figure 6, one can readily visualize the rapidity with which seams thin and disappear from west to east, making seam correlation difficult and speculative, even between closely spaced sections. As can be seen, some of the eastern Foothills sections are characterized by large covered intervals (i.e. Sec. 76-14), which may be underlain in part or in whole by additional seams of coal.

Figure 7 illustrates the occurrence and distribution of coal from the upper Elk River valley east to the Trap Creek area of the eastern Alberta Foothills. In this area, the Mist Mountain Formation in the thicker western sections is again characterized by a noticeable increase in the number of coal seams, compared to those in the Mist Mountain Formation along strike to the south in the Elkford area. The seams are, however, generally much thinner. As in areas to the south, the number of seams in the formation decreases from west to east. Coals in boreholes E.V. 3 and E.V. 4, from the Elk River valley, range from medium- to high-volatile bituminous with volatile matter content ranging from a low of 27.5 per cent to a high of 36.2 per cent. The coals and lithostratigraphy of boreholes E.V. 1 to E.V. 4 have been studied in detail, analysed petrographically and chemically, and have been discussed and documented in a preliminary report by Graham et al. (1977). At Mist Mountain (Sec. 76-10), east of Elk River valley, the coals are higher in rank than those in the Elk River valley, ranging from predominantly low volatile bituminous to medium volatile bituminous.

In the Mount Allan and Bragg Creek areas farther to the north (Fig. 8), coal in the Mist Mountain Formation becomes less abundant, even in the thick western sections such as Mount Allan. As in the other areas to the south, the number of seams decreases from west to east. Locally, some seams may be thick with good economic potential, as in the Canmore area of Alberta. There, up to 14 seams have been recognized, some of which are up to 4.3 m thick (Norris, 1971). As in other areas to the south, coal in the Mist Mountain Formation of this area is bright, vitreous and commonly blocky, but is characterized by an unusually high rank, which ranges from predominantly semianthracite to low volatile bituminous. Volatile matter concentrations range from a low of 8.2 per cent to a high of 16.2 per cent. The seams in this area are noticeably higher in rank than those at all other section locations in the report area.

Figure 9 is the northernmost of the cross-sections transverse to the regional strike. It includes four measured sections from the area between Barrier Mountain, near the headwaters of Red Deer River on the west (Sec. 76-17), to the Gap Lake area, south of North Saskatchewan River, on the northeast (Sec. 77-5). A reduction in both the number and thickness of seams is again apparent in the area of Barrier Mountain, when compared with seams in the thicker western sections of the Mist Mountain Formation to the south (figs. 5-7). It can also be seen that coal is absent from the section at Limestone Mountain (Sec. 76-18), and may also be absent from the sections at Cutoff Creek (Sec. 77-3) and Gap Lake (Sec. 77-5). At the last two localities, the Mist Mountain Formation is characterized by large covered intervals, which may be underlain in part by coal, although no evidence was found to suggest its presence. Like the Mount Allan-Canmore area to the south, coal in the Mist Mountain Formation at Barrier Mountain was found to be generally high in rank, ranging from predominantly semianthracite to low volatile bituminous. The volatile matter content ranges from a low of 9.6 per cent to a high of 14.4 per cent.

In order to complete the discussion on the occurrence and distribution of coals in the Mist Mountain Formation, two longitudinal north-south cross-sections have been included, one linking the thinner, easternmost sections of the central and eastern segments of the Alberta Foothills (Fig. 10), and the other linking the thicker sections of the western Foothills and eastern Front Ranges of Alberta and British Columbia (Fig. 11). The latter cross-section includes a field section of the Nikanassin Formation at Wapiabi Creek, north of North Saskatchewan River. Coal in the Nikanassin is found only in the upper third of the formation, occurring as very thin seams of medium volatile bituminous rank.

Elk Formation

Elk strata, in contrast to those of the Mist Mountain Formation, are characterized by a conspicuous reduction in the number and thickness of coal seams. Seams rarely exceed 60 cm in thickness, and are commonly confined to the thicker western sections of the report area (figs. 5-11). For example, Figure 5 illustrates the distribution of coal in the Elk Formation of the Fernie Basin. As can be seen, the Elk Formation does not extend eastward into the Coleman-Blairmore area of Alberta. As in the case of the Mist Mountain Formation, the coal is vitreous to dull in lustre, and is mainly sheared and crushed, although blocky coal is found in some sections. Volatile matter content ranges from a low of 28.2 per cent to a high of 40.9 per cent in the few samples petrographically analysed. Most coal in the Elk of this area is high volatile bituminous although some medium volatile bituminous is present. In the Fernie Basin, most seams in the Elk are less than 60 cm thick, with exceptions at Marten Ridge (Sec. 75-12), where one seam is 1.2 m thick, and at Mount Taylor (Sec. 75-15), where one seam near the base of the Elk is 70 cm thick.

As noted previously, the Elk Formation is characterized in part by an unusual type of coal found mainly in the area of the Fernie Basin, but also recognized in isolated field exposures in the upper Elk River valley and at Mount Allan. The coal consists of a compacted mass of rod-like "needles", in beds which rarely exceed a thickness of 15 cm (Fig. 59). It is only found in the upper third of the Elk Formation. This unusual coal, first described by Newmarch (1953), is locally referred to as "Needle Coal". One sample from Sparwood Ridge (Sec. 75-8) was petrographically analysed and found to have a volatile matter content of 43 per cent, based on a mean maximum reflectance value of 0.58, thus classifying it as a high volatile bituminous coal. "Needle Coal", because of its distinctive appearance, can be used alone, or in combination with "Needle Siltstone" (previously discussed), to assist in identifying isolated exposures as belonging to the Elk Formation. In an earlier preliminary report, the writer (Gibson, 1977b) suggested that the "needles" may be of probable coniferous (gymnospermous) origin. Recent work by Kalkreuth (1982) and L.R. Snowdon of the Geological Survey (pers. comm., 1982) now suggests that, on the basis of petrographic and geochemical evidence (a high hydrogen to carbon ratio and n-alkane distribution), and examination by fluorescence microscopy (a high degree of fluorescence) the coal is of algal origin. Results of the geochemical study will be reported at a later date. Furthermore, Pearson and Grieve (1980) identified "Needle Coal" samples from the Fernie-Sparwood area of British Columbia to be rich in the liptite maceral, alginite.

In the Eagle Mountain area, north of the Fernie Basin (Sec. 75-19; Fig. 6), coal seams are present in the Elk Formation, but are thin and relatively uncommon, although at Eagle Mountain the Elk Formation is incomplete. "Needle Coal" was not observed in the section, although at adjacent localities in the area one may find additional coal seams, including possible "Needle Coal", in the upper 30 to 60 m of the formation. The few seams petrographically examined in the Eagle Mountain area, ranged in rank from high volatile 'B' bituminous near the top of the measured section, to a high volatile "A" bituminous near the base, with a volatile matter content ranging from 42 per cent to 36 per cent.

In the eastern part of the central Foothills area, coal in the Elk is rare. At Wilkinson Creek summit (Sec. 76-13; Fig. 6) for example, only four thin seams were recorded. In contrast to the coals found at Eagle Mountain, these are characterized by a higher rank and classed as medium volatile bituminous. Coal was not observed in Elk strata at the other two sections referred to in Figure 6.

In contrast to the Eagle Mountain area, coal is more common in the Elk Formation of the upper Elk River valley north of Elkford (Fig. 7). The seams in this area are generally thinner, as shown by boreholes E.V. 3 and E.V. 4, although one seam in borehole E.V. 4 is 2.1 m thick. The coal in the boreholes, like that in the Elk Formation at Eagle Mountain to the south, is low in rank and classified mainly as high volatile "B" bituminous, with a petrographically determined volatile matter content ranging from a low of 37 per cent to a high of 40.9 per cent. Additional data on the chemical and petrographic character of the coal in these boreholes has been documented in an earlier preliminary paper by Graham et al. (1977). In the Mist Mountain area to the east (secs. 76-10, 11) the seams again increase in rank, ranging in volatile matter content from a high of 34 per cent to a low of 24 per cent. Coal was not observed in the Highwood-Sentinel Ranger Station section. Only one section in the cross-section in Figure 8 displays coal in the Elk.

At Mount Allan (Sec. 76-7) coal is scarce. Most seams are less than 60 cm thick, although one seam attains a thickness of 1.5 m. "Needle Coal" was observed in a thin lenticular seam at the contact between the Elk Formation and overlying Pocaterra Creek Member of the Blairmore Group. Coals in both the Elk and Mist Mountain formations of this northern area are higher in rank than those of other regions in the report area. Reflectance analysis of the Elk coals at Mount Allan, by A.R. Cameron of the Geological Survey, indicate a volatile matter content ranging from 23.0 per cent to 16.3 per cent, thus indicating a rank of medium- to low-volatile bituminous.

At Barrier Mountain (Sec. 76-17; Fig. 9), the northernmost section locality where Elk strata have been identified, coal is rare and seams are generally thin, although again some exceptions may be found. One seam penetrated in a borehole during a coal assessment drilling program, by Meadowlark Farms Inc., was 2 m thick. The coal at Barrier Mountain, based on a few samples analysed for reflectance, had a volatile matter content ranging from a low of 14.1 per cent to a high of 17.6 per cent, thus indicating a low volatile bituminous rank, the highest average coal rank in the Elk Formation in the report area.

It can thus be seen, from the cross-sections of the Elk Formation, that coal in the Elk is generally thin, sporadic in occurrence, and generally of low rank. It is not, therefore, considered to be of economic value, especially when compared with the thick and generally more abundant coals in the underlying Mist Mountain Formation.

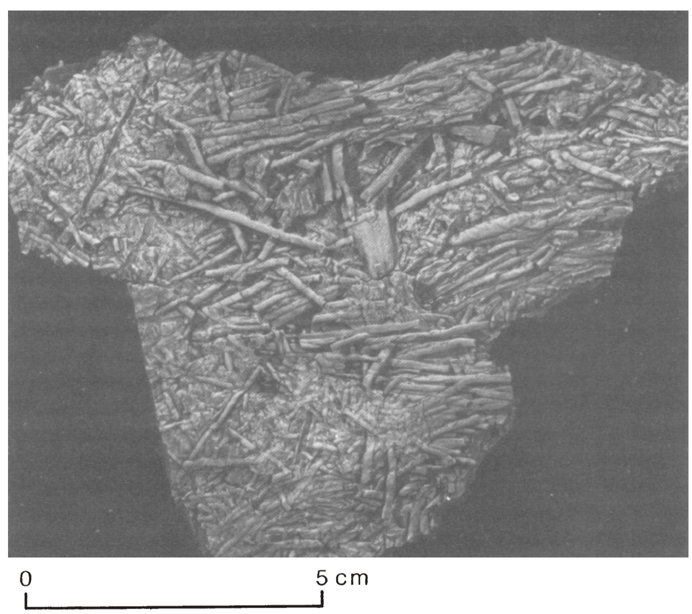


Figure 59. *"Needle Coal" from upper Elk Formation, Sparwood Ridge (Sec. 75-8). Scale in cm.*

PETROLOGY (DESCRIPTIVE MINERALOGY)

Little detailed information has been provided by other workers on the petrology of the Kootenay rock succession in the report area. Rapson (1964, 1965) described the lithology and petrography of the transitional rocks of the Lower Blairmore and upper Kootenay rock succession in part of the report area. Mellon (1967), in a study of the stratigraphy and petrology of the Blairmore and Mannville groups of the Alberta Foothills, provided some mineralogical information and data on strata equivalent to the upper Mist Mountain Formation of this report. Later, Jansa (1972) described the mineralogy and petrology of the Kootenay Formation (now Kootenay Group) in the Fernie, Crowsnest Pass, Canmore, and Panther River areas of British Columbia and Alberta. However, only a few field sections and samples were included in the study. Recently, Hamblin and Walker (1979), in a sedimentological study of the Kootenay-Fernie lithologic transition in Alberta and British Columbia, briefly documented some of the mineralogical, textural, and petrological features of the Morrissey and basal part of the Mist Mountain Formation. Thus, it can be seen that most petrological and mineralogical research to date has been directed mainly toward strata adjacent to the upper and lower Kootenay Group contacts, with only Jansa (*op. cit.*) providing information on the entire stratigraphic interval between.

The following discussion will, therefore, document the mineralogy of each member and formation of the Kootenay Group in all parts of the report area. Information and data are included on such features as the main lithotypes encountered, the composition and textural properties of the cement and matrix, the nature of the source rock and, where possible, suggestions are made as to the possible source rock area.

Thin sections were made from many field samples of rock from each member and formation. Examination of the thin sections indicated that, because of the secondary silicification common to many of the sandstones (which in many observations masked the textural relationships of the detrital components), and because of the compositional similarity between many of the chert grains and between rock fragments, point count analyses of the mineral components and lithic fragments would be difficult, probably unreliable, very time consuming, and of limited value in classifying the sample as to rock type. Instead, visual estimates were made using an A.G.I. Visual Estimation of Percentage Composition Chart (Terry and Chilingar, 1955).

X-ray diffraction analyses were also undertaken on many selected rock samples, which included, in addition to the sandstones, many siltstones, shales, and mudstones. These analyses were undertaken to identify clay, opaque minerals, and other submicroscopic minerals not readily detected during the microscope examination. The X-ray analyses also served to check the semi-quantitative mineral estimates made during the petrographic analyses.

For the petrographic phase of the investigation, the sedimentary rock classification of Folk (1968) was adopted.

Weary Ridge Member (Morrissey Formation)

Chert

Chert in the Weary Ridge Member occurs mainly as a lithic detrital component, composed of an interlocking mosaic of randomly oriented quartz crystallites up to approximately five microns in diameter. It differs from polycrystalline quartz, which is also present, because of a conspicuous increase in the concentration and reduction in size of its constituent quartz crystallites. Chalcedonic chert, in contrast, consists of grains composed of radiating or sheaf-like bundles of quartz fibres. Crystal size within the chert grains is variable, ranging from very finely crystalline to microcrystalline, and to microcryptocrystalline in some grains. The microcryptocrystalline grains appear isotropic in thin section. Some chert grains, in which crystal size is large, are difficult to distinguish from polycrystalline quartz and accordingly may be classified as such in some instances.

Chert is a conspicuous component of the Weary Ridge Member (figs. 60, 61), although its concentration appears to be dependant on the average detrital grain size of the rock sample under investigation. For example, the coarser grained sandstones contain a conspicuously greater concentration of detrital chert than the finer grained sandstones. This

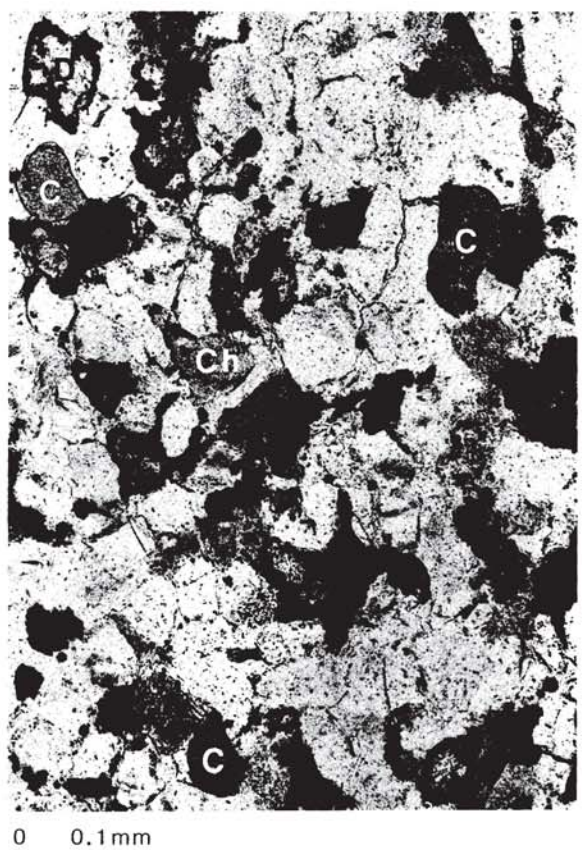


Figure 60. *Subangular to well rounded grains of quartz and chert, with some collophane and subhedral crystals of dolomite coated by opaque ferruginous (limonitic?) and organic carbonaceous matter. Cement mainly quartz, minor chert and rare carbonate. Weary Ridge Member (Sec. 76-15). Collophane (C); Dolomite (D); Chert (Ch). Bar scale 0.1 mm.*

textural-compositional relationship also occurs in other members of formations of the Kootenay Group, and was also observed by Rapson (1964, 1965) and Mellon (1967) in strata of both the Kootenay and Blairmore groups. Relative to quartz, chert is uncommon in the siltstones and finer grained sandstones of the Weary Ridge Member. The concentration of chert ranges from less than five per cent by volume in the very fine grained sandstones to an estimated maximum of 60 per cent in the coarser grained sandstone (in a sample from Coal Creek).

In hand specimens, because of the generally fine grain size of the sandstone, chert is not always evident. When discernible it is light to dark grey. In thin section, most chert is brown, the colour intensity apparently dependant on the concentration of phosphate (collophane) or carbonaceous matter; with increasing concentrations of these constituents the chert becomes progressively darker brown, so that some of the very phosphatic grains of chert appear isotropic under crossed nicols. Some grains contain grey to brown clay minerals, silt- and sand-sized grains of quartz, brown to opaque carbonaceous matter, and/or small rhombic crystals of dolomite, in varying concentrations. Spicular chert is also present but rare in comparison to that found in the rest of the Kootenay Group. Spicular chert was observed at Greenhills (<1%, Sec. 75-17), and at Barrier Mountain (Sec. 76-17). It was not observed in samples from the type section at Weary Ridge (Sec. 76-15). Most chert grains are angular, although in some samples they may be rounded. The textural relationships between grains in most samples is masked by quartz and minor chert cement or secondary quartz overgrowths (figs. 60, 61).

Figure 61. *Same thin section as Figure 60; crossed nicols.*

Chert is most abundant in samples from the Fernie Basin area, particularly along the western margin adjacent to Elk River valley. In the samples examined, chert content decreases eastward and northward, and chert is not common in samples from the eastern part of the Foothills of Alberta. The decrease may, however, be correlated with the decrease in average grain size of the detrital grains eastward in the report area.

Rare grains of brownish grey, chalcedonic chert were observed in some samples. The brown colouration of the grains is probably a result of submicroscopic air bubbles in the quartz (Folk and Weaver, 1952).

Quartz

Quartz is the most conspicuous of the major detrital components in the Weary Ridge Member. The concentration ranges from a low of 35 per cent to a high of 98 per cent by volume, with the latter value found in samples from Bragg Creek (Sec. 76-19) and Ridge Creek (Sec. 76-3) in the Foothills. Most quartz is inclusion free, although rutile "needles", small elongate crystals of apatite, and small vacuoles characterize some grains. Boehm lamellae or strain shadows were also noted in some grains (see Fig. 64). These grains are slightly brown in colour. Extinction ranges from predominantly non-undulatory (rotation of less than 5°) to slightly undulose, although grains displaying strain shadows are strongly undulose. The predominance of grains displaying a relatively low degree of undulose extinction suggests that much of the original quartz was of plutonic origin. Grain to grain contact ranges from concavo-convex, common in the finer grain sizes, to stylolitic, a feature found in many of the coarser grain sizes and in many samples of quartz arenite. Polycrystalline quartz is present but rare.

Quartz also forms the predominant cement of the member, resulting in a well developed quartzitic texture, a property characteristic of most sandstones in the Kootenay Group. The quartz cement occurs as subhedral to euhedral overgrowths on many grains (Fig. 60). The quartzitic texture commonly masks the original textural relationships between grains, especially in the absence of a "dust" rim. Fortunately, in most thin sections, grain boundaries are generally visible because of the presence of a thin "dust" rim. The grains are commonly well rounded to subrounded, and range in size from medium- to coarse-silt (0.03-0.65 mm) to medium grained sand, with the coarsest grains up to 0.55 mm in diameter. Sorting of the quartz grains ranges from poor to good.

Lithic grains (exclusive of chert and carbonate)

Lithic grains do not form a common component of the Weary Ridge Member. They were never observed to exceed a concentration of one per cent by volume of the total mineralogy. Four types were noted, the most common being a brown, faintly laminated, silicified argillite-mudstone, which in many samples is semi-opaque. The brown colour is interpreted to be the result of a relatively high concentration of ferruginous and/or organic carbonaceous matter, some of which is in the form of small crystals or grains of pyrite. Another lithic type consists of quartz sandstone grains with a light brown, carbonaceous-phosphatic cement. These were observed only in samples from the Greenhills (Sec. 75-17) and Cabin Ridge (Sec. 76-2) localities. Angular to subangular grains of quartz siltstone, containing a cement and matrix composed of medium to light brown, carbonaceous-clay-ferruginous matter, and rare grains of subangular, clean, fine grained quartz arenite comprise the remaining lithic grains.

Carbonate minerals

Although present in most samples of the Weary Ridge Member, carbonate minerals were rarely found to exceed five per cent by volume of the total mineralogy and, therefore, do not volumetrically comprise a significant mineralogical component of the member. Earlier in this report, it was noted that carbonate minerals in the Weary Ridge Member serve as an aid in differentiating the sandstones of the Weary Ridge Member from those in the overlying Moose Mountain Member. Sandstones in the latter member were not observed to contain carbonate minerals.

The carbonate minerals occur as angular to well rounded, sand-sized grains of calcite and dolomite, or most conspicuously as authigenic, euhedral, rhombic crystals of dolomite displaying well developed, zoned overgrowths (Fig. 60). Carbonate also occurs rarely as cement and matrix. Siderite was identified by X-ray analysis, but was not readily apparent in thin section. Subrounded grains, up to 0.14 mm in diameter, of sucrosic dolomite were observed in thin sections from Barrier Mountain (Sec. 76-17). The concentration of dolomite in these samples was estimated to be 10 per cent, although some of the carbonate occurred as cement and matrix.

X-ray analysis of a sandstone sample from the type section at Weary Ridge (Sec. 76-15) indicated a total carbonate concentration of five per cent. The carbonate consists mainly of euhedral rhombs of dolomite (3%), sucrosic grains of calcite or limestone (1%), and siderite (1%).

Carbonate minerals were not observed in thin sections of samples from Greenhills (Sec. 75-17), Bragg Creek (Sec. 76-19), Ridge Creek (Sec. 76-3), or Cabin Ridge (Sec. 76-2).

Clay minerals

Clay minerals, comprising kaolinite, chlorite, and illite are ubiquitous in all samples of the Weary Ridge Member, although, like the carbonate minerals, they rarely exceed five per cent of the total mineral concentration. Identification of the clays was mainly by X-ray diffraction, although some clays could be recognized and identified in thin section. Most clay minerals, however, are difficult to differentiate from chert in thin sections, because both display a similar birefringence. Some of the clay minerals identified in samples by X-ray analysis may include clay minerals contained within the lithic grains of argillite or mudstone, so that the analysis may be contaminated and the results may not be representative of the authigenic or detrital cement or matrix material of the sandstone sample.

The most common clay mineral association is that of kaolinite-chlorite, with kaolinite the more common of the two. Examination of several thin sections indicates a random presence of flakes or grains of a green, micaceous mineral, which is identified as chlorite. The kaolinite-chlorite association appears to occur mainly as part of the matrix and cement of the samples analysed. Some of the quartz grains are rimmed by a thin layer of clay with the optical properties of kaolinite. The clay is conspicuous because of its light brown colour and low birefringence. Illite, although not identified in thin section, was detected in most X-ray samples, but did not exceed one per cent of the total mineral concentration in the analysed samples.

Because of the occurrence of clay in some of the grains of chert, argillite or mudstone, the concentration estimates by X-ray diffraction may not accurately represent the total layered silicate mineral concentration in the cement and matrix of the sandstone samples analysed. However, because of the low concentration of these detrital argillaceous grains, the clay content from detrital grains in terms of the total analysis is considered to be negligible.

Opaque constituents

The opaque constituents, comprising mainly carbonaceous matter, and the less common ferruginous minerals such as pyrite, magnetite, hematite, and probable limonite, are quantitatively insignificant compared to the total mineralogy of the member (figs. 60, 61). Dark brown to black, comminuted, carbonaceous plant matter is the most conspicuous of the opaque components. It occurs disseminated throughout the sandstones, in places forming thin, regular to wavy laminations. The ferruginous minerals, along with the carbonaceous matter and clay minerals, produce the brown colour, and the less well-indurated and recessive weathering character of the member. Only pyrite was detected by X-ray analysis in some samples. The other ferruginous minerals were not detected because of low concentration (<1%), or because the mineral is amorphous or too finely crystalline to be detected.

Miscellaneous minerals

The miscellaneous minerals form a ubiquitous but quantitatively insignificant mineral component, rarely exceeding one per cent by volume of the total mineralogy. They include the common "heavy" minerals such as zircon, rutile, apatite, tourmaline, sphene, and rare feldspar. Collophane, a cryptocrystalline form of apatite, forms the predominant mineral of the group, occurring as well rounded grains up to 0.21 mm in diameter (Fig. 60), as cement in some of the detrital rock fragments, and as an authigenic replacement of probable carbonate grains. Some collophane grains look pelletal, but these may actually be large pollen spores. The collophane is not as common in samples of the Weary Ridge Member as in samples from other formations or members of the Kootenay Group. Tourmaline, zircon, rutile, apatite, and sphene occur as trace concentrations (<1%). The tourmaline is mainly green and strongly pleochroic. Zircon is relatively common and readily identifiable because of its conspicuous high relief and birefringence. Rutile and sphene, both of which are yellow, are rare. The apatite, exclusive of collophane, occurs as subhedral, clear crystals, or as elongate inclusions in some quartz grains. Plagioclase feldspar, with distinctive albite twinning, was observed as rare, small, subangular grains in three thin sections. Orthoclase feldspar was not identified in thin section, but was detected by X-ray analysis in a sample from the type section on Weary Ridge (Sec. 76-15).

Lithology

Based on the above mineralogy, strata of the Weary Ridge Member can be grouped into three main lithotypes according to the classification of Folk (1974). They are, in order of decreasing abundance: lithic arenite; sublitharenite; and rare quartz arenite. The detrital components consist mainly of quartz and chert with lesser concentrations of argillite, mudstone, sandstone, siltstone, and carbonate. Grain sizes range mainly from fine- to very fine-grained, with one sample from Line Creek (Sec. 76-16) classified as medium grained lithic arenite.

Moose Mountain Member (Morrissey Formation)

Chert

Chert is the most conspicuous detrital component of the Moose Mountain Member, comprising up to 75 per cent of the total mineralogy in some of the coarse grained and conglomeratic samples. In the fine- to medium-grained sandstones, quartz commonly exceeds the concentration of chert by 10 to 25 per cent in most samples analysed. The chert ranges from subangular to well rounded, depending on grain size (figs. 62, 63). The coarser the grain size the greater the degree of rounding of the chert, such that very coarse grains and pebbles are well rounded. Colour ranges from predominant shades of brown to shades of grey, with light grey the most common. Brown chert comprises over 75 per cent of the chert in the samples, ranging from light to dark brown and semi-opaque. The brown colour is due mainly to the presence of collophane (a cryptocrystalline, isotropic, varietal mineral of the apatite group) and, to a lesser degree, organic, carbonaceous and ferruginous matter. Some grains of chert are so phosphatic that they appear isotropic under crossed nicols, and may be mistakenly identified as silicified phosphate in some cases. Most chert is microcrystalline, although in some grains the crystallinity is almost submicroscopic, so that the chert appears isotropic. Chalcedonic chert, with its fibrous, sheaf-like bundles, is present but rare. Most chalcedonic grains are angular and under plane polarized light are very light brown.

Other varieties of chert include spicular chert in angular to subrounded grains, which consist of a densely compacted mass of elongate or ovoid spicules. In some grains it is difficult to differentiate spicular chert from spherulitic chert, when the former is cut perpendicular to the length of the spicule. However, in most spicular chert grains the double wall structure of the spicule is usually visible (Fig. 70). This structure is not present in the spherulites. Spherulitic chert was identified in samples from Line Creek (Sec. 76-16). Spicular chert, like that observed in the sandstones of the underlying Weary Ridge Member, is not common, never exceeding one per cent of the total chert concentration. Most spicular grains are phosphatic.

The concentration of detrital chert displays a noticeable reduction in the Limestone Mountain (Sec. 76-18) and Cabin Creek (Sec. 75-18) areas, where it ranges from 5 to 25 per cent by volume of the total mineralogy. The sandstones of the member in these areas are commonly finer grained compared to those in most other areas and, consequently, the reduction in chert concentration may be related to the decrease in average detrital grain size of the sandstone; and not related to a regional decrease in concentration because of distance from sediment source or provenance area.

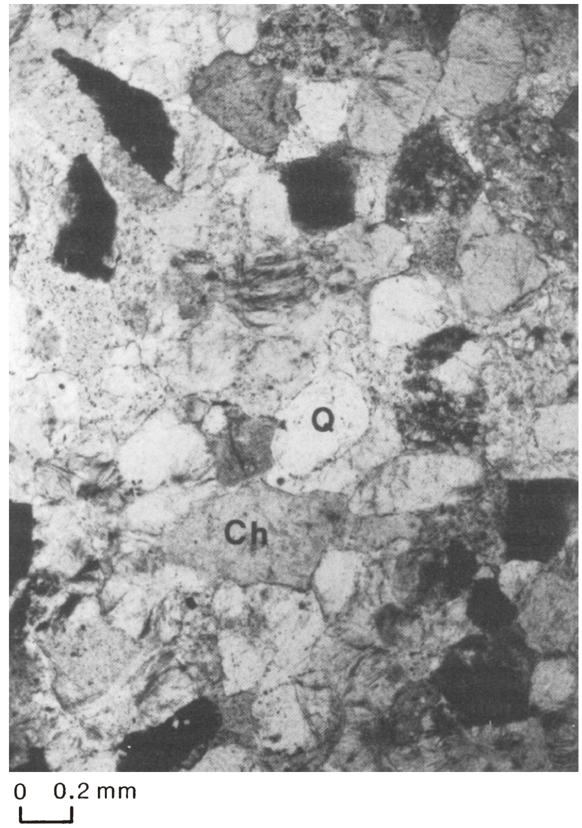
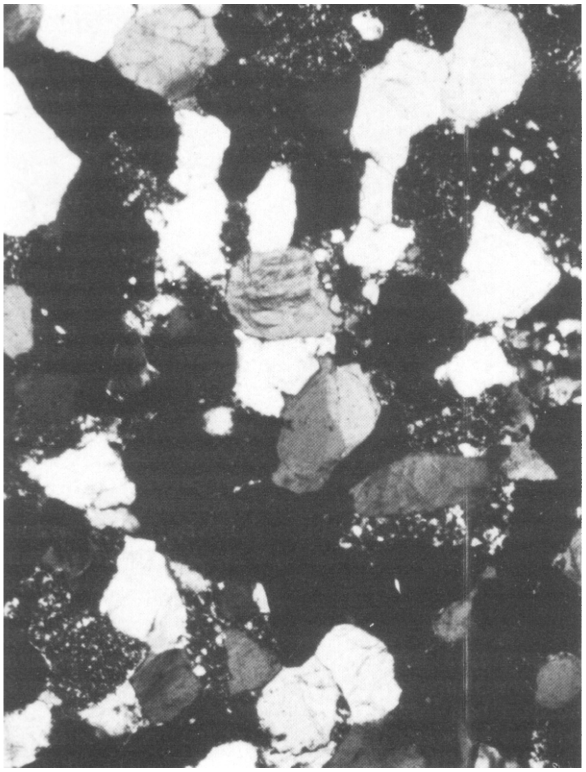


Figure 62. *Moose Mountain Member sandstone. Subangular to well rounded grains of quartz and chert, displaying silica overgrowths. Semi-opaque to opaque grains consist of silicified mudstone and siltstone. Note strain shadows or Boehm lamellae in grains of quartz. Coal Creek Mountain (Loc. 75-16). Chert (Ch); Quartz (Q). Bar scale 0.2 mm.*

Chert was not observed as either cement or matrix in the member.

Quartz

As in the case of the Weary Ridge Member, the most abundant detrital mineral constituent of the Moose Mountain Member sediments is quartz, which volumetrically ranges in concentration from 35 per cent to slightly in excess of 95 per cent of the total mineralogy. Sandstones composed almost exclusively of quartz were observed at Flathead Ridge, Limestone Mountain, and section localities between Limestone Mountain and North Saskatchewan River (figs. 64, 65, 66, 67). Like the chert, quartz ranges from predominantly fine and medium grained to lesser coarse



0 0.2 mm

Figure 63. *Same thin section as Figure 62. Note siltstone lithic grains on right side of photomicrograph; crossed nicols.*

grained and least commonly silt-sized grains. Most grains are subangular to angular (figs. 62, 63, 66, 67), although many are conspicuously subrounded to well rounded. Many grains are characterized by a thin "dust" rim of reddish-brown iron staining, or clay minerals, or small opaque iron minerals; or liquid(?), bubble-like inclusions between the grain and the cement; or secondary silica overgrowths (figs. 64, 65).

Most sandstones of the Moose Mountain Member have been extensively silicified, resulting in a "welded" or quartzitic texture, a feature common to all sandstones of the Kootenay Group (figs. 66, 67). When using a standard petrographic microscope, the quartzitic texture commonly makes it difficult to visually differentiate individual grains from cement or secondary overgrowth, especially in the absence of a "dust" rim. The degree of angularity of the actual grain boundary is masked by the quartz cement and/or secondary overgrowth. Consequently, while most grains appear angular (figs. 66, 67), they may in fact be subrounded to well rounded. Alternatively, the majority of the grains may in actual fact be angular. The occurrence of a relatively high proportion of angular chert grains in the sandstone, along with the quartz, supports this conclusion. The occurrence of angular grains suggests a nearby sediment source; an area where the distance of detrital transport has been minimal or insufficient to round the grains. The conspicuous, well rounded to subrounded grains (figs. 64, 65), with the "dust" rims noted above, may represent recycled material, derived from an older, mature, quartzitic sandstone, composed of well rounded grains of quartz with a silica or quartz cement. In one sample from Ridge Creek (Sec. 76-3; Fig. 3), most quartz grains appear angular, although, within the same sample, some well rounded grains with thin "dust" rims were also noted. The sample is characterized by a well developed "welded" texture. This association suggests therefore, that many, if not most, grains are angular to subangular.

Where discernible, the contact between grains is mainly concavo-convex (Fig. 67). In the coarse grained and conglomeratic samples (Line Creek, Sec. 76-16; Cat Mountain, Sec. 75-13) many grains display stylolitic contacts, especially where quartz is in contact with chert (see Fig. 70). The occurrence of the sutured or stylolitic contacts indicates that the strata have been subjected to pressure, resulting in the release of excess silica. This excess silica would thus serve as a major source of silica for much of the secondary silicification characteristic of the member, and consequent development of the quartzitic or "welded" texture.

Most quartz displays regular to undulatory extinction (greater than 5° rotation), and contains authigenic inclusions of apatite, carbonate, and acicular crystals of rutile. The occurrence of regular extinction, and the presence of acicular "needles" of rutile in some of the grains, suggest that some or most of the quartz may be of plutonic origin (Blatt et al., 1972). In contrast, the grains displaying undulatory extinction may originally have been derived from a region of low rank metamorphic rocks (Basu et al., 1975). Recent research has, however, demonstrated that inclusions and the presence or absence of undulatory extinction in quartz grains must be treated with caution, when used as a means of determining the genesis of detrital quartz (Blatt and Christie, 1963; Blatt, 1967; Anderson and Picard, 1971). Undulatory extinction in quartz may also result from post depositional (post-Kootenay) tectonism, as was suggested by Mellon (1967) for quartz grains in strata of the overlying Blairmore Group. Some grains were characterized by strain shadows or Boehm lamellae, a property also resulting from post depositional tectonic stress (Moorhouse, 1959, p. 441).

In the Moose Mountain Member, polycrystalline quartz is present but not abundant, occurring in concentrations of less than one per cent. The grains are subrounded, inclusion free, and commonly display well developed quartz overgrowths. Most grains are composed of three or four randomly oriented crystallites or "grains". Because of their textural similarity to grains of metamorphic quartzite, some may have been interpreted as being of probable metamorphic origin by Rapson (1964) and Jansa (1972). The writer, however, interprets them to be of sedimentary rock origin, a product of a former vug or cavity filling. Individual "grains", or crystallites, do not display any degree of preferred orientation, which one might expect if the polycrystalline grain were of metamorphic origin.

The average detrital grain size of the quartz in the Moose Mountain Member is conspicuously larger than the average size of quartz grains in the underlying Weary Ridge Member.

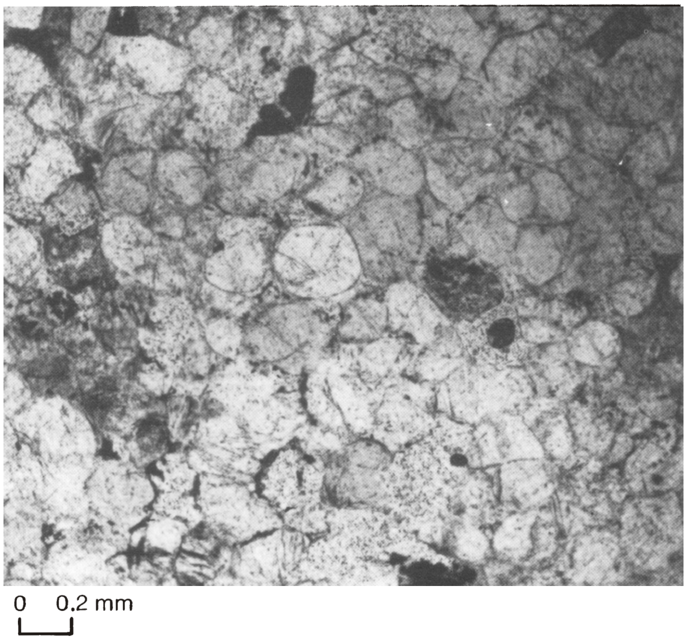


Figure 64. *Well sorted quartz arenite (orthoquartzite) of Moose Mountain Member. Note well rounded grains of quartz outlined in part by semi-opaque ferruginous rims, silica overgrowths and cement, and absence of carbonate grains. Flathead Ridge Pipeline (Sec. 75-6). Bar scale 0.2 mm.*

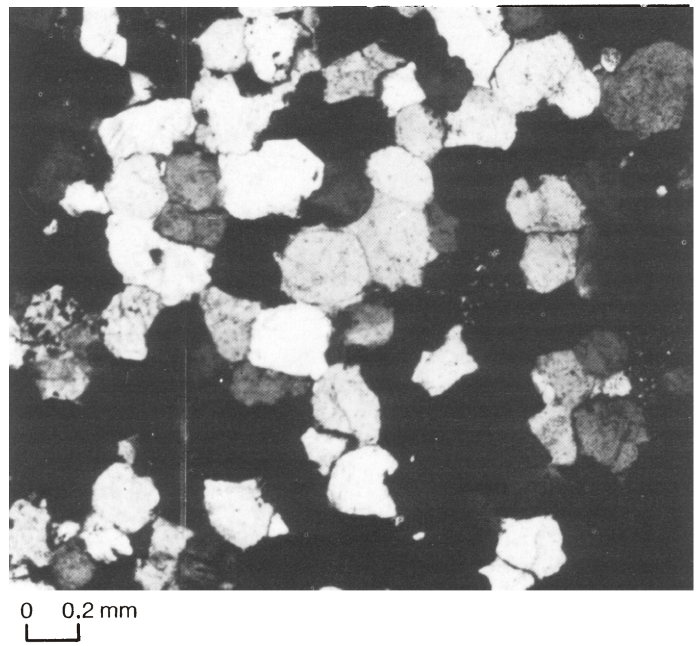


Figure 65. *Same thin section as Figure 64; crossed nicols.*

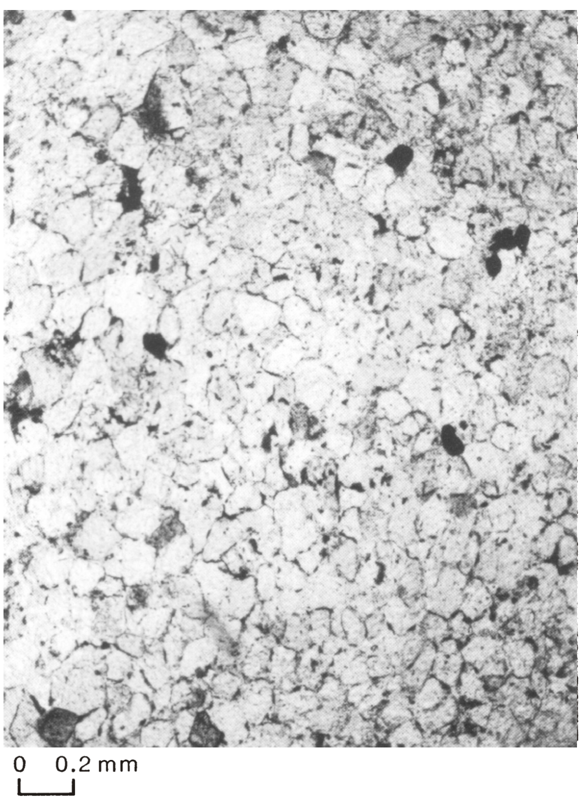


Figure 66. *Quartzitic texture in sandstone of Morrissey Formation at Limestone Mountain (Sec. 76-18), illustrating "welded" and subangular nature of quartz grains. Note semi-opaque ferruginous rim on many grains and conspicuous absence of chert. Bar scale 0.2 mm.*

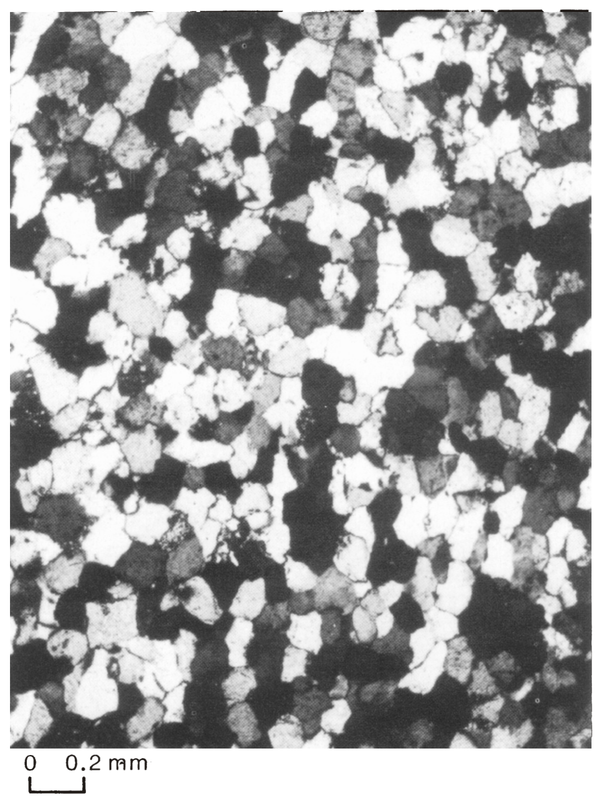


Figure 67. *Same thin section as Figure 66. Note "welded" nature of grain contact; crossed nicols.*

Lithic grains (exclusive of chert and carbonate)

Three main types were observed, none of which combined to exceed five per cent of the total detrital mineralogy. The concentration in most samples ranged between one and two per cent by volume. Angular to subrounded grains of light brown, argillaceous-ferruginous-phosphatic quartz sandstone and siltstone are most common. The cement and matrix of these grains consist mainly of a mixture of brown, phosphatic-ferruginous chert. These grains were most evident in the thicker, more westerly sections of the area (Fig. 63), and were generally rare to absent in the cleaner sandstones in the thinner eastern sections such as Limestone Mountain (Fig. 66). Brown, semi-opaque to opaque, siliceous argillite-mudstone grains were noted in all samples. They ranged from predominantly angular to, less commonly, well rounded. Some contained small, silt-sized grains of clear quartz, opaque crystals of probable pyrite, and rare spicules or spherulites of chert. The last of the noteworthy lithic grains consist of subangular to subrounded grains of quartz arenite and quartz siltstone. These grains are clear, inclusion free and cemented by quartz. They were most conspicuous in samples from the Greenhills area of Elk River valley (figs. 62, 63).

Clay minerals

Clay minerals are not common and, like those in most samples of the Kootenay Group, were identified by X-ray diffraction analysis. However, in a few samples, kaolinite, some chlorite, and possible glauconite were identified using a standard petrographic microscope. A grain of muscovite was identified in one sample. Clay minerals are confined mainly to the interstices between some of the detrital grains, or occur as a thin "rind", mixed with ferruginous and/or carbonaceous matter, coating some of the well rounded quartz grains; a feature also noted for some of the quartz in the underlying Weary Ridge Member. The most common clays detected were kaolinite and chlorite. Semi-quantitative estimates, using X-ray diffraction patterns, indicated a combined concentration not exceeding three per cent of the total mineralogy. Green chlorite and/or glauconite are ubiquitously distributed throughout the samples but in trace amounts. Illite was not observed in thin sections or detected by X-ray analysis.

Opaque constituents

The opaque constituents are readily evident but quantitatively are insignificant. In most samples they consist of dark brown to almost black, carbonaceous plant material, which occurs interspersed in the cement, or as thin, regular to wavy laminations. In some samples small authigenic crystals of pyrite were noted. During X-ray analysis, ferruginous minerals such as pyrite were not detected, suggesting that most of the obvious opaque material is comminuted plant debris. It should be noted, however, that some of the ferruginous minerals or other opaque mineral matter may be noncrystalline, or microcrystalline to submicroscopic, or, alternatively, may not be present in sufficient concentration to be detected.

Miscellaneous minerals

With the exception of collophane, miscellaneous minerals are not common in the Moose Mountain Member. Although never exceeding one per cent of the total mineralogy, collophane is a ubiquitous component in the sandstone, occurring as well rounded grains – up to 0.24 mm in diameter – or less commonly as small pellets. Most grains contain semi-opaque to opaque ferruginous-carbonaceous inclusions such as pyrite and plant matter. Some collophane grains contain a high concentration of chert as cement, as well as detrital silt-sized grains of quartz. Other minerals include rare plagioclase feldspar, and very rare, pale yellow, subhedral to euhedral crystals of sphene or titanite, observed in a sample from Weary Ridge (Sec. 76-15). Other common "heavy" minerals such as tourmaline, rutile, and zircon were not observed in any of the samples examined. Their absence may serve as a diagnostic mineralogical feature of the Moose Mountain Member.

Lithology

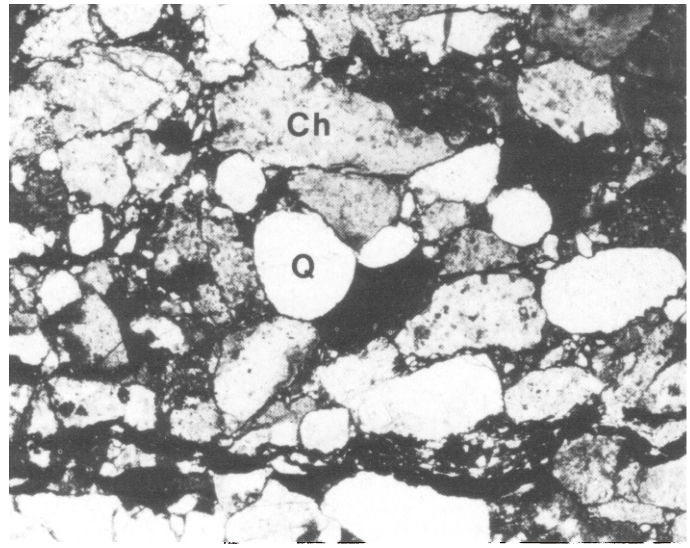
Based on the occurrence and concentration of the detrital components and cement described above, three main lithotypes dominate the member. All are sandstones, which in order of decreasing abundance are: chert lithic arenite; quartz arenite; and chert sublitharenite (Folk, 1968, 1974). The chert lithic arenite constitutes an estimated 95 per cent of the lithology. It is light grey, free of vegetal matter, well indurated, and displays the prominent quartzitic texture previously discussed. The quartz arenite is found mainly at sections between Limestone Mountain (Sec. 76-18) and North Saskatchewan River (figs. 64, 66), and at Flathead Ridge (Sec. 75-6). As noted previously, sandstone in the Limestone Mountain - North Saskatchewan River area is finer grained than sandstone elsewhere in the report area and, accordingly, may lack chert because of the average decrease in detrital grain size, rather than geographic location in the report area. Carbonate minerals were not observed or detected by X-ray analysis in any of the samples. Matrix minerals are rare, or have been replaced or assimilated into the silica cement. However, one sample from the Sentinel-Highwood Ranger Station area (Sec. 76-5) was characterized by a matrix concentration of approximately 15 per cent. The matrix consists of small angular grains of quartz, some chert, and lithic rock fragments. The sample was classified as a chert sublitharenite.

Mist Mountain Formation

Chert

Chert in the Mist Mountain Formation is similar in appearance and concentration to that described from samples of the underlying Moose Mountain Member. It comprises the second most abundant detrital component in the Formation, forming up to 75 per cent of the detrital framework in some of the conglomerate and coarse grained sandstones (figs. 68, 69, 70, 71, 72). In contrast, it rarely exceeds 25 per cent of the detrital components in the finer grained sandstones and siltstones (figs. 73, 74). The most common variety of chert is brown in colour and contains a variable concentration of phosphatic, organic, and ferruginous matter. Next in abundance is chert containing "floating" silt- and sand-sized grains of quartz (figs. 68, 69, 70, 71); followed by a variety of chert containing small rhombic crystals and patches of dolomite; inclusion free grains of light grey chert; and lastly spicular chert. The spicular chert is composed of a compacted mass of spicules and is found in the coarse grained sandstones and conglomerates, especially those in the thicker western sections near or adjacent to Elk River valley (figs. 70, 71, 72). The largest concentration of spicular chert was noted in samples from the area of the Fernie Basin, where chert-pebble conglomerate is a conspicuous lithotype in the Mist Mountain Formation. Fibrous chalcedonic grains were also observed, but occur only in trace concentrations of less than one per cent. Many of the chert clasts containing phosphate, especially those from the pebble conglomerates, are characterized by well rounded sand- and silt-sized grains of collophane and phosphate pellets.

Detrital chert appears angular, especially in samples from the finer grained sandstones and siltstones (figs. 68, 69). In the coarse grained sandstones and conglomerates, however, it is mainly subrounded to well rounded. Grain to grain contacts range from concavo-convex to stylolitic (figs. 68-72). Chert also occurs as a cement and matrix component in some sandstones and siltstones of the formation (figs. 73, 74). It ranges from colourless to various shades of brown, permeated and stained by brown, organic, carbonaceous or ferruginous matter such as hematite, limonite, or possibly pyrite. Clay minerals are commonly mixed with the chert cement and, as a result, make recognition and identification difficult in thin sections. Both chert and quartz in part form a "welded" or quartzitic texture, which is best developed in the finer grained sandstones and siltstones.



0 0.2 mm

Figure 68. *Subangular to well rounded grains of chert and quartz in a matrix and cement of predominant chert. Cement permeated and stained by semi-opaque carbonaceous matter. Note sutured nature of some grain contacts. Sorting moderate. Chert grains larger than quartz. Mist Mountain Formation at Trap Creek (Sec. 76-12). Quartz (Q); Chert (Ch). Bar scale 0.2 mm.*

Quartz

Quartz is the most abundant mineral in the Mist Mountain Formation. As previously noted, however, the concentration relative to chert appears to be a function of the average detrital grain size. The finer the average grain size of the sample, the higher the concentration of quartz. In some sandstones, especially those in the Limestone Mountain and North Saskatchewan River area, the concentration of quartz exceeds 95 per cent of the mineral components, so that these sandstones are classified as quartz arenites (figs. 75, 76).

Most grains are angular to well rounded, and the latter, where discernible, are characterized by "dust" rims (figs. 75, 76). The angular grains display silica overgrowths that are in optical continuity with the parent grain (figs. 73, 74). Because of the secondary silicification and secondary overgrowths, it is generally not possible to determine the percentage of detrital quartz grains using standard petrographic microscope techniques. As noted previously, many if not most of the detrital quartz grains are angular to subangular, suggesting, therefore, a relatively short distance of sediment transport from the source area. In some samples, conspicuous, well rounded quartz grains occur with the angular grains; all of which display secondary silicification in the form of a "welded" or quartzitic texture (figs. 75, 76). Most well rounded grains displaying "dust" rims are interpreted to have been secondarily derived from an earlier, mature, quartz arenitic sandstone.

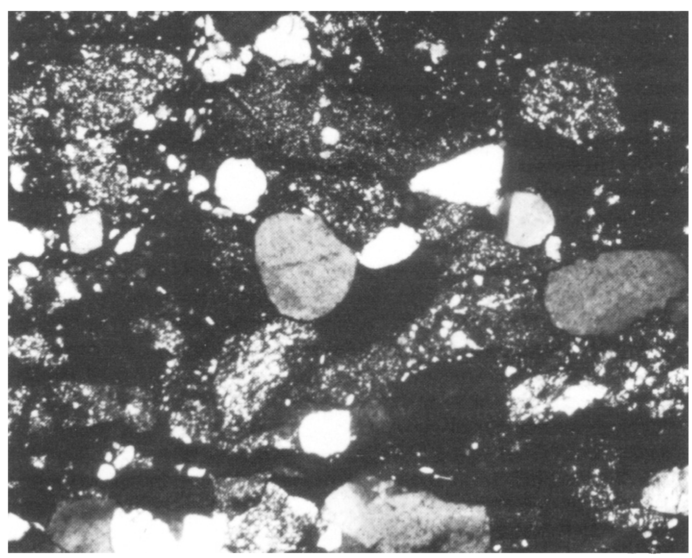


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Figure 69. *Same thin section as Figure 68; crossed nicols.*

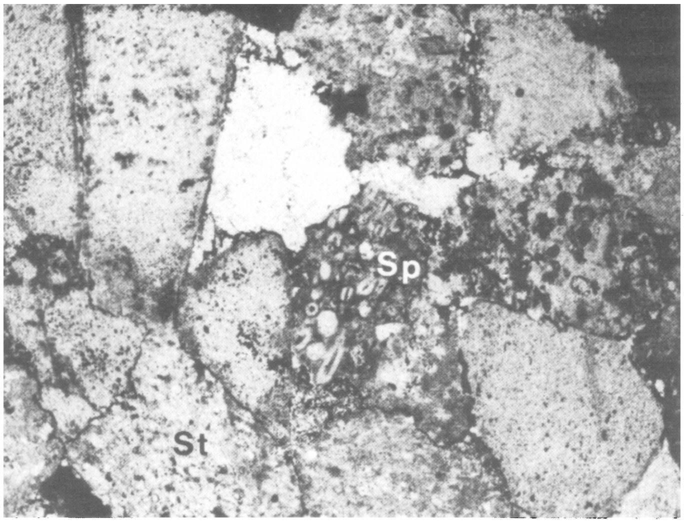

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Figure 70. *Coarse grained chert litharenite in Mist Mountain Formation at Weary Ridge (Sec. 76-15). Note subangular "welded" nature of grains, and occurrence of spicules in centre of photo. Coarser grained sandstones, composed predominantly of chert. Silicified siltstone grain on lower left side of photo. Spicules (Sp); Siltstone (St). Bar scale 0.5 mm.*

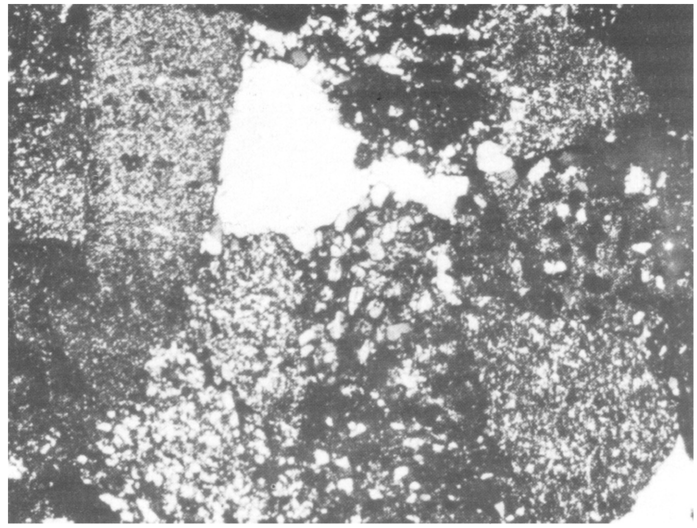

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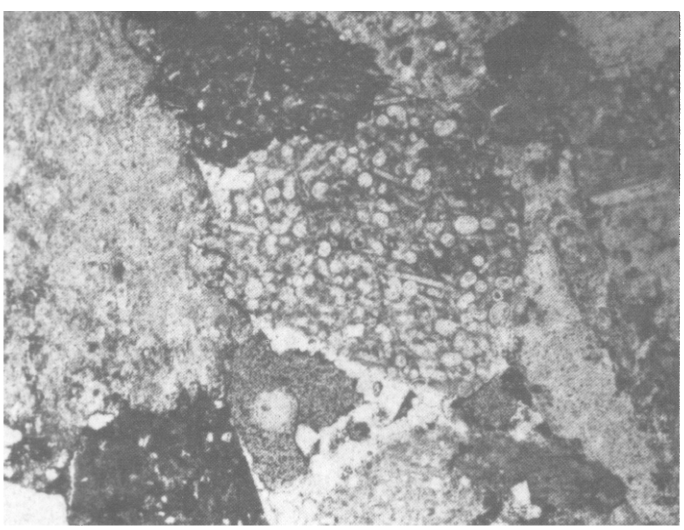
Figure 71. *Same thin section as Figure 70; crossed nicols.*



0 0.5 mm

Figure 72. *Chert-granule conglomerate in Mist Mountain Formation near Coal Creek, Fernie (Sec. 75-16), illustrating spicular grains and granules of chert with well developed sutured grain contacts. Small vugs in lower centre lined with small crystals of quartz. Bar scale 0.5 mm.*

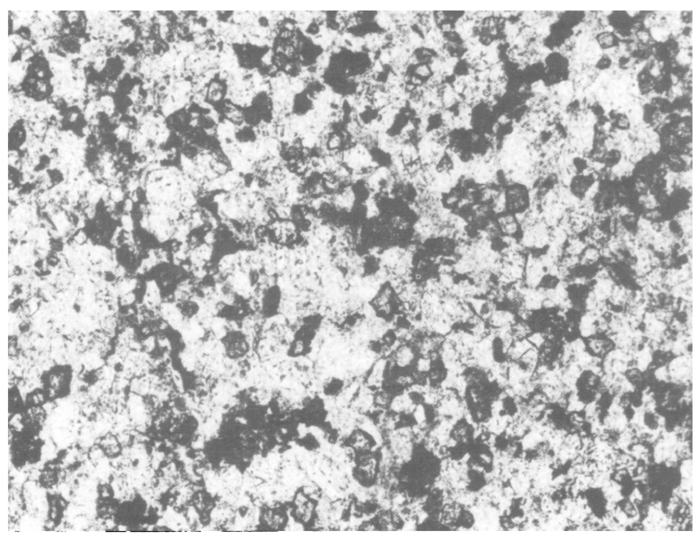


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Figure 73. *Calcareous, quartz siltstone of Mist Mountain Formation at Sparwood Ridge (Sec. 75-8). Angular to subangular grains of quartz in matrix and cement of calcite and chert. Note ferruginous-rimmed subhedral to euhedral rhombs of dolomite. Bar scale 0.1 mm.*

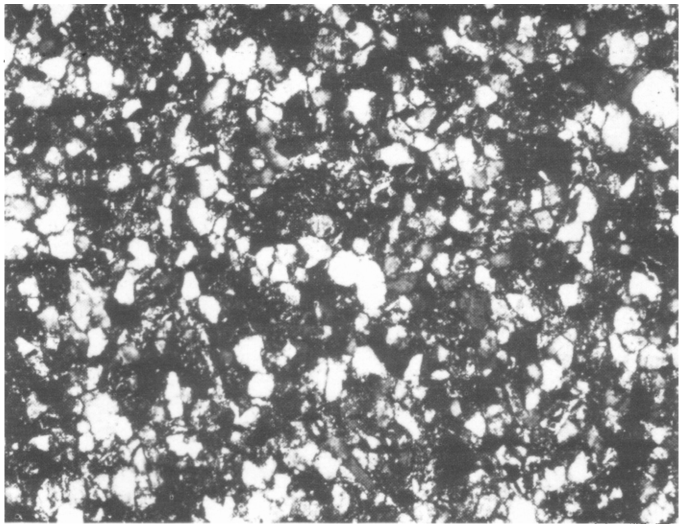


Figure 74. *Same thin section as Figure 73; crossed nicols.*

Quartz also occurs as isolated, "floating", or carbonate-supported grains in a cement and matrix of dolomite and calcite, in some samples of dolostone and rare limestone. These grains are mainly silt-sized, angular, and commonly display serrated or corroded grain boundaries, the result of solution or replacement by dolomite or calcite. Quartz also occurs as "welded" clumps or patches, composed of an interlocking mosaic of silt- to sand-sized angular grains in some of the minor and local dolostone strata. Where quartz is readily discernible and occurs with well rounded detrital carbonate grains, the average size of the quartz grain is noticeably smaller than that of the carbonate (Fig. 81).

Polycrystalline quartz is present but rare, and occurs as subangular to well rounded grains, composed generally of three or four randomly oriented crystallites or "grains", ranging from 20 to 50 microns in diameter. Polycrystalline grains were never observed to exceed one per cent of the detrital mineral components. In a sample from Marten Ridge (Sec. 75-12; Fig. 3), one grain was observed (figs. 77, 78) with oriented crystallites containing small flakes of parallel oriented mica (muscovite?). This polycrystalline grain may be of metamorphic origin, a product of an earlier metamorphic quartzite. No other grains of this type were noted by the writer in samples examined from the Kootenay Group, although metamorphic detrital grains have been reported by others, including Rapson (1964, 1965) and Jansa (1972).

Most of the quartz grains in the Mist Mountain Formation display straight to slightly undulose extinction and, like those in the underlying Morrissey Formation, are commonly free of solid inclusions, except for rare euhedral crystals of apatite, rutile and pyrite. Straight or regular extinction is most prevalent, but extinction does not appear to form any conspicuous trends in the formation, although, in samples from a tectonically disturbed area in the upper Elk River valley, most quartz from the lower Mist Mountain Formation was characterized by undulatory extinction. This may be interpreted to suggest that, in this area, the type and degree of undulatory extinction, may be related to post-depositional or post diagenetic tectonism. Grains displaying regular or non-undulatory extinction, and which contain only rare inclusions, may have been originally derived from a plutonic source area. However, because of the absence of plutonic, volcanic and metamorphic minerals, grains or clasts, most grains, and perhaps all detrital grains in the Kootenay Group, are interpreted to be of secondary origin and to have been derived from pre-existing sedimentary strata. In the finer grained lithologies, such as most siltstone and very fine grained sandstone, quartz is typified by straight extinction. Strain shadows and Boehm lamellae were noted in some grains but, like those in other members and formations of the Kootenay, such grains do not form a quantitatively significant concentration of the mineral components.

Grain to grain contacts, where discernible, are predominantly concavo-convex to stylolitic in most coarser grained sandstones and conglomerates (figs. 68-72). Quartz grains in the very fine grained sandstone and coarse grained siltstone display even or normal grain to grain contact relationships.

Lithic grains (exclusive of chert and carbonate)

Lithic grains in the Mist Mountain Formation are similar to those described for strata in the Morrissey Formation, being most abundant in the coarser grained sandstone and conglomerates, especially those in the area of Fernie Basin. The grains do not volumetrically exceed five per cent of the total mineral components. They consist of subangular, quartzose sandstone and siltstone with a silica-chert cement (figs. 70, 71) (this cement is stained and permeated by phosphate and/or brown, organic, carbonaceous matter), and brown to almost black, semi-opaque, siliceous argillite-mudstone grains displaying a laminated, parallel mineral alignment. These argillite-mudstone grains may contain incipient crystals and grains of pyrite. Other noteworthy lithic grains are those consisting of siliceous phosphate, and quartz sandstone and siltstone grains with a recrystallized calcite or limestone cement and matrix. These sandstone and siltstone grains, observed in samples from the Fording Mine area near Elkford, display a similar composition and texture to some of the sandstones in the Triassic Whitehorse Formation of the Alberta Foothills and Front Ranges (Gibson, 1974).

Carbonate minerals

Carbonate minerals do not form a volumetrically abundant component in the formation when compared to quartz, chert, and other lithic grains. They are, however, ubiquitous in their distribution and occur alone or in combination as cement, matrix, and detrital and authigenic grains and crystals, in all rock types, in concentrations ranging from less than 1 per cent to over 75 per cent of the mineralogy. In some of the thicker western sections, especially those adjacent to the upper Elk River valley, dolostone and rare limestone form distinct and separate lithotypes. The carbonate minerals comprise, in order of relative abundance: dolomite, calcite, and siderite. Any or all of these minerals may be present in the same rock sample.

Dolomite. Dolomite comprises the most conspicuous and abundant mineral of the carbonate group, ranging in concentration from less than one per cent, in some of the clean quartz arenites, to slightly in excess of 75 per cent in some thin beds of silty to sandy dolostone in the area of Elk

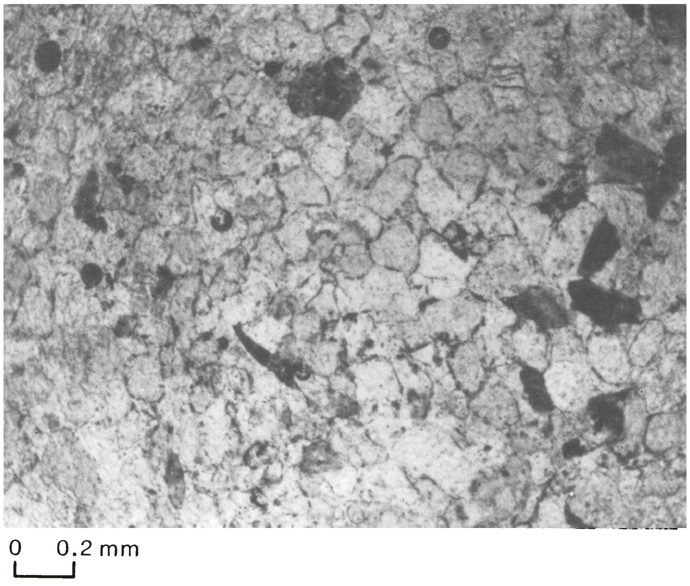


Figure 75. *Subrounded to well rounded grains of quartz, displaying quartzitic texture, in sandstone of Mist Mountain Formation at Limestone Mountain (Sec. 76-18). Note semi-opaque ferruginous rims around many grains. Bar scale 0.2 mm.*

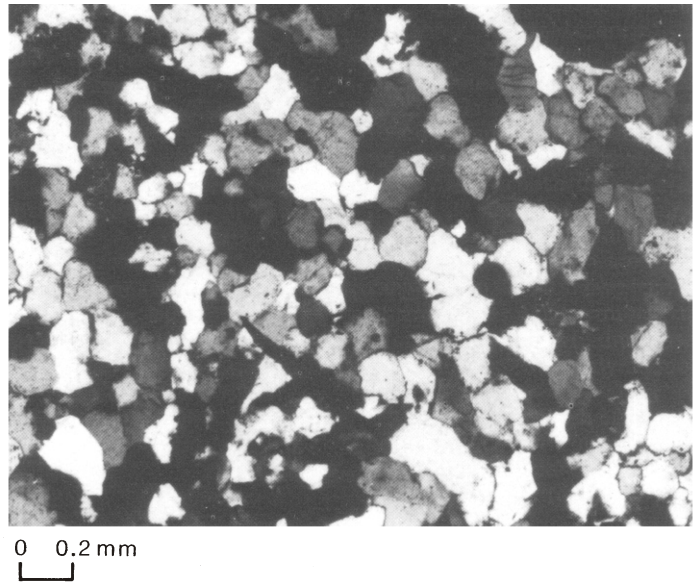


Figure 76. *Same thin section as Figure 75. Note well developed secondary silicification and quartzitic texture.*

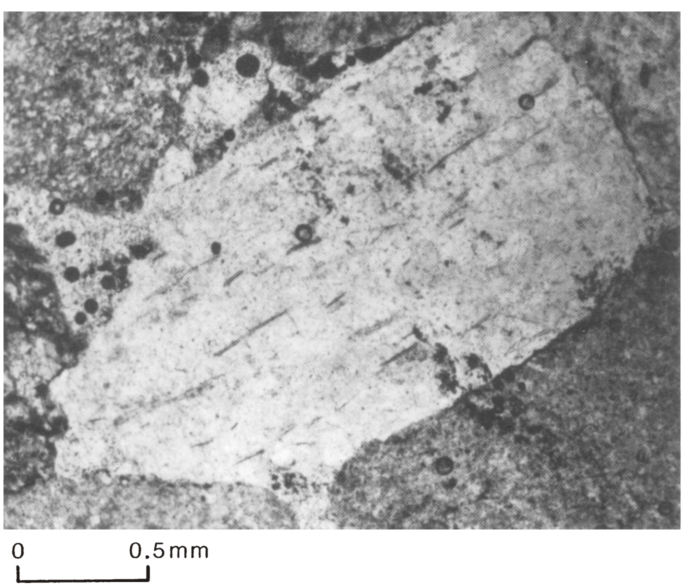


Figure 77. *Possible metamorphic quartzite clast in chert pebble conglomerate of Mist Mountain Formation at Marten Ridge (Sec. 75-12). Note parallel alignment of mica grains. Bar scale 0.5 mm.*

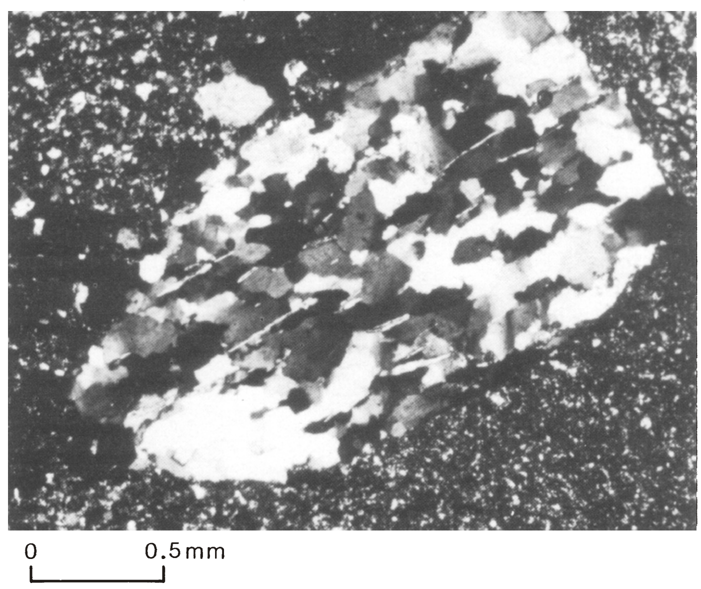


Figure 78. *Same thin section as Figure 77; crossed nicols.*

River valley. The dolomite occurs most commonly as authigenic sand- to silt-sized rhombic or euhedral crystals, which, in most observations, display one or two zoned rhombic overgrowths (figs. 73, 74, 79, 80). The individual zone boundaries are marked by minute concentrations of hematitic, limonitic, or pyritiferous mineral matter. In addition, comminuted carbonaceous matter may also be mixed with ferruginous minerals. The euhedral dolomite crystals are also conspicuous replacement minerals in some of the larger, well rounded grains of chert. Dolomite also occurs as inclusion free, well rounded, monocrystalline to polycrystalline detrital grains, as shown in figures 79 and 80; as well rounded to subrounded recrystallized "sucrosic" grains, which are permeated and stained by brown ferruginous-carbonaceous or possibly bituminous matter (figs. 81, 82); and also as a finely crystalline, recrystallized cement and matrix in some of the finer grained sandstones and siltstones (figs. 79, 80). The concentration is such that, in some samples, the rock may be classified as a silty to sandy dolostone. These dolostones occur as rare interbeds in some of the more recessive weathering and partially talus covered siltstone-mudstone lithofacies in the thicker sections of the formation, especially in the area of the upper Elk River valley and Fernie Basin. In many samples where dolomite forms the predominant mineral component, the subordinate quartz and rare chert occur as "floating", or matrix and cement supported grains in the recrystallized cement and matrix of the dolostone. The occurrence of "floating" grains of quartz and chert, combined with the presence of well rounded detrital grains of dolostone and some limestone in some of the samples, suggests that some, if not most, carbonate in the sandy to silty dolostones, may have originally been deposited as detrital grains with quartz and chert, but has subsequently been recrystallized into matrix and cement.

Calcite. Microscope examination, HCl acid testing, and X-ray diffraction analysis, indicate calcite to be a ubiquitous but generally quantitatively insignificant mineral component of the formation. It occurs as a fine to coarsely crystalline "sparry" cement or pore filler in some of the conglomerate and coarser grained sandstone samples, or, less commonly, as well rounded to subrounded grains. Calcite also occurs as finely to medium crystalline "patches" in some of the sandy to silty dolostone interbeds. Calcite rarely exceeds 10 to 15 per cent of the carbonate mineral concentration, although, in a sample from the Greenhills Range near Elkford (Sec. 75-17; Fig. 3), medium to finely crystalline calcite forms the predominant mineral, and, accordingly, the rock was classed as a dolomitic quartz limestone. Another unusual occurrence of calcite was noted in a silty dolostone from a borehole sample from the Fording Coal mine area. The sample contained thin, wavy bands of fibrous calcite, up to 2 cm thick (Fig. 83). The calcite represents a secondary authigenic cavity infilling after consolidation and cementation of the dolostone.

Siderite. Siderite, although not usually observed in thin section, was detected by X-ray diffraction analysis in many samples, but in relatively low concentrations – one to two per cent of the total mineralogy. However, in one siltstone sample from Sparwood Ridge (Sec. 75-8; Fig. 3), the concentration was 15 per cent of the total mineralogy. From the same area a mudstone-shale sample had a siderite concentration of eight per cent. In general, the concentration of siderite was highest in the finer grained siltstones and the mudstone-shale samples of the formation.

Clay minerals

Clay minerals occur in most lithotypes of the formation, but are most abundant in the finer grained strata such as mudstone and shale, where concentrations up to 23 per cent of the total mineralogy were recorded. In the coarser grained strata, clay occurs mixed with quartz, chert, or carbonate, as cement or as matrix, with very fine grained quartz, chert and ferruginous-carbonaceous matter. Because of the masking effect of the semi-opaque organic matter, the opaque ferruginous minerals and the optical resemblance to some of the chert, identification of clays by petrographic microscope methods was generally not possible. Consequently, identification and concentration estimates were made by X-ray diffraction analysis, and, therefore, concentration values are approximate. In some samples green "flakes" or grains of chlorite are readily visible and identifiable in thin sections. They invariably occur in concentrations of less than one per cent. Grains or "flakes" of muscovite were noted in a few grains of chert.

X-ray analysis of many samples, including sandstone, siltstone, mudstone-shale, and samples of dolostone and limestone, indicate three main clay mineral groups. The first comprises the mixed-layered silicates, which attain a concentration in some of the mudstone-shale samples up to eight per cent of the total mineralogy. The second is the illite group, which had a maximum concentration of nine per cent of the mineralogy, again in a sample of mudstone-shale. The last group is the kaolinite/chlorite group, which attained a maximum concentration of eight per cent of the total mineralogy. Some of the samples do not indicate the presence of chlorite in the X-ray diffractogram, and, therefore, this clay was interpreted to be entirely composed of kaolinite. Where this was noted, the maximum concentration was five per cent. A typical fine grained sandstone in the report area was found to contain three per cent kaolinite and three per cent mixed-layered silicate. The clay mineral content of a typical siltstone in the formation was found to be one per cent illite, and two per cent kaolinite/chlorite. Lastly, the clay concentration of a typical mudstone-shale yielded values of eight per cent mixed-layered silicates, seven per cent illite, and eight per cent kaolinite/chlorite.

The results of the analyses suggest that, in terms of relative abundance, the kaolinite/chlorite group formed the predominant group in most sandstones, siltstones, and the dolostones, while the mixed-layered silicate group and illite formed the dominant clays in the finer grained mudstone-shale lithofacies.

Opaque constituents

The opaque components are similar in appearance and physical character to those described for strata of the underlying Morrissey Formation. In the Mist Mountain Formation, however, they generally are more abundant, depending on the type of strata under study. For example, most Mist Mountain sandstones contain a much larger concentration of brown to black carbonaceous matter. The carbonaceous matter, mainly comminuted vegetal fragments, is mainly responsible for the darker colour of the sandstones and other strata in the formation. Other opaque constituents include crystals and grains of pyrite, hematite-limonite, and possible magnetite. These minerals do not occur in sufficient concentration to be detected by X-ray analysis.

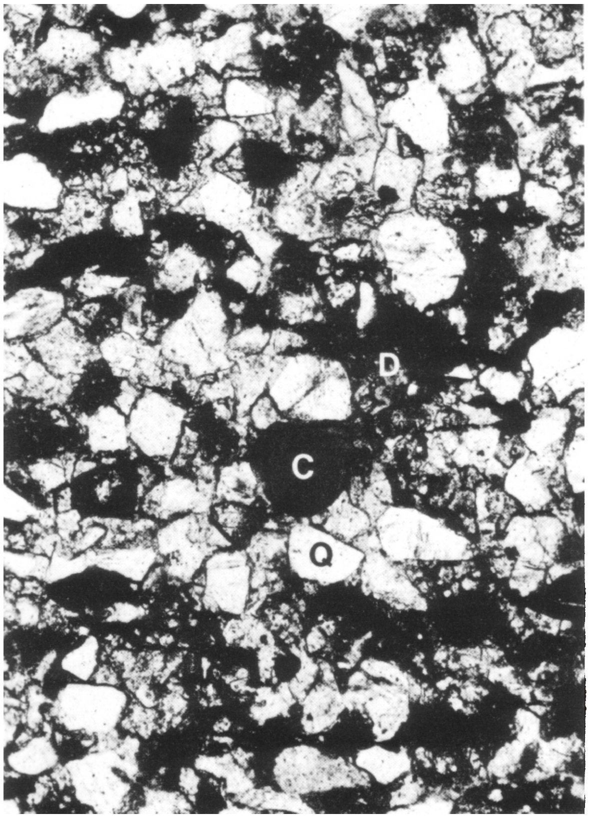


Figure 79. *Dolomitic, quartz sandstone of Mist Mountain Formation, Line Creek (Sec. 76-16). Note subangular grains of quartz in matrix and cement of coarsely crystalline dolomite. Large, well rounded grain of collophane in centre. Collophane (C); Quartz (Q); Dolomite (D). Bar scale 0.1 mm.*

Figure 80. *Same thin section as Figure 79; crossed nicols.*

Miscellaneous minerals

The most noteworthy mineral of this group is collophane, a ubiquitous phosphate mineral found in all members and formations of the Kootenay Group (figs. 79, 80). It occurs as well rounded grains (some of which contain nuclei of angular grains of quartz), elongate pellets, and as irregularly shaped "patches", which have replaced some of the carbonate cement and matrix in some samples, and chert in others. The concentration of collophane was not observed to exceed 3 per cent of the total mineralogy. Collophane is most conspicuous in detrital chert in the coarser grained sandstones and conglomerates of the formation, where it comprises part of the cement and matrix.

Other minerals include plagioclase feldspar, sphene, rutile, tourmaline and zircon. Anhydrite was identified in a few samples by X-ray diffraction analysis, and in one sample attained an approximate concentration of one per cent. The other "heavy" minerals occur only in trace amounts. Ferromagnesian minerals of probable igneous, volcanic, or metamorphic origin were not observed.

Lithology

Mineralogically, the Mist Mountain Formation is similar to the underlying Morrissey Formation, differing only in relative concentration of the component minerals. Exclusive of coal, eight lithotypes characterize the strata. The sandstone consists predominantly of chert lithic arenite, followed by chert sublitharenite, and finally by rare quartz arenite. Chert-pebble conglomerate characterizes the strata at some sections in the area of the Fernie Basin. Mudstone-shale and siltstone are common lithotypes in all areas, although they are most prevalent in the thicker western sections. Rare interbeds of limestone and dolostone were noted only in areas adjacent or close to the Elk River valley, and, accordingly, display the only noteworthy mineralogical trend in the formation, being thus confined to the western area. In addition to forming separate stratal types, random grains of carbonate most commonly occur in the thicker western sections of the area, and exhibit a vertical increase in concentration from the base to the top of the formation, a pattern which continues into and through strata of the overlying Elk Formation.

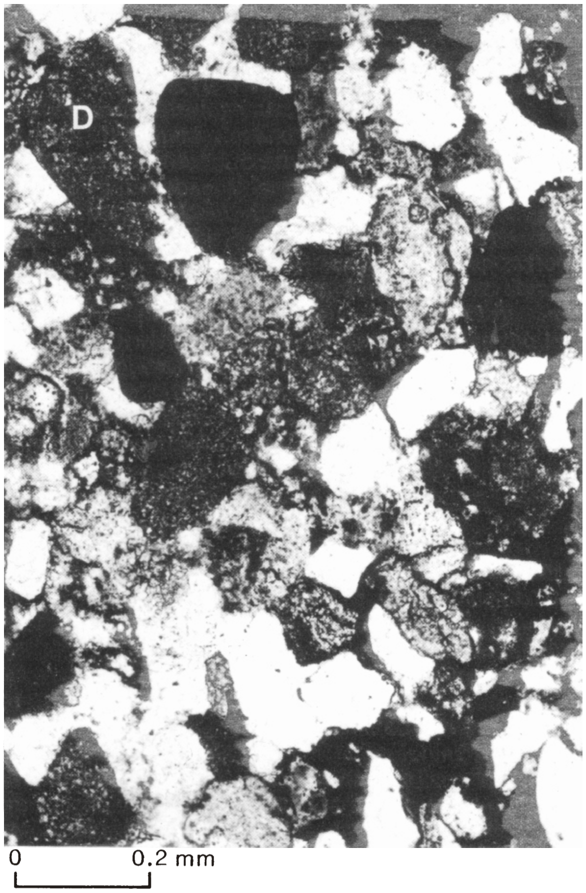


Figure 81. Well rounded grains of dolomite with subangular grains of quartz and chert. Note "welded" nature of quartz grains. Mist Mountain Formation, Fording Coal Property (Sec. 75-24). Dolomite (D). Bar scale 0.2 mm.

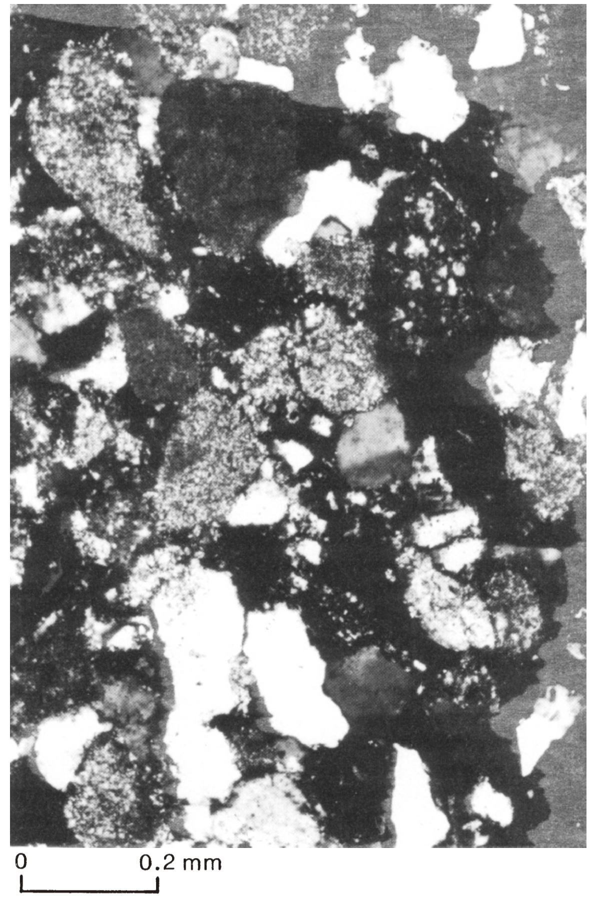


Figure 82. Same thin section as Figure 81; crossed nicols.

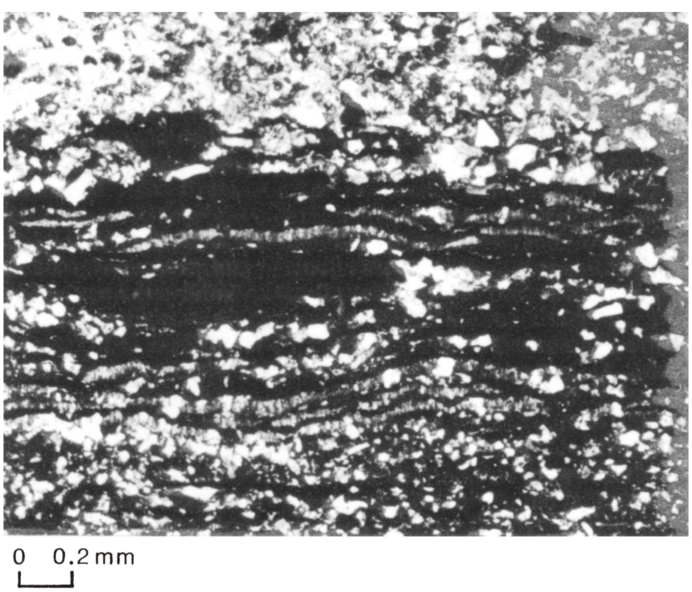
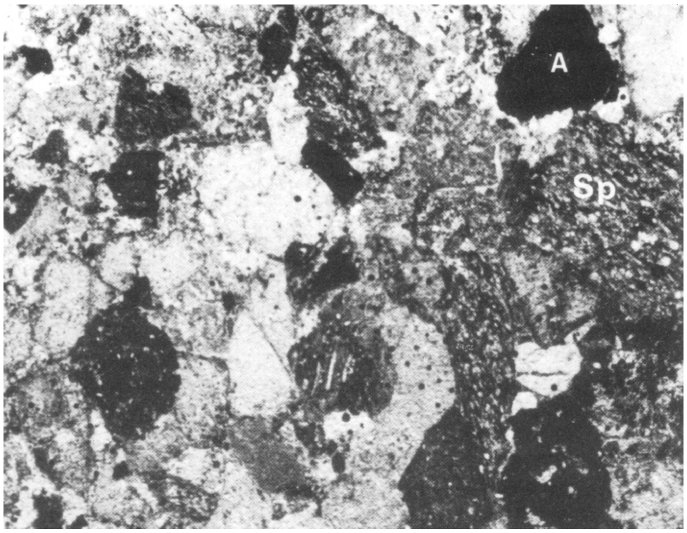


Figure 83. Fibrous calcite in very carbonaceous lamination of a calcareous, quartzose siltstone. Mist Mountain Formation (Sec. 75-24). Note "floating" or matrix supported quartz grains. Bar scale 0.2 mm.

Elk Formation

Chert

The variety, concentration and general petrographic properties of chert in the Elk Formation are similar to those described for strata of the underlying Mist Mountain and Morrissey formations, with two noteworthy exceptions. As noted previously, chert-pebble and granule conglomerate characterize Elk strata in some areas of the Fernie Basin. The conglomerate contains a distinctive and unusual variety of pale green chert along with other more common varieties of chert and lithic pebbles and cobbles. The green chert consists of a microcrystalline mosaic of quartz, containing randomly oriented lath-like flakes or crystals of clay. The size of the crystals is too small for standard petrographic or microscope identification. Some of the green chert samples were X-rayed, with the results indicating a composition of mainly quartz with only trace amounts of clay. Rapson (1965), in a petrographic study that included rocks of the Elk Formation, and the Cadomin Formation of the overlying Blairmore Group, described the occurrence of similar green chert pebbles. However, Rapson (*op. cit.*) reported these pebbles to be composed of shards of volcanic glass and to contain small euhedral crystals of feldspar. They were interpreted by Rapson as pebbles or clasts of silicified volcanic tuff. The writer did not observe any evidence, either in thin section or from the X-ray diffraction analyses,



0 1.0 mm

Figure 84. *Conglomeratic sandstone, composed of subrounded grains of chert and spicular chert. Opaque grains consist of silicified argillite, and vegetal fragments. Variation in colour tone of chert grains due to variable concentration of phosphate in chert. Elk Formation at Marten Ridge (Sec. 75-12). Spicules (Sp); Argillite (A). Bar scale 1.0 mm.*

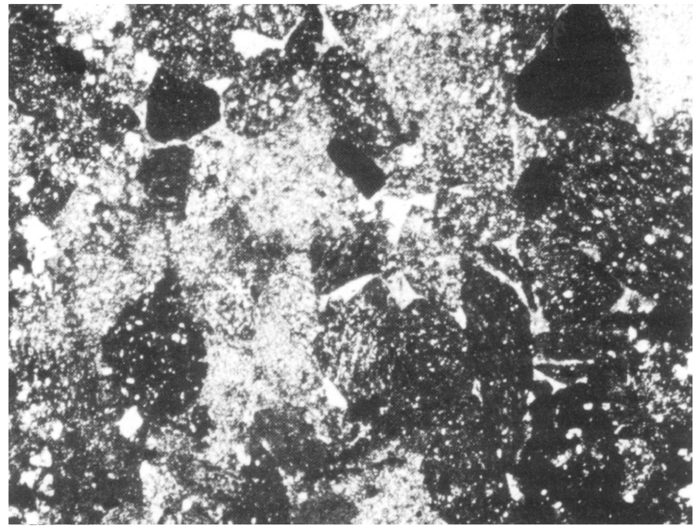


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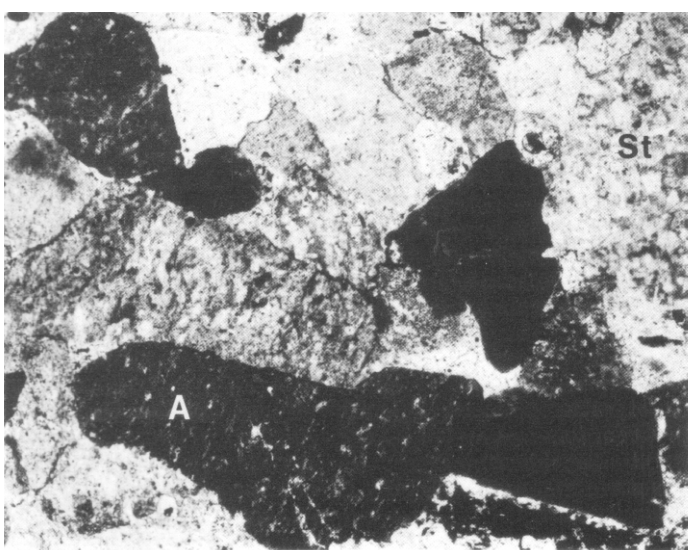
Figure 85. *Same thin section as Figure 84; crossed nicols.*



0 0.5 mm

Figure 86. *Chert-granule conglomerate from Elk Formation at Sparwood Ridge (Sec. 75-8), illustrating subangular nature of detrital granules and semi-opaque, siliceous, argillite-mudstone grains; large lithic siltstone-sandstone grain upper right corner. Argillite-mudstone (A); Siltstone-sandstone (St). Bar scale 0.5 mm.*

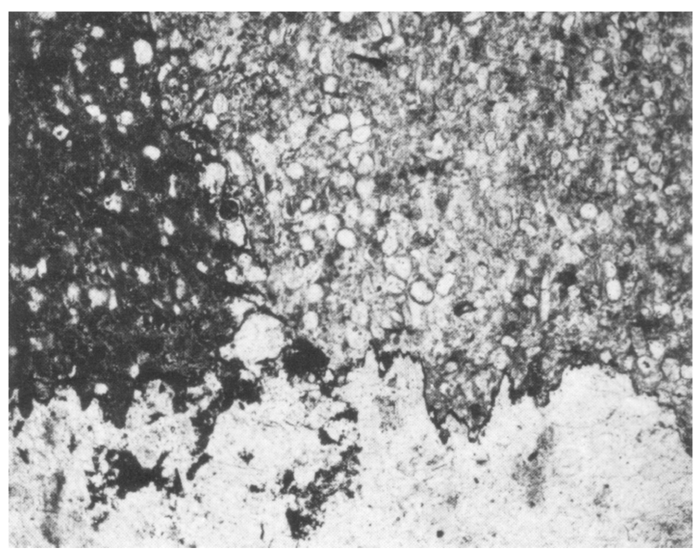


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Figure 87. *Chert-pebble conglomerate of Elk Formation, illustrating three varieties of chert: slightly phosphatic spicular chert, clear chert, and semi-opaque chert containing high concentration of organic matter and silt-sized grains of quartz. Note stylolitic contact between grains. Flathead Ridge (Sec. 75-6). Bar scale 0.5 mm.*

to suggest such a composition and possible volcanic origin. Similar green chert pebbles have been described by Schultheis (1970) from the Cadomin Formation in Alberta, and the writer has observed them in strata of the Bullhead Group and lower Ft. St. John Group in the Foothills of northeastern British Columbia. Green chert pebbles and cobbles have only been observed in conglomerate samples.

The second unusual occurrence of chert in the Elk is that found in the "Needle siltstones", where it occurs mainly as cement (figs. 53, 54, 55). The "Needle siltstones" are diagnostic of the upper Elk Formation in many areas, especially in the thicker western sections, because of their white to light grey weathering, siliceous, tough, well indurated character. Mineralogically, they are composed of "floating", angular, silt- to sand-size grains of quartz and rare chert and feldspar, cemented by microcrystalline quartz or chert. The cement is characteristically permeated and stained by dark brown to black, finely comminuted carbonaceous matter (figs. 54, 55). When fractured, the samples are dark grey to black on a fresh surface (Fig. 53). Some samples also contain "pockets" or "patches" of vitreous coal "needles", floating in the chert or silica cement (Fig. 53). X-ray analysis of a few selected samples of "Needle siltstone" indicate the presence of illite and kaolinite, although the concentration does not exceed one per cent of the total mineralogy. The origin of the chert cement is uncertain. It may represent an unusual authigenic silica precipitate or it may represent a secondary replacement of a former carbonate cement or matrix.

Brown, phosphatic, and spicular cherts are common detrital components in most sandstones and conglomerates of the Elk Formation (figs. 84-87), and, because of the general average increase in grain size in many of the sandstone interbeds, and the occurrence of pebble and granule conglomerate in the Elk Formation at many section localities, chert forms a relatively high concentration compared to quartz. In most observations of the coarse clastic facies, chert exceeds the concentration of quartz by 10 to 20 per cent. Likewise, the occurrence and concentration of spicular chert is greater in the sandstones and conglomerates of the Elk Formation than in the underlying Mist Mountain Formation. Also observed were rare chalcedonic chert and a few chert grains containing subangular sand and silt-sized detrital grains of quartz. Inclusions of pyrite, dolomite, phosphate, and organic carbonaceous or bituminous matter are present in most grains, but only as trace concentrations. Grain to grain contacts vary from concavo-convex to stylolitic, with the latter most prevalent between the larger grains in the coarse sandstones, and between the pebbles and cobbles of the conglomerates (Fig. 87).

Quartz

Quartz, the most common and most conspicuous of the mineral components in the Elk Formation, is similar in character, concentration, and physical properties to that described in the underlying Mist Mountain and Morrissey formations. "Welded" or quartzitic textures are common in the sandstones and most siltstones, and, like those in the underlying Mist Mountain and Morrissey formations, mask the textural relationships in many samples (figs. 88, 89). However, where textural relationships are evident, grains range from angular to well rounded, the latter displaying well developed "dust" rims (figs. 90, 91). Sorting is fair to poor. Grains range in size from clay to silt to very coarse sand to granules. In the conglomerates and very coarse grained sandstones, quartz occurs mainly as a detrital matrix component with chert and other lithic rock fragments, and as a cement. Where quartz and chert occur together as matrix or detrital framework components in the sandstones, quartz is generally finer grained than the chert. When associated as a detrital component with a carbonate cement or matrix, most quartz displays a serrated or corroded grain boundary, some silica having been removed and replaced by carbonate (figs. 90-93).

Inclusions in the quartz consist of acicular "needles" of rutile, euhedral crystals of apatite, and rare collophane. Polycrystalline quartz, conspicuous in the sandstones of the underlying Mist Mountain Formation, is rarely observed in the Elk.

Carbonate minerals

Dolomite and calcite are more common in the Elk than in strata of the underlying Mist Mountain Formation. The combination of the two minerals however, rarely exceeds the concentration of either quartz or chert, although in a few samples carbonate minerals do exceed quartz and chert, forming distinctive interbeds which are classed as silty to sandy dolostone and rare limestone. These strata are found mainly in the thicker western sections. Siderite, a mineral detected by X-ray analysis of Mist Mountain Formation samples, was not recognized or detected by X-ray analysis in samples from the Elk.

Dolomite is the dominant carbonate mineral, occurring as sand-sized, well rounded grains and pellets in many of the coarser grained sandstones. It commonly occurs dispersed or mixed with the detrital grains of quartz, chert, and lithic rock fragments. Authigenic euhedral crystals, some with zoned overgrowths, occur in some of the larger chert grains and in some of the chert and quartz cement (Fig. 92). Most detrital dolomite is composed of crystallized or sucrosic "grains". As noted in the discussion of the Mist Mountain Formation, well rounded carbonate grains generally occur in the same sample as the zoned, authigenic, euhedral crystals and subangular grains.

The concentration of detrital dolomite in the sandstone generally ranges from less than 1 per cent to over 15 per cent of the mineral components, and displays a conspicuous increase from the base to the top of the formation. In addition, it generally increases in concentration from the southern to the northern part of the report area. In some rock samples containing quartz, chert and carbonate as cement and detrital components, the carbonate detrital components may form up to 75 per cent of the total mineralogy. Fossils or fossil fragments were not observed in the carbonate.

Dolomite also forms individual beds of dolostone, consisting of a medium crystalline, interlocking mosaic of dolomite, with random "patches" of sparry calcite. Some dolostone beds contain "floating" grains of quartz, chert, and other lithic rock fragments. In these beds the occurrence of "floating", or cement and matrix supported grains, suggests that, again, much of the carbonate that now occurs as recrystallized cement and matrix may have originally been present as detrital grains along with detrital quartz and chert. Additional evidence suggesting a detrital origin for the carbonate is the occurrence of small scale festoon crossbedding in the dolomitic strata. Dolomite may also occur as cement in the finer grained sandstones and siltstones. When found as a distinct lithotype, it is interbedded with the finer grained, recessive-weathering siltstones, mudstones, and shales.

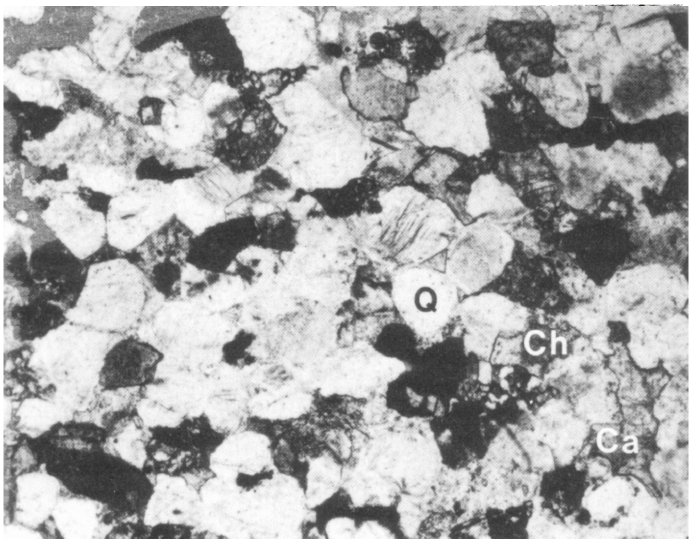

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Figure 88. *Medium grained sandstone of Elk Formation at Flathead Ridge Pipeline (Sec. 75-6), illustrating mixture of quartz and chert in a cement of quartz and calcite. Note secondary quartz overgrowths, welded nature of grain contacts, and occurrence of strain shadows in some grains of quartz. Well rounded pellet-like grain of limestone in lower left corner. Quartz (Q); Chert (Ch); Calcite (Ca). Bar scale 0.2 mm.*

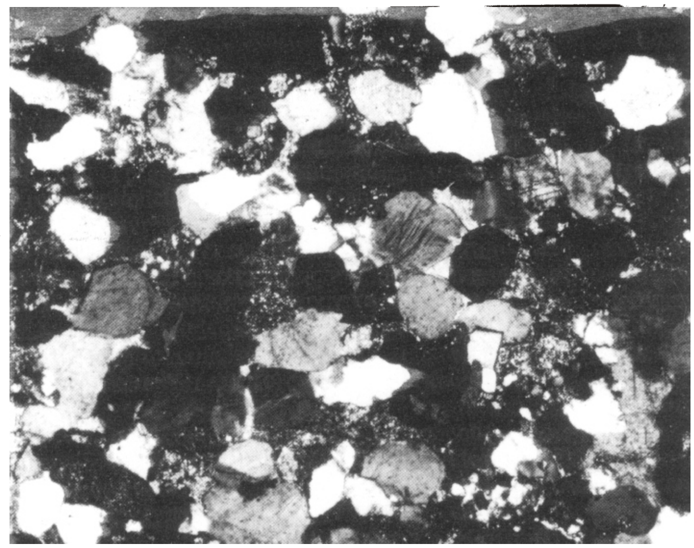

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Figure 89. *Same thin section as Figure 88; crossed nicols.*

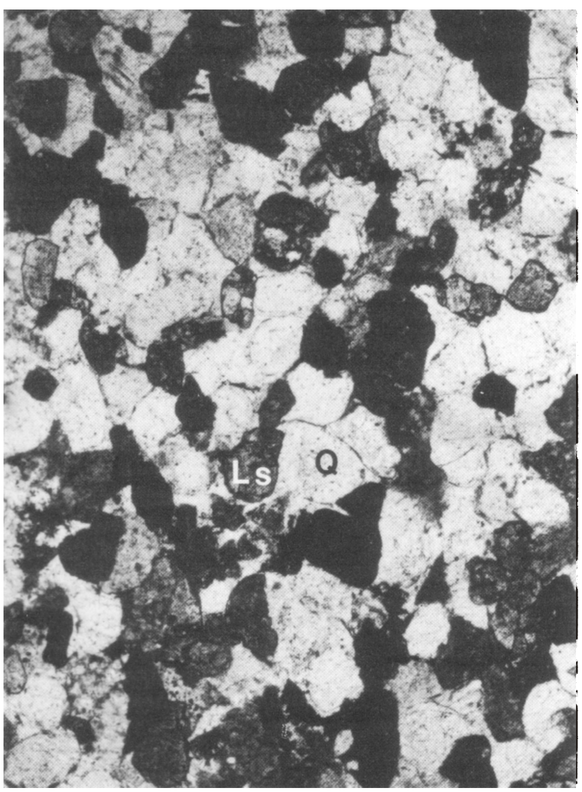

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Figure 90. *Quartz, chert, and detrital grains of limestone in a predominantly quartz cemented sandstone of Elk Formation at Barrier Mountain (Sec. 76-17). Note secondary overgrowth "rims" on well-rounded grains of quartz, and well developed quartzitic texture. Limestone (Ls); Quartz (Q). Bar scale 0.2 mm.*

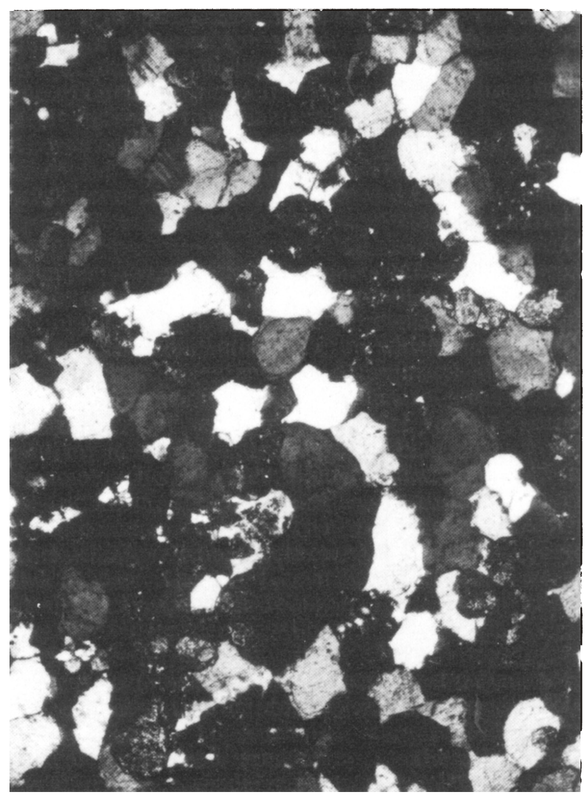

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Figure 91. *Same thin section as Figure 90; crossed nicols.*

Calcite was observed mainly in coarse grained sandstones and some of the coarser grained siltstones (figs. 88-93). The concentration is generally lower than that of dolomite. The calcite is coarsely crystalline, occurring usually as a pore- or vug-filling in the very coarse grained sandstones and some conglomerates. It may also occur, along with quartz and chert, as a medium to coarsely crystalline cement in some of the finer grained sandstones and siltstones (Fig. 88). Calcite is more common in strata of the Elk, especially the sandstones, than in the underlying strata of the Mist Mountain Formation.

Sucrosic, detrital, subrounded grains of calcite are conspicuous in some of the coarser grained sandstones (figs. 90-93). The amount of calcite, however, does not usually exceed the concentration of dolomite.

Lithic grains (exclusive of chert and carbonate)

Two types of lithic grains occur ubiquitously in most of the Elk sandstones and conglomerates and in some of the siltstones. The first type consists of subangular grains of brownish grey, quartz siltstone to very fine grained sandstone with a silica-chert cement (Fig. 86). This type was not observed to exceed five per cent of the total detrital components. The second lithic type consists of angular, brown, semi-opaque to opaque, argillite-mudstone grains (figs. 84, 86), which, like those above, do not form a quantitatively significant component in the formation. They are, however, similar to those described from the Mist Mountain Formation, being very siliceous, composed of quartz and probable clay minerals and cemented by chert. They contain an abundance of opaque to semi-opaque pyrite, hematite and/or limonite, and probable organic, carbonaceous plant or bituminous matter. Collophane may be responsible in part for the brown colouration of the grains. Most grains display oriented clay minerals, giving the grains a laminated appearance both in hand specimen and in thin section (Fig. 86).

The conglomerate, in addition to other detrital components, also contains well rounded pebbles, cobbles, and coarse matrix grains of pink to colourless quartz arenite. The quartz arenite is composed of well rounded, smaller grains of quartz with a reddish brown to pink quartz cement. The pink to reddish brown colour is attributable to minor ferruginous staining and inclusions.

Clay minerals

Clay minerals were visually observed in thin sections and were detected by X-ray diffraction in all lithotypes of the formation. The maximum recorded concentration of clay minerals detected by X-ray diffraction was 34 per cent, in a mudstone-shale-claystone sample from Eagle Mountain (Sec. 75-19; Fig. 3). Two main groups were identified by X-ray analysis. The first group consists of the mixed-layered silicate-illite group, which, in most samples analysed, has a concentration ranging between one and two per cent of the total mineralogy. However, in one sample from Eagle Mountain, the concentration constitutes 23 per cent of the total mineral components. The second group is the kaolinite/chlorite group which occurs in concentrations ranging from two to three per cent of the total mineral components. The maximum recorded concentration for this group was 11 per cent.

Green flakes or grains of detrital chlorite are conspicuous in some thin sections, although they only occur in trace concentrations of less than one per cent. A few large sand-sized grains of muscovite were also observed in thin section.

Opaque constituents

The opaque constituents consist mainly of dark brown to black, comminuted fragments of vegetal matter, which occur throughout the strata although in generally low concentrations. This vegetal matter may, however, occur in greater concentration in the finer grained more argillaceous strata, especially the siltstones and mudstones associated with coal seams. The detrital vegetal fragments also occur as thin, wavy to parallel, regular laminations in many of the siltstones and sandstones.

Also present, and in relatively low concentrations, rarely exceeding one to two per cent of the total mineral content, are the common ferruginous minerals such as pyrite, hematite, possible magnetite, and limonite. X-ray analysis of Elk samples, however, does not indicate the presence of the ferruginous minerals, but, as previously noted, their low concentration may inhibit detection by X-rays.

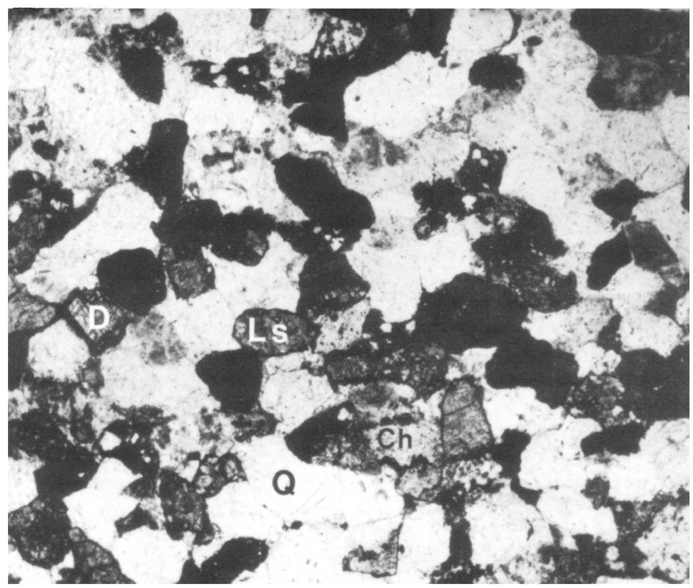

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Figure 92. *Mixture of well-rounded and subhedral to euhedral grains and crystals of limestone and dolomite, and angular to subangular grains of quartz and chert, in sandstone of Elk Formation at Sparwood Ridge (Sec. 75-8). Note welded nature of quartz grains and sucrosic texture of detrital carbonate. Limestone (Ls); Dolomite (D); Chert (Ch); Quartz (Q). Bar scale 0.2 mm.*

Miscellaneous minerals

Miscellaneous minerals in the Elk are similar to those in the underlying members and formations of the Kootenay Group. The most conspicuous and ubiquitous mineral in this category is collophane, which occurs as well rounded grains, elongate pellets, rare ooliths, and as irregular replacement "patches" in some of the silty to sandy dolostone interbeds. Collophane also occurs with the cement in many of the detrital chert grains, pebbles and cobbles. Concentration of collophane in the samples examined did not exceed two per cent of the total mineralogy. The rounded grains and pellets occur most commonly as components in the chert clasts of the conglomerate facies, and as individual detrital grains in the coarser grained sandstones. Ooliths, some with a core of quartz or pyrite, were observed in two sandstone samples from Sparwood Ridge. Grains of bisaccate pollen were also observed in some of the "Needle siltstone" samples. Caution must be exercised in differentiating these pollen grains or spores from the superficially similar pellets and well rounded grains of collophane.

Other, less common, accessory minerals include rare grains of green and brown tourmaline, pale yellow rutile, and clear, colourless zircon and apatite. These "heavy" minerals are not as abundant or conspicuous as those in samples from the underlying Mist Mountain Formation. Also present, but rare in occurrence, are angular grains of feldspar (microcline and probable orthoclase), anhydrite and biotite. Feldspar and anhydrite were identified mainly by X-ray analysis. The concentration of the feldspar was estimated from X-ray peak intensities to be up to five per cent in the samples analysed. The feldspar content estimated from analyses of thin sections was only one per cent. Rare biotite grains were noted in a sandstone sample from Flathead Ridge.

Lithology

Based on the mineral content described above, it can readily be seen that lithotypes in the Elk are similar to those in the underlying Mist Mountain Formation. Accordingly, most sandstone is classified as chert lithic arenite. Chert sublitharenite is rare, and quartz arenite was not observed. Chert-pebble conglomerate is common in some areas of the Fernie Basin, but occurs only sporadically elsewhere. Also present, in relatively high concentration, are quartz siltstone and mudstone-shale, and there are rare beds of sandy to silty dolostone. The finer grained rock types and rare carbonate strata are commonly less well indurated compared to the coarser grained sandstones and conglomerates. Thus, the finer rocks weather more recessively and typically are overlain by vegetation and talus cover.

The only noteworthy mineralogical trend in the formation is shown by the carbonate minerals, which exhibit a conspicuous increase in concentration from the base to the top of the formation at most localities. A similar increase occurs from the underlying Mist Mountain into the Elk Formation.

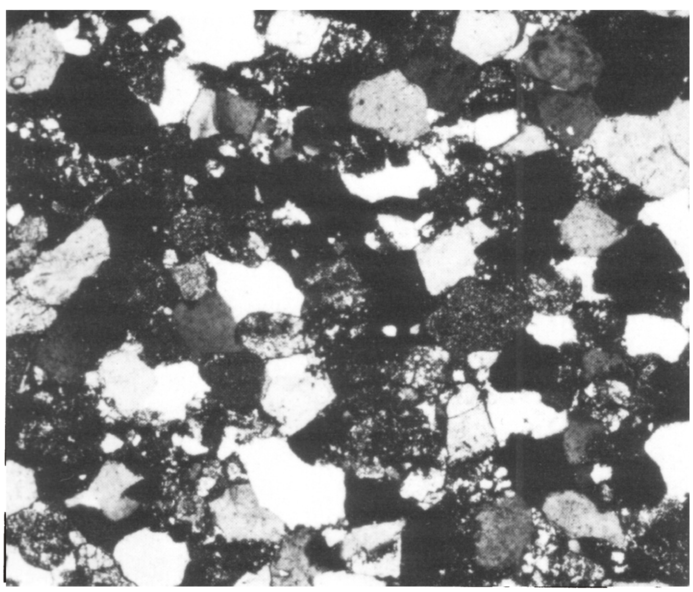

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Figure 93. *Same thin section as Figure 92; crossed nicols. Note presence of a few lithic grains of quartz siltstone. Siltstone (St).*

SEDIMENT SOURCE AND PROVENANCE AREA

The sediment source rock and source area for the mineral and rock components of the Kootenay and overlying basal Blairmore Group have been described and discussed in varying detail by such workers as Norris (1964b, 1971), Rapson (1964, 1965), Price (1965), Mellon (1967), Schultheis (1970), Jansa (1971, 1972), Schultheis and Mountjoy (1978), and the writer (Gibson, 1977b). Mellon (1967) provided information and data mainly on the Blairmore Group, whereas Schultheis (1970) and Schultheis and Mountjoy (1978) included only information on the Cadomin Formation. The investigation by Rapson (1964, 1965) included data on both the Cadomin and Elk formations of the Blairmore and Kootenay groups respectively, whereas Norris (1964b, 1971), Price (1965), Jansa (1971, 1972) and the writer (Gibson, 1977b) were concerned mainly with the Kootenay Group.

Because of the conspicuous similarity in composition and texture of conglomerates, conglomeratic sandstones and sandstones of the Elk and Mist Mountain formations of the Kootenay Group with those of the Cadomin and lower Gladstone formations (Mellon, 1967) of the Blairmore Group, the writer agrees with some of the interpretations of other workers that the sediment source and provenance area for both the basal Blairmore and Kootenay groups may be related and similar. The following discussion summarizes some of the more important observations of earlier workers, and at the same time includes the observations and interpretative suggestions of the writer, applicable to strata of the Kootenay Group.

Sediment source

The composition and internal textures of the Kootenay Group rocks indicate that most if not all detrital components were derived from pre-existing sedimentary rocks. The mineral and rock components described and discussed above consist of two main types, quartz and lithic rock fragments. The latter include several varieties of chert, grains and pebbles of sedimentary quartzite or quartz arenite, grains of dolostone and limestone (commonly sandy to silty), grains and pebbles of silicified mudstone-argillite, and grains of collophane. The cement consists of quartz, chert, and less commonly dolomite, calcite, and rare clay minerals.

Quartz is the most common detrital component in the Kootenay Group. However, the composition and physical character of most grains are not distinctive enough to indicate the probable type of source rock from which they were obtained. Quartz sandstone and siltstone are common lithotypes in many early Mesozoic/Triassic (Spray River Group); late Paleozoic/Permian-Pennsylvanian (Ishbel and Spray Lakes groups); and early Paleozoic/Cambrian-Ordovician (Gog Group-Mount Wilson Formation) rock successions. In addition, some of the thick, predominantly carbonate, Paleozoic sequences of the Rocky Mountain Front and Main ranges contain sandy, quartzose strata, which, upon weathering and disaggregation, would provide a quartz-sediment source. Thus, any of the above quartz sandstone lithotypes would serve as a potential source for the detrital quartz of the Kootenay Group. The occurrence of rutile, tourmaline and apatite as inclusions, and the presence of undulatory extinction in some grains of quartz, may be interpreted to indicate a plutonic igneous or metamorphic source terrain (Blatt et al., 1972; Folk, 1974). However, as noted previously, the writer suggests that these quartz grains are recycled grains derived from a sedimentary rock, although the quartz was originally derived from igneous and metamorphic rocks of the Canadian or Precambrian Shield. Moreover, the "heavy" minerals may also be derived from an older sedimentary rock.

Although a common and conspicuous component of the Kootenay Group, the detrital chert grains, pebbles, and cobbles are difficult to relate, with any degree of confidence, to the older sedimentary rock unit or units from which they were derived. Chert nodules, lenses, and thin, lenticular beds have been reported in a number of major carbonate units which range in age from early Mesozoic (Triassic) to late Paleozoic (Permian to Mississippian) to early Paleozoic (Devonian and Ordovician). For example, light and dark grey chert, brown phosphatic chert, and spicular chert have been reported as relatively common components in facies of the Triassic Whitehorse Formation (Gibson, 1974), the Permian Ranger Canyon and Johnson Canyon formations (McGugan and Rapson, 1963; Rapson, 1964, 1965; McGugan et al., 1968), the Mississippian Banff Formation (Rapson, *op. cit.*; Schultheis, 1970; Schultheis and Mountjoy, 1978), the Devonian Flume Formation (Schultheis and Mountjoy, 1978), and the Ordovician Skoki and Outram formations (Norford, 1969). The spicular chert in some of the pebble conglomerates and coarse grained sandstones of the Elk Formation might at first glance appear easy to recognize in the older sedimentary rock formations. However, spicular chert is common in strata of the Mississippian Banff Formation, the Permian Johnson Canyon Formation and the Devonian Flume Formation. Thus, the spicular chert in the Kootenay Group may have come from any one, two, or all three of these potential source units. Price (1965) noted small spherical structures in some of the chert pebbles from the Elk Formation in the Flathead area of British Columbia, and considered this chert to be similar to that in the Banff Formation of the Rocky Mountains. He suggested that at least part of the chert in the conglomerates and sandstones of the Kootenay Group may have been derived from the Banff Formation. Similar suggestions have been made by Rapson (1964, 1965). The writer agrees with the suggestions that the Banff Formation was a probable source rock for the detrital chert.

The source rock of the unusual, green, chert pebbles and cobbles in the conglomerates of the Elk and Cadomin formations would again seem potentially easy to recognize in the older Paleozoic formations. However, to the writer's knowledge, green chert of the variety found in the Kootenay Group has not been reported from any of the Paleozoic, Proterozoic, or even Mesozoic strata in the Rocky Mountains. The nearest reported occurrence of green chert similar in appearance to that of the Kootenay clasts is in the argillites of the Permian Cache Creek Group of the Cache Creek-Clinton-Ashcroft area of central British Columbia (Rapson, 1965; Trettin, 1980). However, the green chert in the Cache Creek Group contains feldspar, white mica, and chlorite minerals, and occurs in the same units which contain dark grey to black chert. The green colour of the chert may, therefore, be actually a weathering or bleaching characteristic, and not the original colour of the chert at the time of formation or deposition. The green chert may have originally been dark grey to black. It seems unlikely that the green chert pebbles and cobbles in the Kootenay and Cadomin strata, which also differ slightly in composition from the chert in the Cache Creek Group, could have all been derived from such a distant source area as Cache Creek, Clinton and Ashcroft. The main source terrain for green chert of the Kootenay and Cadomin, in all probability, may have been much closer, such as a stratigraphic unit or facies in the ancestral Rocky Mountains, which subsequently has been eroded and removed.

Other unusual varieties of chert in the Kootenay consist of grains and pebbles containing sand- and silt-sized grains of quartz, which may have been derived from the Permian Ranger Canyon and Mowitch formations of the Ishbel Group (Rapson, 1965), and grains and pebbles of medium to light grey chert containing authigenic, euhedral rhombs of dolomite. Chert of the latter type has been reported in the nodular and bedded cherts of the lower Ishbel Group (McGugan and Rapson, 1963, p. 157).

The sandy and silty, quartzose, recrystallized, sucrosic carbonate grains in the Kootenay Group may have been derived from many different source formations. The upper Triassic Whitehorse Formation contains an abundance of carbonate strata with a commonly high concentration of silt- and sand-sized quartz (Gibson, 1971). Carbonates dominate the Mississippian Rundle Group (Macqueen and Bamber, 1967, 1968) and the Devonian Fairholme Group (McLaren, 1955). The Permian and Pennsylvanian Ishbel Group also contains an abundance of carbonate strata (McGugan et al., 1968). Any of these formations may have acted as a potential source rock for the detrital carbonate in the Kootenay succession. Unfortunately, none of the grains observed by the writer in the Kootenay contained fossils or were distinct enough compositionally to permit identification of or correlation with their original source rock.

Sedimentary quartzite or quartz arenite grains, pebbles, and cobbles comprise another noteworthy lithic component in the Elk and Mist Mountain formations. They are most conspicuous in the conglomerate lithofacies. Quartz arenites, similar in appearance to those in the Kootenay, are found in two main lithostratigraphic units, the Ordovician Mount Wilson Quartzite (Norford, 1969); and the older, Cambrian, Gog Group (Palonen, 1976). Quartz arenite also occurs in the Pennsylvanian, Spray Lakes Group of the Banff area (McGugan and Rapson, 1963), and in some units of the Proterozoic Miette Group. However, these source strata are in general finer grained and their constituent grains differ in colour and texture from the detrital grains in the Kootenay. The Cadomin Formation is characterized by quartz arenite pebbles and cobbles that are lithologically similar to those in the Kootenay Group (Schultheis, 1970; Schultheis and Mountjoy, 1978). Schultheis and Mountjoy (*op. cit.*) suggested that the Cadomin pebbles and cobbles were derived from either the Ordovician Mount Wilson Quartzite, or from strata of the Cambrian Gog Group. They also suggested, however, that the quartzites of the Mount Wilson were too thin and areally limited in their distribution to be a major source of the quartzite in the Cadomin. The Mount Wilson outcrops only in the Main Ranges of the Rocky Mountains in the vicinity of North Saskatchewan River. For the same reasons, the writer suggests that the Mount Wilson is not the main source for the grains, pebbles, and cobbles in the Kootenay Group. Furthermore, the area where the Mount Wilson outcrops is only 77 km southwest of the northernmost occurrence of Kootenay strata. Since the direction of Kootenay sediment transport is postulated to be from the south, southwest and west, most of the area underlain by Kootenay strata is south of the present location of the Mount Wilson outcrop. Another, more widely distributed sediment source rock must, therefore, be sought for the quartzite detrital components. The Cambrian Gog Group was suggested by Schultheis and Mountjoy (1978) as an alternative source for the pebbles and cobbles in the Cadomin. The Gog also seems an appropriate source rock for similar detrital components in the Kootenay Group. The colour, texture, and impurities of the Kootenay quartzites are similar to those described for the Gog Group (Young, 1979; Palonen, 1976). In addition, strata of the Gog are thick and have widespread distribution in the Rocky Mountains. The rare quartz sandstones in the Pennsylvanian Spray Lakes Group (McGugan and Rapson, 1963), and in some of the Proterozoic rock sequences, may also have contributed to the quartzite components in the Kootenay. However, if the Proterozoic sequences were a major contributor, one would expect, in addition, other detrital components such as phyllites, slates, and conglomerates to be present in the Kootenay. To date, none have been reported by other workers or observed by the writer.

Although a conspicuous component in the coarser grained sandstones and conglomerates of the Kootenay, dark grey to brown, siliceous, semi-opaque to opaque, mudstone-argillite grains are difficult to relate to a source rock. Pebbles and cobbles of similar composition have been described in the Cadomin Formation by Schultheis and Mountjoy (1978), who suggested the Triassic Spray River Group as the most probable source. The writer has examined many samples of mudstone and siltstone in the Spray River Group using a petrographic microscope (Gibson, 1971, 1974, 1975), and would not agree with the Triassic source suggested by Schultheis and Mountjoy (*op. cit.*). Most grains in the Kootenay display a siliceous, cherty cement, and are characterized in part by brown to black, semi-opaque, ferruginous or carbonaceous matter. These properties are not found in Triassic strata. Thus, an alternative source rock must be suggested. One may again suggest the Permian Ishbel Group. It has been described as containing siliceous mudstone-argillite interbeds by McGugan and Rapson (1963). Other possible source rocks containing siliceous mudstones, argillites, and shales are strata of the Banff, Exshaw and Perdrix formations. Jansa (1972) considered the metamorphic rock complexes of the Purcell Mountains and the Shuswap area as possible source rocks for some of the Kootenay sediment.

Collophane is the last of the noteworthy detrital components in the Kootenay Group. It occurs as well rounded grains, pellets and rare ooliths, ubiquitously distributed throughout the Kootenay strata, although in relatively low concentration. The detrital phosphate may be from three possible source rocks; the Triassic Spray River Group (Whistler and Winnifred members); the Permian Ishbel Group (Ranger Canyon and Mowitch formations); or the Permian Phosphoria Formation of Montana, Idaho and Wyoming. The Triassic phosphates are thin and limited in their distribution, although they are characterized by granular beds containing pellets, well rounded grains and ooliths (Gibson, 1971). The phosphate in the Permian Ranger Canyon and Mowitch formations is more common and laterally more extensive, and thus may represent a more probable source rock for the phosphate in the Kootenay. Potentially the most phosphatic source rock, however, is that of the Permian Phosphoria Formation of Montana, Idaho and Wyoming (Sheldon, 1963). With a postulated sediment transport direction for the Kootenay strata from the south, southwest and west, the Phosphoria may also have contributed some of the phosphate detritus to the Kootenay.

Provenance

Two different possible source areas have been suggested for strata of the Kootenay Group and overlying Cadomin Formation. One group of investigators, including Norris (1964b, 1971), Rapson (1964, 1965), Mellon (1967), Jansa (1971, 1972), and McLean (1977), suggest that the Kootenay and/or Cadomin sediments were derived from the Western Ranges of the Rocky Mountains, the Purcell and Selkirk Mountains, and the Shuswap Metamorphic Complex of central British Columbia. The last three areas are west of the Rocky Mountain Trench. The second group, including Price (1965), Schultheis (1970), Schultheis and Mountjoy (1978), and the writer (Gibson, 1977b), suggest a provenance or source area comprising mainly the Main and Front ranges of the Rocky Mountains.

Price and Mountjoy (1970), Schultheis (1970), and Schultheis and Mountjoy (1978) have provided data to suggest that the Upper Jurassic-Lower Cretaceous sediments (Kootenay and Cadomin), in the Rocky Mountains of Alberta and British Columbia, were derived from rising thrust sheets developing in the Rocky Mountains, in the area east of the Rocky Mountain Trench. The writer agrees with these observations and conclusions, and suggests a similar provenance for strata and sediment of the Kootenay Group (Gibson, 1977b). Evidence in support of the above source area has been outlined in the foregoing discussion of source rocks. Evidence in support of a more westerly sediment source area (i.e. west of the Rocky Mountain Trench) for the Kootenay Group and Cadomin Formation, has been mainly based on the identification of lithic rock fragments and minerals, which have been suggested to be of metamorphic and pyroclastic volcanic origin (Mellon, 1967; Rapson, 1964, 1965; Jansa, 1971, 1972). However, as noted in the foregoing paragraphs, these grains, which are rarely observed, except for the metamorphic quartzite fragments reported by Rapson (1964, 1965), may actually represent recycled grains that have been derived, not from a western source area, but from an area to the east on the Canadian or Precambrian Shield where metamorphic and volcanic rocks are common. It is possible, however, that some of the "Kootenay" and "Cadomin" streams and rivers had their headwaters or source in the area west of the Rocky Mountain Trench. This possibility may account for the occurrence of the enigmatic, green chert pebbles and cobbles and, perhaps, some of the rare metamorphic minerals and grains. Most evidence to date suggests that the main source of sediment was from the rising thrust sheets east of the Rocky Mountain Trench. Convincing evidence in support of a more westerly sediment source is lacking.

PALEOENVIRONMENTS AND DEPOSITIONAL HISTORY

Introduction

Paleoenvironments and the depositional history of the Kootenay Group have been described and discussed by such writers as Bell (1956), Rapson (1964, 1965), Norris (1964b, 1971), Mellon (1967), Jansa (1972, 1981), Stelck et al. (1972), Gibson (1977b), Hamblin and Walker (1979), Gibson and Hughes (1981), Gibson (1983), Gibson, Hughes and Norris (1983), and Hughes and Cameron (in press). Many of these discussions or reports are brief and lack data, concern only specific geographic areas, or discuss only specific formations or stratigraphic units of the Kootenay Group.

The writer, in an earlier preliminary report (Gibson, 1977b), described and discussed the paleoenvironments and depositional history of the Kootenay rocks in the Crowsnest Pass area of Alberta and British Columbia. The interpretation presented was of a preliminary nature, based mainly on fauna, lithology, lithological relationships and sedimentary structures. With the petrographical laboratory phase of the investigation now complete, it is found that some modification is necessary in the paleoenvironmental interpretation of part of the Morrissey Formation. The original interpretation of the Mist Mountain (Coal-Bearing member) and Elk formations (Elk Member) remains essentially the same, with only minor revision for the Elk Formation. The following discussion will, therefore, emphasize the paleoenvironments and depositional history in the central and northern part of the report area, but will include, where pertinent, a review of the depositional events in the Crowsnest Pass area.

Kootenay strata are depicted as having formed part of a major north to northeasterly prograding clastic wedge, deposited along the western margin of a large Jurassic-Cretaceous epicontinental sea, occupying what is commonly referred to as the Alberta basin (Stelck et al., 1972). The basin was bounded on the west by an elevated or highland sediment source area, the origin of which appears to have been a series of rising thrust sheets (Price and Mountjoy, 1970; Schultheis, 1970; Schultheis and Mountjoy, 1978), which later formed part of the Rocky Mountains. To the south was another elevated land mass, part of which may have been attached to the Sweetgrass Arch. It is not known what the basin configuration was like to the east because Kootenay strata have been erosionally truncated by the pre-Cadomin unconformity. Hamblin and Walker (1979) have indicated that the southeastern margin was bounded by a highland area called the "Aptian Ridge". The nature of the northern boundary is speculative and uncertain. Stelck et al. (1972) have suggested that the Peace River Arch formed a natural barrier, thus necessitating a "Pacific connection" for the Jura-Cretaceous sea. However, Stott (1968) has recorded strata equivalent to the Kootenay Group much farther north than the Peace River Arch area, at least to the area of Mount Trimble and Sikanni Chief River.

Kootenay strata are envisaged as forming part of a broad coastal plain depositional environment, characterized by a number of large and small, high energy, wave-dominated deltas with extensive deltaic and interdeltaic areas typified by laterally extensive beaches, beach ridges and, possibly, small sand dunes (Fig. 94). Reineck and Singh (1973) have described a typical vertical stratigraphic profile of a prograding mainland beach environment. The major facies noted were, in descending order: alluvium, marshes with peat-coal, coastal sand, transition zone, and shelf mud. Tidal flat and lagoonal deposits were absent, but may occur on prograding coasts of a barrier island. The sandstones of the Weary Ridge Member, and those of the overlying Moose Mountain Member, typify the coastal sand facies, while strata of the underlying Passage and "Grey beds" of the Fernie Formation are characteristic of sediments of the transition and shelf zones respectively. The alluvium and marshes correspond to the lower strata of the Mist Mountain Formation.

The analysis of sedimentary facies, facies relationships and petrographic data; the occurrence or absence of diagnostic sedimentary and biogenic structures; and the presence or absence of characteristic megafossil, microfossil, and microfloral assemblages suggest that strata of the Kootenay Group were deposited in three major depositional environments. At the base, the Morrissey Formation is diagnostic of a paralic environment, with available evidence suggesting that the sandstones formed part of a littoral environment, which included beach, beach ridge and, possibly, small coastal dune deposits. The overlying Mist Mountain Formation, although characterized by sporadic marine or brackish-marine incursions in the northern part of the report area, is interpreted as a fluvial-deltaic-interdeltaic succession, deposited in an environment largely unaffected by marine or brackish water inundations. The Elk Formation represents deposition within a major, coastal, fluvial-alluvial plain depositional environment, similarly unaffected by marine brackish water incursions. In the area of the southern Rocky Mountain Front Ranges, the Elk Formation contains strata which, in part, are characteristic of a distal alluvial fan or braidplain depositional environment.

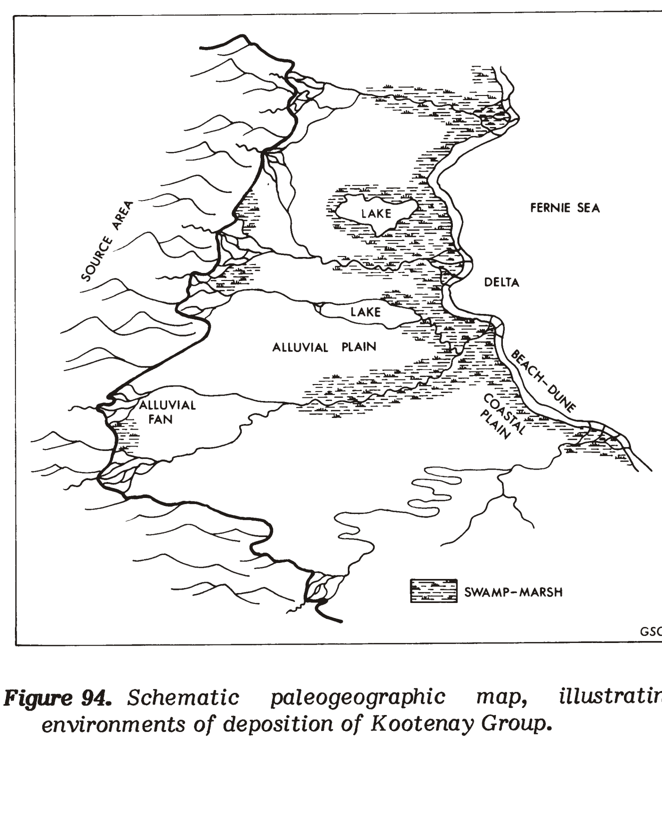

Figure 94. *Schematic paleogeographic map, illustrating environments of deposition of Kootenay Group.*

Morrissey Formation

Modern deltas and deltaic environments have long been of interest to stratigraphers and sedimentologists involved with the study of ancient deltaic rocks. With much of the early work on deltas directed toward the Mississippi Delta (Russell, 1940; Fisk et al., 1954; Coleman and Gagliano, 1964, 1965; Coleman et al., 1969), little published information has been available on deltas and deltaic processes in other parts of the world with which to compare the Kootenay and other ancient examples. Accordingly, many workers by necessity were limited to the Mississippi model. Some were successful but others were not, and encountered difficulties in their comparisons. In recent years, however, several other modern deltaic systems have been studied from other parts of the world, such that new information on these deltas is now making its way into the literature. Investigations by such workers as Allan (1965, 1970), Oomkens (1967, 1974), Mathews and Shepard (1962), Meckel (1975), Wright and Coleman (1973), Coleman and Wright (1975), Galloway (1975), and Van Andel (1967) have done much to alleviate the problem and assist stratigraphers and sedimentologists in their interpretations of ancient rocks, by making new and additional data on recent deltas available.

Of most relevance and importance to the study and interpretation of the Morrissey Formation are the studies on modern deltas by Galloway (1975) and Coleman and Wright (1975). Their investigations have assisted the writer in establishing an overall depositional model for rocks of the Morrissey Formation. For example, Galloway (1975) has proposed three major delta models into which most modern delta complexes may be assigned. These include: 1) fluvial-dominated deltas such as the Mississippi River, 2) wave-dominated deltas such as the São Francisco off the coast of Brazil, and 3) tide-dominated deltas such as the Klang Langat of Malaysia. Coleman and Wright (1975) have proposed six delta model types. Their São Francisco River model is most applicable to the interpretation of the Morrissey sandstones. This delta is characterized by high, continuous wave energy with an intermediate tidal range, dominated by strong littoral currents along a relatively steep offshore slope. Some of the remaining five delta models exhibit some similarities to the sandstones of the Morrissey, but not to the same degree as those of the São Francisco. A similar analogy to that of the São Francisco was suggested in reports by Hamblin and Walker (1979), Gibson and Hughes (1981), Gibson (1983), Gibson, Hughes and Norris (1983), and Hughes and Cameron (in press).

The depositional environment of the basal sandstone of the Kootenay (Morrissey Formation) has been discussed in varying detail for part of the report area by Norris (1964b), Mellon (1967), Jansa (1972), Gibson (1977b), Hamblin and Walker (1979), Gibson and Hughes (1981), Gibson (1983), Gibson, Hughes and Norris (1983), and Hughes and Cameron (in press). All agree that the Morrissey presents part of a paralic paleoenvironment, consisting predominantly of littoral sandstone. The writer, in an earlier report (Gibson, 1977b), described and discussed some of the problems related to the environmental interpretation of these strata in the Crowsnest Pass area. It was suggested that the sandstones represent a combination of delta front sheet sands, strand plain and barrier island depositional environments. Since the earlier work of the writer, additional reports have been published containing information on the stratigraphy and paleoenvironments of the Morrissey Formation. Hamblin and Walker (1979), in a predominantly sedimentological study of the Fernie - Kootenay lithostratigraphic transition, provided information and data on paleocurrent trends and depositional regime, and proposed a depositional model for the marine to nonmarine transitional lithofacies that included the Morrissey Formation. Gibson and Hughes (1981), Gibson, Hughes and Norris (1983) in a structural, stratigraphic and sedimentological study of the Kootenay Group in the Crowsnest Pass area; Gibson (1983), in a stratigraphic and sedimentologic study of the Kootenay group in the Highwood Pass-Kananaskis Country area; and Hughes and Cameron (in press), in a stratigraphic, sedimentologic and coal-rank study of the Kootenay Group near Mount Allan and Canmore, Alberta, likewise proposed a depositional model for the Morrissey as well as the overlying strata of the Kootenay Group. The writer, as a result of discussions with J.D. Hughes and other colleagues at the Geological Survey of Canada, has reinterpreted and modified some of his earlier observations.

Weary Ridge Member

The Weary Ridge Member of the Morrissey Formation comprises a medium- to thick-bedded, slightly argillaceous, ferruginous and partly calcareous, fine- to medium-grained quartz sandstone. It is characterized by coarse, parallel, light and dark grey laminations, medium to large scale planar-tabular crossbedding, and medium to small scale festoon or trough crossbedding. The member forms the basal part of a general coarsening-upward lithostratigraphic succession. The sandstones are interpreted to have been deposited as part of a laterally extensive beach (backshore, foreshore and shoreface) within a high energy, wave-dominated delta environment, similar in many ways to that found today on the São Francisco delta of Brazil. The delta of the São Francisco River consists of a laterally extensive, prograding, sheet sand beach facies, deposited along a relatively steep-sloped coastal environment characterized by a high wave-energy index (Coleman and Wright, 1975). In addition, the Brazilian coast at this locality is subjected to high wind velocities which, when coupled with the wave activity, produce a smooth non-lobate shoreline. This coastal complex contrasts, for example, with that developed off the mouth of the Mississippi River in the Gulf of Mexico, where the delta complex displays a protruding lobate configuration. In addition, the sands of the São Francisco delta are clean, well sorted and very quartzose (95% quartz). They are overlain by an extensive development of beach ridges and sand dunes. The sandstones of the Weary Ridge Member have similar physical and compositional properties to those in the São Francisco delta, and regionally display a laterally extensive sheet sandstone configuration (Fig. 16). In addition, sedimentary structures and the combination of sedimentary structures, plus facies relationships with the underlying prodelta strata of the "Passage Beds" of the Fernie Formation, support the beach interpretation. Coleman and Gagliano (1965), Bernard et al. (1973), Clifton et al. (1971), and Davidson-Arnott and Greenwood (1976) have recorded and described sedimentary structures and structural combinations (in recent deltaic and coastal beach sandstone lithofacies) that are similar in scale to those found in the Weary Ridge Member. Likewise, Young (1955), Masters (1967), Frazier (1967), Fisher and McGowan (1967), Davies et al. (1971), Van de Graaff (1972), and Erxleben (1975) have described sedimentary structures in ancient sandstone strata, which they have interpreted as characteristic of coastal interdeltaic beach, barrier beach and delta front sheet sandstones. Unlike the recent São Francisco delta, whose sediment is mainly the product of one major river, the sheet sandstones of the Weary Ridge Member are suggested to be the product of several fluvial systems with the source area located to the west, southwest, or south.

Paleocurrent observations by Hamblin and Walker (1979) have suggested sediment transport for the Fernie-Kootenay transition strata to be predominantly from the south and southeast. However, as noted by Jansa (1981), some, or perhaps most, paleocurrent values may reflect coastal longshore drift and not necessarily the direction of fluvial transport into the depositional basin. It is suggested herein that, based on lithologic relationships and thickness trends, the sediments were mainly derived from the south and southwest. Evidence is not available as to the nature of the sediment source or distribution along the eastern margin of the Jurassic-Cretaceous sea, because of pre-Cadomin erosion. Reliable paleocurrent readings are difficult to obtain for the member because of its generally poor exposure, or, where well exposed, because of its generally cliff-forming and inaccessible nature (figs. 12, 13, 20). In general, three-dimensional views of the crossbedding are not available. Thus, systematic paleocurrent analyses were not attempted by the writer. The interested reader is referred to the work of Hamblin and Walker (1979), even though, as noted above, their results may in some cases be open to alternative interpretations (Jansa, 1981).

It is interesting to note that, to date, the writer and other workers have not observed strata in the Weary Ridge Member suggestive of a major, or even minor, distributary channel facies, a feature one might expect in a delta succession. This may be explained by suggesting that the channel and associated facies may be present in some areas but are not exposed, or, if present, have perhaps been misinterpreted. However, it is much more likely that evidence of such a channel facies has been removed by sediment reworking within the postulated high energy, wave dominated environment.

Burrowing is not common in strata of the Weary Ridge Member, although Hamblin and Walker (1979) noted small organic trails and burrows in sandstones equivalent to the Weary Ridge. The level at which burrows were observed and the geographic area of observation were not reported. Burrowing and evidence of bioturbation are generally common in modern beach facies, particularly in the area of the middle and lower shoreface (Bernard et al., 1973; Hayes and Kana, 1976; Davidson-Arnott and Greenwood, 1976). The general lack of burrowing or evidence of bioturbation in the Weary Ridge Member may be the result of the high energy depositional environment in which the sandstones were deposited, or, alternatively, may be due to rapid progradation and burial of the sediments. Under such conditions, burrowing organisms may not have been able to keep pace with sediment accumulation, and consequently moved seaward into a more hospitable and deeper water environment. Evidence in support of this alternative interpretation is shown by the burrows and intense bioturbation in the siltstones, mudstones, and shales of the underlying prodelta "Passage Beds" of the Fernie Formation (Jansa, 1972; Hamblin and Walker, 1979).

Another unusual characteristic related to the beach interpretation was recognized and discussed by Hamblin and Walker (1979). The thickness of the member, when compared to recent and other ancient beach examples, is not typical of a beach depositional environment. In addition, Hamblin and Walker (*op. cit.*) also noted the presence of a sharp erosive base with sole marks at some of their measured sections, a characteristic which is considered unusual in most recent beach lithofacies. Commonly, beach facies display a gradational contact, with the sandstones interfingering or interdigitating with marine mudstones and shales of the delta front facies (Bernard et al., 1973; Coleman and Wright, 1975). To explain the abrupt, erosional basal contact and unusually thick sandstone, Hamblin and Walker (1979) suggested that the upper part of the Weary Ridge Member may in fact comprise an eolian dune facies, with evidence for such a facies having gone unrecognized or having been overlooked. The writer suggests, however, as an alternative explanation, that the thicker than normal beach sandstones of the Weary Ridge represent the product of rapid sedimentation and progradation into a depositional basin undergoing active and rapid subsidence. The erosional base and rare sole marks may have been noted at a few field sections by Hamblin and Walker (*op. cit.*), but generally are not in accordance with observations by the writer or Hughes and Cameron (in press) elsewhere in the report area. As noted and discussed in an earlier section, the contact with the underlying "Passage Beds" of the Fernie Formation, although abrupt in many places, is sedimentologically gradational (figs. 12-18, 20).

The anomalous isopach patterns (displayed in Fig. 16) of the Morrissey Formation are interpreted as being mainly due to strata of the Weary Ridge Member. At first glance the isopach anomalies may be interpreted as a result of the presence of distributary channel or distributary mouth bar lithofacies. However, to accept this interpretation one requires some evidence of distributary channel or distributary mouth bar facies where the strata are anomalously thick; for example, evidence of a locally conspicuous grain size change, or the presence of sedimentary structures typical of channels or mouth bars, or evidence in the lithological relationship between Weary Ridge strata and the underlying "Passage Beds" facies. No evidence of this kind has been found in the Weary Ridge strata at the localities where the member is anomalously thick.

At a few sections one finds an unusually thick "Passage Beds" facies compared to the Weary Ridge facies and vice versa. A thick "Passage Beds" facies may reflect the location of a former major distributary channel or distributary mouth bar development. One may expect this sandy facies to be overlain by a thin, or at least thinner, beach facies. Any excess sand normally available for beach buildup would be distributed by wave and longshore current activity away from the distributary into the interdistributary area. A facies in which the "Passage Beds" are thin or absent may be interpreted as representing the interdistributary-interdeltaic area on the coast, where the deeper water, offshore shale facies would be directly overlain by the thicker sheet sandstones of the prograding beach. These interpretations may be postulated for the sections near Sentinel-Highwood Ranger Station (Sec. 76-5), Isolation Ridge (Sec. 76-14), Mount Allan (Sec. 76-7), and the Cascade River-Banff traffic circle locality (Sec. 76-8) of Figure 3. Similar facies relationships have not been observed at other localities, because strata of the "Passage Beds" facies are typically poorly exposed or covered.

Available evidence suggests that the unusual thickness patterns depicted on Figure 16 are a result of the interfingering and gradational nature of the Weary Ridge to "Passage Beds" contact. The contact, as noted previously, is assigned according to the presence or absence of mudstone-siltstone-shale interbeds in the transitional sandstone lithofacies. If these interbeds are present in the strata near the contact, much of the sandstone unit would be interpreted as part of the "Passage Beds" strata; if, however, the mudstone-siltstone-shale facies is absent in the transitional strata, the sandstone unit would thus be interpreted as part of the Weary Ridge Member.

It has been suggested by Jansa (1972), and accepted as a possibility by the writer (Gibson, 1977b), that strata of the Weary Ridge Member may be interpreted as a delta front sheet sand (i.e. a series of coalescing baymouth bars, subaqueous distributary channels, and distal bars). With this interpretation, one is immediately faced with the difficulty of explaining the great lateral extent of the basal sandstone unit – over 384 km long by 140 km wide – as the product of one or two prograding deltas. In addition, the Weary Ridge Member lacks, in most observations, evidence of marine intertonguing or the presence of marine shales or siltstone interbeds, a facies common in distributary mouth bar and delta front sandstones and sheet sands. Coleman and Gagliano (1965), Fisher and McGowan (1967), Saxena et al. (1972) and Bernard et al. (1973) have described recent and ancient examples of distributary mouth bar-delta front sheet sand lithofacies that are composed mainly of fine grained sands with marine mud interbeds, containing evidence of a marine fauna or flora. Such lithologic and faunal characteristics have been noted by Jansa (1972), Gibson (1977b), and Hamblin and Walker (1979) only in strata characteristic of the underlying upper beds of the "Passage Beds" of the Fernie Formation. Such lithologic attributes have not been described as typical of the Weary Ridge Member. However, at localities between Limestone Mountain (Sec. 76-18; figs. 1, 3) and North Saskatchewan River, strata of the Morrissey Formation cannot be separated into individual members. In this area, the sandstones become generally finer grained, more siliceous, and occasionally contain thin mudstone-siltstone interbeds, the concentration of which increases in the vicinity and north of North Saskatchewan River. In the northern region, the basal sandstone unit thins and grades laterally into a succession of fine- to very fine-grained sandstone containing a conspicuous concentration of siltstone, mudstone and shale interbeds (Fig. 21). These strata form the basal part of the Nikanassin Formation and resemble in many ways those typical of the upper "Passage Beds" of the Fernie Formation. Thus, in the Limestone Mountain - North Saskatchewan River area, the basal sandstones of the Kootenay Group may represent facies of a former distributary mouth bar or a delta front sheet sandstone. In this area, coal has not been observed in the Mist Mountain strata adjacent to the Morrissey Formation (see Sec. 76-18; Fig. 9). The basal strata of the Mist Mountain in this region contain evidence of marine to brackish-marine incursions, lithofacies that one would expect to find in association with distributary mouth bars and delta front sheet sandstones. The beach-beach ridge-dune lithofacies, so characteristic of the Morrissey Formation to the south, cannot be recognized in this area.

Hamblin and Walker (1979) interpreted the upper "Passage Beds" (hummocky, cross-stratified sandstones) as a product of turbidity current deposition below normal wave base, and subsequently reworked, probably at or near storm wave base. In view of the gradational but generally abrupt nature of the contact between the "Passage Beds" and the Weary Ridge Member, the writer suggests that only the lower facies of the upper "Passage Beds" (hummocky cross-stratified sandstone) was deposited below normal wave base. The upper "Passage Beds" strata, with their predominance of sandstone, may, in areas where the facies is thick, represent a distributary mouth bar facies. In areas where the facies is thin, however, and consists mainly of shale with only rare sandstone interbeds [i.e Sentinel-Highwood Ranger Station (Sec. 76-5), Isolation Ridge (Sec. 76-14) and Trap Creek (Sec. 76-12)], the upper "Passage Beds" facies may represent interdeltaic or interdistributary basinal areas.

Moose Mountain Member

The Moose Mountain Member forms a conspicuous portion of the basal unit of the Kootenay Group, and consists of well indurated, dark grey weathering, massive, cliff-forming sandstone (figs. 12, 13, 14, 20). These sandstones, with those in the underlying Weary Ridge Member, form part of the same high energy, wave-dominated delta-coastal plain complex, although the depositional subenvironment for Moose Mountain strata has proven more difficult to interpret. Three main subenvironments have been postulated: a beach or paralic depositional environment; a braided stream, fluvial environment; and, most recently, a beach ridge-eolian dune depositional environment. Norris (1964b) suggested that the Moose Mountain sandstones formed part of a beach environment which, at some localities in the Fernie area, was subjected to marine inundations. Jansa (1972) suggested that the Moose Mountain comprised a stacked offshore barrier system overlain by a distributary mouth bar complex. He suggested that the upper two thirds of the member were locally (at Banff) deposited as part of a medium energy, tidal flat environment.

The writer, in an earlier preliminary report (Gibson, 1977b), implied that the sandstones of the Moose Mountain may be interpreted as forming part of either an interdeltaic, beach-barrier island, or a delta front-sheet sand depositional environment. It was, however, suggested by the writer, that perhaps the sandstones of the Moose Mountain, along with those of the Weary Ridge Member, may in fact represent a combination of all the above environments. Upon completion of all phases of the Kootenay study, and after assessing the field and laboratory evidence, the writer has recently modified the earlier interpretation (Gibson and Hughes, 1981; Gibson, Hughes and Norris, 1983; and Gibson, 1983). Conclusive or convincing evidence in support of a delta front-sheet sand or a barrier island-beach sand is generally lacking. For example, in both the delta front and barrier beach interpretations, one would expect to find some marine or brackish water shales or sandstones interfingering with the Moose Mountain sandstones, or at least some evidence of marine or marine-brackish lagoonal strata overlying them. To date, however, no such supportive evidence has been obtained in most of the report area. Only in the vicinity of Red Deer River, near Banff National Park, and in the area of North Saskatchewan River were any marine or brackish marine fossils recovered within or above the Moose Mountain Member. In this northerly area, marine foraminifera were obtained from strata above the Moose Mountain Member and indicate a marine to brackish water depositional environment. One may, therefore, suggest a possible delta front-sheet sand or barrier beach depositional subenvironment for the Moose Mountain strata in this northern area. Marine dinoflagellate cysts have been reported by Pocock (1964) and Norris (1959b) from strata of the Moose Mountain Member at Grassy Mountain, although it is not certain whether they were from the base of the Moose Mountain or top of the Weary Ridge, as recognized and defined by the writer. If they were collected from the basal Moose Mountain Member, they may, depending on concentration, have been introduced as windblown material, or perhaps, alternatively, as reworked specimens from the underlying marine Jurassic Fernie Formation. The discovery of a large ammonite, *Titanites occidentalis*, by Newmarch (1953) at the top of strata equivalent to the Moose Mountain Member, was cited by Norris (1964b) as evidence of at least a local marine depositional environment for the sandstone. A large ammonite fragment, similar in appearance to *Titanites*, was found by Hamblin and Walker (1979) at Tent Mountain, in the stratigraphic equivalent of the Moose Mountain Member. They suggested that the ammonite fragment may represent a piece of reworked shell originally derived from a beach environment. The writer, however, suggests that the ammonite fragment probably represents a wind emplaced specimen or fragment, deposited initially on the beach during an exceptional coastal storm. Today, along some coasts of Australia and the Fiji Islands, shells of *Nautilus*, a recent relative of the ammonite, are found in relative abundance washed up on many beaches. If such shells and shell fragments were washed up on beaches during the time of deposition of the Kootenay and Moose Mountain sands, they could easily be preserved within the subaerial beach or littoral environment. The size and predominant type of laminations and crossbedding in the Moose Mountain Member, and its relationship to the sandstones of the underlying Weary Ridge Member, do not provide sufficient evidence in support of an exclusive subaqueous beach depositional environment interpretation for the member in the study area.

Another paleoenvironmental interpretation of the Moose Mountain sandstones has recently been postulated by Hamblin and Walker (1979). They disagreed with the beach or littoral interpretation of other workers and suggested instead, a fluvial, braided channel depositional environment. It was suggested by Gibson and Hughes (1981); Gibson (1988); Gibson, Hughes and Norris (1983); and Hughes and Cameron (in press) that such an interpretation is not in keeping with the regional distribution, thickness, and other characteristic lithological attributes of the member. It was noted by Hamblin and Walker (*op. cit.*), however, that their interpretation lacked certain criteria diagnostic of a fluvial deposit. The unbroken, widespread distribution of the sandstone, its clean and well sorted nature, general lack of carbonaceous plant fragments and woody material (with the exceptions noted above), do not support a braided or even meandering fluvial origin for the sandstones. Recent fluvial sands, or their ancient analogues, have never been demonstrated to occur uninterrupted along such an extensive area of coastline, 384 km in length. Furthermore, most fluvial strata are characterized by moderate sorting (Reineck and Singh, 1973, and others) and commonly contain coaly, carbonaceous plant or woody material.

It is suggested that most sandstones of the Moose Mountain represent a subaerial beach ridge-eolian dune depositional environment, locally breached by fluvial channels. The rare mudstones and thin coal seams noted in the Elk River valley area are interpreted as representing interdune, lacustrine-swamp depositional environments. Based on the work of Gripp (1968), Reineck and Singh (1973) noted that coastal dunes are common along prograding shorelines, and that the interdune areas may be characterized by hollows or depressions containing water. Such depressions may support the growth of vegetation, leading eventually to the accumulation of peat and coal. Coleman (1975), and Coleman and Wright (1975), in their study of recent deltas, emphasized the importance of wind in some deltaic and coastal environments. For example, they have noted that in recent deltas where persistent winds and high wave energy are present, the subaerial delta facies consists primarily of windblown sand, which is transported over the delta plain as a transgressive sheet, such that, in many observations, the entire subaerial delta deposit consists of windblown sand. Galloway (1975) likewise noted that in wave-dominated delta environments such as the São Francisco, beach ridge and dune sands are a common environmental component. A similar environmental setting is postulated for strata of the Moose Mountain Member.

Examples of some recent beach ridge-coastal dune environments containing strata and sedimentary structures, and displaying basal contact relationships similar in some ways to those of the Moose Mountain Member, have been figured and/or described for subaerial sandstones of the São Francisco delta (Coleman and Wright, 1975; Galloway, 1975); the strand plain coastal complex of Nayarit, Mexico (Curray et al., 1969); the coastal dunes and beach-dune ridges of New Brunswick and Prince Edward Island, Canada (Reinson, 1979); and the coastal dunes and beach-dune ridges of the Paranâ coastal area of Brazil (Bigarella, 1965, 1972; Bigarella et al., 1969). Some of the more important criteria useful in the recognition of the subaerial, dune-beach ridge environment have been described or documented in studies by Bigarella (*op. cit.*), Bigarella et al. (*op. cit.*), McKee (1966a), Campbell (1971), Shelton (1973) and Reinson (1979). For example, Bigarella (1972) observed that crossbedding, a common structure of dune sands, was dominated by medium to large scale wedge-planar and tabular-planar types, with trough or festoon types common locally. Reinson (1979), in a review of backshore-dune deposits on barrier islands, noted that dune sands were characterized mainly by small to medium scale trough crossbedding, but noted also that planar crossbedding was common. Shelton (1973), in a general study of recent and ancient sand and sandstone models, described the base of dune sands and sandstones as being sharp or abrupt. He recognized the presence of large and small scale, horizontal, low angle and festoon crossbedding as typical of dune facies, but, in addition, drew attention to the fact that the scale of structures developed was a function of the original size of the dune or beach ridge.

In support of the beach ridge-dune interpretation for the sandstones of the Moose Mountain Member, evidence provided by the nature of the underlying contact and associated sedimentary structures is most convincing. The contact is abrupt (figs. 12, 13, 14), with the basal strata of the Moose Mountain commonly displaying medium to small scale, festoon crossbedding and, occasionally, wavy, planar laminations. In contrast, strata of the upper Weary Ridge Member display planar laminations and/or planar-tabular crossbedding, structures typical of the backshore facies of a beach depositional environment. A similar contact relationship with similar sedimentary structures has been figured and described by Bigarella et al. (1969), Davies et al. (1971), Campbell (1971), Shelton (1973), and Reinson (1979), as characteristic of the beach-dune depositional environment.

In the fall of 1980, the writer had the opportunity to examine some recent beach, beach ridge and dune sands along the coasts of Prince Edward Island and New Brunswick, Canada, and compare them with sandstones observed in the Morrissey Formation. The similarity in contact relationships and sedimentary structures between the recent sand and ancient sandstone was noteworthy. Sands of the beach backshore environment were characterized by parallel, slightly landward dipping laminae which, at the localities visited, were in abrupt contact with the overlying small to medium scale, festoon and, less common, planar-tabular crossbedded sands of the dunes.

As noted above, crossbedding in many recent and ancient dunes has been described as planar-tabular, commonly displaying a medium to large size profile (McKee, 1966a; Bigarella et al., 1969; Bigarella, 1972). Crossbedding of this type and scale is not commonly found in the Moose Mountain Member, although planar-tabular crossbeds were observed at some localities. Trenching in some modern coastal dunes (see Bigarella et al., 1969, p. 21) provides illustrations of the type and scale of sedimentary structures found both longitudinally and transversely through an eolian dune. Trenches parallel to the prevailing wind direction illustrate a consistent landward dip for the crossbedding, while those transverse to the prevailing wind display a shallow, festoon configuration (Bigarella et al., 1969, p. 21). Crossbedding of the latter type occurs in the sandstones of the Moose Mountain Member. Unfortunately, most exposures of the Moose Mountain occur along northwest-southeast trending escarpments and ridges, which parallel the postulated western margin of the depositional basin (Fig. 94). Access to the field exposures is difficult because of the cliff-forming nature of the strata (figs. 12, 13, 20). Accordingly, the longitudinal profile of the crossbedding is rarely observed. Moreover, when access is available, the rock is often lichen or moss covered, or displays a deep, dark grey weathering rind (figs. 12, 13, 14). Consequently, reliable paleotrend azimuth values are difficult to obtain. Hamblin and Walker (1979), in their study of the Fernie-Kootenay transition, recorded some paleocurrent azimuth values from the Moose Mountain Member, having a vector mean average of 034° and standard deviation of 86°. With the 034° azimuth value reflecting wind direction, as postulated by the writer, rather than the fluvial flow pattern, as postulated by Hamblin and Walker (*op. cit.*), one immediately faces the difficult task of explaining the westward, landward migration or development of the beach ridge-dune lithofacies. Most recent examples of coastal dunes migrate landward rather than seaward. However, because of the high standard deviation and associated or related spread of azimuth values obtained by Hamblin and Walker (*op. cit.*), coupled or combined with, or complicated by the generally inaccessible cliff-forming outcrops, one may suggest that the paleocurrent or paleowind trend direction may have been from an easterly or northeasterly direction. The major depositional framework postulated for the sediments of the Morrissey Formation (Weary Ridge and Moose Mountain members) favors a prevailing easterly or northeasterly wind direction, one which would provide the necessary high energy, wave-dominated environment postulated for the deposition and distribution of the sand-sized sediment. Hamblin and Walker (*op. cit.*) were the first to postulate a wave-dominated depositional environment for the sandstones of the Weary Ridge Member, but did not indicate or suggest the prevailing wind direction necessary for the generation of the coastal waves. During Morrissey and Moose Mountain time, because of the presence of the large epicontinental Jura-Cretaceous sea, these winds may have been from the east.

Eolian dune crossbedding is often described as being of medium to large scale. The scale is, however, dependant upon the size of the original coastal dune. Thus, because of the relatively small scale of crossbedding in the Moose Mountain sandstones, the coastal dunes are interpreted to have been small. Bigarella et al. (1969, p. 21) have illustrated an example of relatively small scale, festoon crossbedding (trough axes less than 1 m) and its relationship to the backshore beach facies along the Paranâ coastal plain of Brazil. A similar environmental relationship is envisaged by the writer for the Morrissey Formation, between the sandstones of the Moose Mountain and Weary Ridge members.

The thin, coal and carbonaceous mudstone-shale facies found in the Moose Mountain of the Elk River valley area may represent the product of a former interdune, lacustrine or swale depositional environment.

The thin, lenticular beds and lenses of pebble conglomerate, observed in the member at some localities in the Crowsnest Pass area, may be indicative of former channel sands and the location of a possible major distributary. Alternatively, the conglomerate may represent a local, wind scoured, pebble lag deposit.

The foregoing beach ridge-dune environmental interpretation for the sandstones of the Moose Mountain Member, although speculative in part, because of a lack of good exposure necessary for obtaining good paleocurrent data, is presented only as an alternative working hypothesis or model. Better exposures, more critical observations, and additional data are necessary to either support or disprove the above interpretation.

Mist Mountain Formation

Following deposition of the Morrissey sandstone the coastal area began a period of active subsidence, accompanied by active progradation and the deposition of a relatively thick, eastward thinning succession of interbedded siltstone, sandstone, mudstone, shale, coal, and, locally, conglomerate, conglomeratic sandstone and rare, carbonaceous, silty limestone of the Mist Mountain Formation. These strata are interpreted to have been deposited on an extensive delta-interdeltaic coastal plain (lower Mist Mountain), and fluvial-alluvial plain (upper Mist Mountain) along the western and southwestern margin of the Jura-Cretaceous epicontinental sea. Rapid subsidence of the coastal Morrissey sandstones is indicated by the abrupt nature of their contact with the overlying Mist Mountain Formation (figs. 12, 13, 22), and by the composition of the basal strata of the Mist Mountain throughout much of the report area. For example, in the Elk River valley-Crowsnest Pass area, basal strata of the Mist Mountain are characterized by an interval of dark grey, very carbonaceous shale, coaly shale, mudstone and siltstone with thin to thick seams of coal (figs. 5-15, 22, 23). The coal and coaly carbonaceous sequence represents a probable coastal marsh environment, developed for the most part on the subaerial beach ridge-dune sand facies of the Moose Mountain Member. Accordingly, in order to accommodate the coal and coaly strata, the Morrissey and Moose Mountain sands must have subsided rapidly to allow the partly subaqueous peat facies to develop on the subaerial beach ridge-dune sands.

Mudstone and shale samples from the base of the Mist Mountain Formation have been analysed for their microfaunal content, and coal samples have been analysed for their sulphur value. To date, throughout most of the study area, no convincing evidence has yet been obtained from the basal strata of the Mist Mountain Formation to conclusively demonstrate the presence of marine or brackish marine microfossils or macrofossils. Moreover, all coals in the Mist Mountain Formation are characterized by a sulphur concentration of less than one per cent, a property typically found in coals associated with freshwater peat growth and preservation (i.e. an environment not influenced by marine or brackish marine conditions). It should be noted that Pocock (1964) recorded some probable marine dinoflagellate cysts from strata equivalent to the lower Mist Mountain Formation at Grassy Mountain (Sec. 75-1; Fig. 3). This eastern locality may represent a marginal marine delta front area, or alternatively, as suggested previously, the cysts may represent windblown specimens or possible reworked material from the underlying Jurassic Fernie Formation.

If one postulates a possible lagoonal or barrier island mud flat facies for the coal and coaly strata deposited under the influence of marine or brackish water on the landward side of a barrier system, subsidence of the barrier sands would need to be rapid in order to accommodate the development of the swamp-marsh, lagoonal facies. Evidence in support of this paleoenvironmental interpretation, as noted and discussed previously, is scarce throughout most of the study region, with the exception of the Barrier Mountain-Limestone Mountain area to the north (Fig. 3). In this northern area, marine microfossils were recovered from the lower strata of the Mist Mountain Formation, suggesting that, in this area at least, and probably in the area to the north as far as North Saskatchewan River, the lower or basal strata of the Mist Mountain Formation formed part of a delta complex (lower delta plain), adjacent to and periodically inundated by marine or brackish water. This observation is in keeping with the distributary mouth bar-delta front sheet sand environment, suggested for the sandstones of the Morrissey Formation in this northern area.

Lithofacies, lithofacies relationships and sedimentary structures have been used to interpret the main depositional subenvironments within the formation. One of the most conspicuous and sedimentologically most interesting facies of the Mist Mountain is sandstone. It ranges from very fine- to coarse-grained, and occurs most noticeably as massive, cliff-forming escarpments, along many ridges in the report area, especially in the Fernie Basin and Elk River valley (Fig. 31). Most sandstone, however, occurs as thin to medium beds interbedded with siltstone and mudstone or shale (figs. 25, 26, 27).

The cliff-forming sandstones are lenticular in profile and are interpreted to represent point bar deposits of a major channel, developed within a meandering channel system (Fig. 31). These channel sandstones are thickest and most numerous in the Fernie area, ranging from a few metres in thickness to massive units exceeding 37 m (Fig. 5). In the eastern and some northern sections, the channel sandstones, although present, are not as common, and generally are not as thick, rarely exceeding 14 m (figs. 6, 32). The reduction in the number and thickness of individual units may partly be a result of a general thinning of the Kootenay and Mist Mountain strata in an eastward direction (figs. 4, 35). The thinning is attributed to sedimentary convergence and/or pre-Cadomin erosion, or, alternatively, it may be a result of a reduction in the number of fluvial channels in the eastern area.

The channel sandstones commonly fine upwards, although some display reverse or inverse grading or no obvious grading at all. Large- to medium-scale festoon crossbedding is common in most of the facies (figs. 36, 37), although it is generally best developed in the lower parts of the channels. The size of individual crossbedded units exhibits a noticeable decrease toward the top of each channel. The upper third of these channel sandstones is commonly characterized by well preserved ripple and ripple drift or climbing ripple laminations (Fig. 58), interspersed in places with horizontal laminations. Medium to small scale planar-tabular crossbedding was also recognized, but found to be much less common than the festoon or trough type. Many of the channel sandstones are capped by or grade vertically into ripple laminated siltstone and fine, parallel to wavy laminated mudstone. Some of the latter contain a relatively conspicuous concentration of carbonized plant material.

In addition to the crossbedding and ripple laminations, some of the well developed channel sandstones in the Fernie and Sparwood area contain lenticular beds and pockets of chert-pebble conglomerate and angular clasts of siltstone-mudstone at or near the base of the channel unit. The pebbles and clasts, some of which are up to 5 cm in diameter, represent probable channel "lag deposits", a facies common to many channel sandstone deposits (Reineck and Singh, 1973). In addition to, and commonly associated with, the pebble or "lag facies" are flattened or compressed, large and small tree branch or log molds and casts, some of which are up to 15 by 76 cm in dimension (figs. 46, 47). They are concentrated mainly near the base of the channel facies, but may occur at any level in the channel sandstone. Similar structures have been reported in channel facies by Reineck and Singh (1973). They are interpreted as representing waterlogged channel debris, when found near or at the base of the sandstone. Many of the wood molds and casts contain "rinds" of vitreous coal or coal spars.

These thick, massive sandstone units in the Mist Mountain Formation are considered to be mainly the products of meandering streams as opposed to braided streams. However, some very coarse grained and conglomeratic sandstone units in the Fernie and Mount Taylor areas (Fig. 5) may represent the distal channel facies of a braided stream, although the thickness and limited lateral distribution of the conglomerate units favor a meandering model.

Farther east, in the Alberta Foothills of the Crowsnest Pass area, the rare but conspicuous channel sandstones are generally finer grained, nonconglomeratic, and relatively thin (up to 14 m thick). In addition, the concentration of wood molds and casts in the sandstone is greatly reduced. Internal sedimentary structures and contact relationships are, however, similar to those found in the channels to the west.

In the Limestone Mountain area in the north (Sec. 76-18; Fig. 3), the lower Mist Mountain Formation is dominated by an unusual, very siliceous, well indurated, fine- to medium-grained quartz sandstone, containing wavy to lenticular micaceous laminae, which give the rock a nodular, wavy appearance (Fig. 28). In addition, the sandstone contains an abundance of horizontal and vertical burrows, some of which are up to 2.5 cm in diameter (figs. 43, 44). These sandstones do not display the physical characteristics or bed geometry of channel sandstones and, accordingly, are suggested as representing part of the distributary mouth bar-delta front sheet sand lithofacies. They are interbedded with thick units of dark grey, silty to sandy shale. Some of the shales were analysed for microfossils, although at this locality they proved to be barren. However, at Barrier Mountain to the southwest (Sec. 76-17; Fig. 3), shale samples taken from strata adjacent to or interfingering with similar, but stratigraphically higher, burrowed, siliceous, nodular sandstone, contain marine foraminifera (Appendix 4).

The most common depositional environment represented by strata of the Mist Mountain Formation is that of the floodplain. This environment includes levee, crevasse splay or overbank splay, and flood basin deposits. The last subenvironment includes the fluvial swamp-marsh and lacustrine lithofacies. Within all these subenvironments sandstone remains an important lithotype. These sandstones contain many of the same sedimentary structures and lithological attributes as those of the channel facies (Fig. 27). However, in contrast to the channel sandstones, the size of the sandstone units and individual sedimentary structures are noticeably smaller. The texture and composition of the sandstone also differs by being generally finer grained, and displays a greater concentration of carbonaceous-argillaceous and vegetal matter.

The crevasse splay sandstones, which are generally thicker bedded and coarser grained than the overbank sandstones, are characterized by small scale, and rare medium scale, festoon and ripple drift crossbedding and ripple laminations. In addition, these sandstones fine upwards and become finer grained laterally, away from the main channel source area.

Most of these sandstones, including the crevasse splay and overbank facies, are darker grey than those of the main channel-point bar facies, reflecting an increase in concentration of coaly vegetal matter, as well as an associated increase in concentration of clay. In addition, most of the sandstones grade vertically into thin units of siltstone and/or mudstone, strata indicative of waning current activity and deposition in a relatively tranquil depositional environment.

The crevasse splay sandstones resemble those of a levee deposit and, as noted by Reineck and Singh (1973), may be difficult to differentiate in both continuous and isolated exposures. Levee sandstones, however, tend to be finer grained but, most importantly, may contain evidence of subaerial exposure, such as the presence of mud cracks, raindrop imprints, and vegetal or coaly layering in the more muddy units (Reineck and Singh, *op. cit.*). In addition, levee deposits may resemble the texture and composition of upper point bar deposits but, like those of a crevasse splay, are generally finer grained and display some evidence of subaerial exposure. Levee deposits were not identified in the Mist Mountain Formation, although some of the very fine grained sandstone-siltstone-mudstone combinations or cycles overlying major channel sandstones may represent levee strata.

Most of the thinner sandstone units and/or individual thin sandstone beds, especially those alternating or interdigitating with the siltstone and mudstone facies, represent probable floodplain overbank or distal crevasse splay deposits (Fig. 27). At Line Creek (Sec. 76-16; Fig. 3) for example, in a freshly bulldozed exposure, an interval of fine, parallel laminated siltstone to mudstone was observed at the base of a sedimentary cycle. The laminated unit was overlain by a silty, very fine grained sandstone with well developed climbing ripple laminations. The sandstone was overlain in turn by a thick band of very fine grained sandstone containing convolute laminations, and above this the cyclical sequence was repeated. Similar lithologic combinations and sedimentary structures have been described and illustrated by McKee (1966b), McKee et al. (1967), and Reineck and Singh (1973). These sediments are interpreted as typical of an alluvial floodplain depositional environment. Because of the deeply weathered nature of the strata in most areas, sedimentary structures were not always readily apparent. Some of the very fine grained sandstones and coarse grained siltstones, in core samples from the Elk River valley near Elkford, contained small, horizontal and vertical sand-filled burrows and syneresis cracks up to 1.2 cm in diameter (figs. 38, 42). These strata may represent possible flood basin and/or distal, overbank splay facies. They are interbedded with dark grey, carbonaceous mudstones and shales, some of which contain a high concentration of vegetal matter.

The finer grained strata, including the predominant siltstones and mudstones, shales, and claystones, represent facies characteristic of waning fluvial current activity or quiet water suspension. They commonly occur in association with the sandstones of the point bar, crevasse splay, levee and floodplain depositional environments. Where they form relatively thick units in the absence of sandstones and coarse siltstones (examples can be seen in some of the columnar sections of figures 5 to 11), they are interpreted as suspension or vertical accretion deposits of a quiet water depositional environment, such as a flood basin swamp, marsh, or lake. Where vegetal matter or phytoclasts form a conspicuous component of the mudstone strata, they may represent the vegetated margin of an alluvial plain lake, or, possibly, part of a flood basin marsh or swamp depositional environment. In the latter case, the mudstone-shale may grade or interfinger laterally with thin to thick beds of coal. In the former case, the thick mudstone-shale facies grades into relatively plant-free claystones-siltstones or mudstones typical of an alluvial plain, lacustrine, depositional environment. Some of the lacustrine mudstones and shales in the thicker southwestern sections contain pelecypods, ostracodes, and esthyriids (Pearson and Duff, 1975). These strata are most conspicuous in the upper half of the Mist Mountain Formation, where they are interpreted to have formed part of an extensive alluvial coastal plain, located some distance inland from the coast).

In the Barrier Mountain and Limestone Mountain areas to the north, however, basal strata of the Mist Mountain Formation contain relatively thick units (up to 5 m) of dark grey, carbonaceous mudstone-shale, which are generally devoid of conspicuous plant matter. These pelitic rocks are extensively burrowed (figs. 43, 44, 45) and are interpreted to represent part of a distributary mouth bar depositional environment, specifically representing the subaqueous interdistributary bay lithofacies. At Limestone Mountain (Sec. 76-18; Fig. 3), coal was not found in the Mist Mountain Formation. At most field sections near the northern border of the report area, the potential coal-bearing intervals were commonly talus and grass covered, thus making it difficult to determine whether coal or coaly strata were present. However, north of North Saskatchewan River, in the laterally equivalent lower Nikanassin Formation, coal and coaly strata were not observed. The strata probably represent former deltaic and/or shallow marine sediments. Coal and coaly strata were found only in the upper facies of the Nikanassin Formation, suggesting, therefore, a deltaic, probably nonmarine, depositional environment for this stratigraphic interval. It is possible that some of the pelitic siltstone-mudstone and shale units illustrated on figures 5 to 11 may represent "mud plug" facies, deposited in abandoned oxbow channels. Because of the limited lateral exposure of these units (many are exposed in bulldozed road cuts) the configuration of the facies is not readily apparent. However, because of the abundance and well developed nature of the meandering channel facies in the western sections of the report area, the existence of this type of subenvironmental lithofacies would be expected.

The thickness, composition and distribution of coal seams in the Mist Mountain Formation may also be used to assist in the interpretation of the depositional subenvironment. As noted previously, the thick coal seam (Balmer No. 10) and coaly mudstone interval, at or near the base of the formation, occurs throughout much of the southern Crowsnest Pass-Fernie Basin area (figs. 13, 15, 22, 23). The thickness of the seam (up to 18 m) and its widespread distribution (figs. 5, 6), suggest deposition within an interdeltaic-lower coastal plain, marsh-swamp environment, a facies formed directly above the littoral sandstones of the Morrissey Formation. The coastal marsh environmental interpretation is supported by the petrographic studies of Cameron (1972), who examined coal samples from strata equivalent to the Mist Mountain Formation, including the Balmer and overlying seams, in the Sparwood-Elk River valley area. Maceral identifications by Cameron (*op. cit.*) suggest that the thick Balmer seam, near the base of the Mist Mountain Formation, was composed mainly of finely banded vitrinite and inertinite, with relatively large amounts of the latter. This observation suggests, therefore, that the coal was derived mainly from non-woody, herbaceous vegetation, typical of a coastal marsh environment. In contrast, coals occurring stratigraphically higher in the Mist Mountain Formation are in general thinner, more numerous, and laterally less extensive (Fig. 5), and were found by Cameron to have a maceral composition predominantly of vitrinite with low amounts of inertinite. This observation suggests that the coals at this higher stratigraphic level formed mainly from woody material, which had been deposited in a forested swamp environment where conditions for preservation of plant material were good. These upper coals in the Mist Mountain Formation of the thicker western sections are interpreted to represent peats formed mainly in swamps adjacent or close to major fluvial channels. Alternatively, some of the coals may represent the products of marshes and swamps formed adjacent to lakes and ponds, which, over a period of time, were infilled by pelitic sediment and vegetation.

At two localities in the upper Elk River valley near Elkford, rare, light brown claystone occurs as thin bands, up to 6 cm thick, in a coal and mudstone unit of the formation (Graham et al., 1977). These claystones are interpreted as tonsteins, the product of airborne volcanic ash, deposited in a swamp or lacustrine environment. Other tonsteins in the Mist Mountain Formation have been described by Meriaux (1972).

The silty limestone observed in the Fernie area probably represents a facies deposited within a freshwater lake or pond, or, alternatively, may be a diagenetic replacement of a former carbonaceous siltstone or mudstone. The first interpretation is considered more likely.

Elk Formation

Strata of the Elk Formation lithologically resemble those of the underlying Mist Mountain Formation, although in some areas conspicuous differences exist between the two formations, a feature interpreted to represent differences in the respective depositional processes and depositional environments.

The Elk comprises part of the same progradational clastic wedge postulated for the underlying Mist Mountain and Morrissey formations, although occupying only the upper portion of the fluvial-alluvial plain depositional environment (Fig. 94). Accordingly, many of the depositional subenvironments within the alluvial plain succession are similar. For example, channel, crevasse splay, floodplain overbank splay, lacustrine and swamp or marsh deposits are common. The vertical accretion deposits in most areas are thinner than those in the Mist Mountain Formation. Channel sandstone and floodplain or overbank splay deposits in the Elk are more numerous. In some parts of the report area Elk strata are characterized by strata typical of the distal facies of an alluvial fan or braidplain depositional environment (Rust, 1979). This interpretation is based upon the occurrence of thick, cliff-forming units, up to 49 m thick, of chert-pebble conglomerate and medium- to coarse-grained sandstone, at the type section of the Elk Formation on Morrissey Ridge, at Mount Taylor, and at Mount Allan. The intervals between the conglomerates and sandstones are occupied by recessive weathering argillaceous siltstone, mudstone, shale, and thin seams of coal. At other localities within the region, such as Sparwood and Flathead ridges (Fig. 5), the conglomerate-sandstone lithofacies is generally thin. At localities in the Alberta Foothills to the east, similar ledge or cliff-forming facies occur, but in these areas consist mainly of medium- to coarse-grained sandstone and rare conglomeratic sandstone (i.e., Isolation Ridge, Sec. 76-14; Highwood Junction, Sec. 76-5; Cabin Ridge, Sec. 76-2; figs. 5, 10).

The thickness, distribution, clast sizes (coarse sand, pebbles and cobbles), relatively poor sorting, and interdigitation with coarse grained sandstone, suggest that the thick, ledge-forming units of the conglomerate-sandstone lithofacies in the Fernie and Canmore areas probably represent the distal facies of alluvial fan depositional environments, deposited by a series of large and small braided streams or rivers. This idea was first postulated by Jansa (1972). The coarser grained, debris flow, mid-fan, and proximal fan facies, if developed, must have been located farther to the west or southwest, toward the postulated sediment source area. The proximal facies has either been removed by Pleistocene or Recent erosion, or lies buried beneath the thick, thrust-faulted Paleozoic strata west of Elk River valley. It must be noted, however, that typical alluvial fan deposits are commonly much coarser grained and more poorly sorted than those in the Elk Formation (Reineck and Singh, 1973; Nummedal and Boothroyd, 1976; Rust, 1979). Accordingly, the Elk conglomerate-sandstone lithofacies may more appropriately be described as forming part of a braidplain depositional environment (Rust, 1979). Rust (*op. cit.*) documented criteria characteristic of the distal facies of braidplain deposits, the more important of which include fining-upward, clast supported, trough crossbedded units at the base, overlain by horizontally stratified gravel, or trough crossbedded and horizontally bedded sands, with the sequence capped by a massive or laminated mud facies containing plant material. Similar facies and sedimentary structures have been observed in the conglomerates and conglomeratic sandstones of the Elk Formation in the Fernie Basin area.

Nummedal and Boothroyd (in Hayes and Kana, 1976) have reported alluvial fan deposits, typical of glacial or humid environments, which are "characterized by a regular down fan decrease in sediment size with the sandy facies occupying a major portion of each fan". Again, similar characteristics may be found in the conglomerates and associated conglomeratic and coarse grained sandstones of the Elk Formation. Recently, Smith and Putnam (1980) suggested a system of anastomosing streams or rivers as the depositional mechanism for the conglomerates and sandstones in the Elk Formation. They outlined some of the important criteria characteristic of anastomosing stream or river environments. These include "the presence of laterally stable (few epsilon crossbeds), multiple interconnected channels, and extensive interchannel wetlands, coupled with freshwater organisms". In addition, they suggest that coal may be present but is not necessarily a diagnostic criterion. Some of these criteria have been observed in parts of the report area. However, for the conglomerates and coarse grained sandstones found in the Fernie and Mount Allan areas, the writer favors the distal alluvial fan or braidplain model, with the sediment transport mechanism comprising a series of braided streams.

In areas where the massive conglomerate-sandstone facies is absent or rare, such as Sparwood Ridge, upper Elk River valley, Mist Mountain and most eastern sections of the Alberta Foothills, the Elk Formation is dominated by a succession of conspicuous fine- to coarse-grained, ledge-forming units of sandstone (figs. 5-11), containing rare pockets or lenses of chert-pebble conglomerate. In these areas, conglomerate does not form a conspicuous facies of the formation. Most of the coarser grained sandstones contain "lag deposits" of chert, quartz, and quartzite pebbles at or near the base of a unit, with the pebbles having a composition similar to those in the massive conglomerate-sandstone units found in the west. Sedimentary structures consist mainly of medium- to large-scale trough crossbedding near the base (Fig. 57), in some units grading upward into smaller scale crossbedding. Planar crossbedding was also noted. The sandstones may also fine upward with their upper parts characterized by ripple and ripple drift laminated, very fine- to fine-grained sandstone (Fig. 58). At most localities graded bedding is not apparent. In addition, many of these channel sandstones contain well preserved wood molds and casts, similar in appearance to those described in the underlying Mist Mountain Formation (Fig. 46), although in the Elk Formation the wood molds and casts may occur at any level within the channel sandstone. Some sandstone units are more typical of the channel-point bar deposits of a meandering rather than a braided stream and, as such, are interpreted to represent the downstream gradation from the braided stream deposits that were dominant to the west in the Fernie and Mount Allan areas. As the low-lying coastal plain area is approached during progradation of the clastic wedge, one would expect streams to become more sluggish because of a reduced gradient and thus develop into meandering types.

Carbonaceous siltstone, finer grained sandstone, mudstone, shale and coal overlie and are interbedded with these channel sandstones, and represent probable floodplain overbank splay, possible levee, flood basin lacustrine and swamp, and marsh deposits. These vertical accretion or overbank deposits are conspicuously reduced in thickness in the Elk Formation, compared to those in the underlying Mist Mountain Formation (figs. 5-11). It is the conspicuous alternation (in some areas) of these vertical accretion or overbank deposits with the locally thick, fluvial channel sandstones that in part persuaded Smith and Putnam (1980) to suggest an anastomosing model for strata of the Elk Formation.

The increase in the number of channels in the Elk Formation, coupled with a decrease in thickness of coal seams and vertical accretion flood basin deposits, may suggest a rapid lateral migration of the fluvial channels, or the development of many channels, as occurs in a braided or anastomosing system. As can be seen in figures 5 to 11, most coal seams are thin in contrast with the thick seams found in the underlying Mist Mountain Formation. This may be a result of rapid lateral channel migration or the development of multi-channels. Some of the interchannel shales contain freshwater ostracodes and indeterminate but presumed freshwater pelecypods, suggesting a probable lacustrine origin for these strata, similar to that postulated for the fossil-bearing shales in the underlying Mist Mountain Formation.

The occurrence and paleoenvironmental interpretation of the unusual "needle coal" and "needle siltstone" within the upper Elk Formation remains an enigma. As discussed previously, the coal is considered to be of algal origin. The "needle siltstone" occurs either with the coal or independently, but is commonly associated with a very coaly to carbonaceous mudstone of probable flood basin or lacustrine origin. The occurrence of these two unusual lithotypes in the Upper Elk Formation may be related to a change in climatic regime, particularly in the southern areas covered by this report. For example, it may be suggested that the reduction in thickness and number of coal seams in the Elk Formation may not be due entirely to the lateral migration of channels as a result of braiding streams, but, rather may be due to a subtle or gradual change in climate. If a change in climate is indeed responsible, the temperate to subtropical climate envisaged for the formation of peat in the underlying Mist Mountain Formation may have changed to a somewhat drier, but still seasonally wet, climate during deposition of upper Elk strata. In some areas the climate may have been semi-arid. Accordingly, under these generally drier climatic conditions rainfall would become sporadic, perhaps causing a reduction in vegetation growth, and resulting in thinner, less well-developed peat accumulations, compared to those in the underlying Mist Mountain Formation. Because of the reduction in moisture and rainfall, algae may have begun to replace the normal vegetation in some of the ephemeral lakes and ponds. In areas where "needle coals" are scarce, or have been replaced by normal non-algal coal, the moisture or rainfall may have been sufficient to promote the growth of vegetation.

A mechanism which might be responsible for the change in climate and associated rainfall pattern would be the development of rising thrust sheets in the sediment source area to the west, and the creation of a rain shadow in the lee of this highland area. A similar rain shadow effect has been suggested by Peterson (1966) to account for the arid conditions existing during the time of deposition of Cretaceous strata in Montana. One might also suggest a changing climatic regime to explain the occurrence of the braided stream-alluvial fan-braidplain sediments found to the west. In a seasonally wet but semi-arid climate, rainfall may be irregular or episodic (Coleman and Wright, 1975), resulting in the rapid but spasmodic transportation of sediment (pebbles, cobbles, and coarse sand), especially near the sediment source areas. In areas away from the rain shadow, toward the east, precipitation may have been more normal and less arid, resulting in a constant but more gentle stream flow by meandering streams. This alternative interpretation to explain the algal coals and braided channels in the Elk Formation is a modification of that postulated earlier by the writer (Gibson, 1977b), in which it was suggested that strata of the upper Kootenay were deposited in a temperate or subtropical environment.

Following deposition of the Elk Formation, the report area and most other areas of Alberta and eastern British Columbia were subjected to a period of erosion and/or nondeposition, a feature most evident in the central and eastern parts of the Foothills. The erosional interlude is indicated by the marked reduction in thickness of the Elk Formation from west to east (Fig. 56), the absence of the Elk Formation in the eastern Foothills, and by the general contrast in lithofacies with the overlying Blairmore Group. It should be noted, however, that in some areas of the Fernie Basin, deposition appears to have been continuous from the Elk Formation to the Pocaterra Creek Member of the Blairmore Group with no evidence of a major unconformity.

In this area, and some other areas of southeastern British Columbia and southwestern Alberta, the lower Blairmore Group is characterized by generally carbon-free, clean sandstones and conglomerates, olive-grey to reddish brown siltstones and mudstones, and a conspicuous absence of coal seams and carbonaceous (plant) matter. This abrupt contrast in lithology between the Elk and Blairmore rock units, probably reflects a rapid change in climatic conditions. The occurrence of "red beds" and "green beds", and the absence of coal and carbonaceous matter in the lower Blairmore Group, suggest that, at least in this area, the climate was probably arid to semi-arid. This may be cited as further evidence in support of the changing climate hypothesis, outlined above, to explain the unusual sediment character in parts of the Elk Formation. For a summary of the lower Blairmore Group depositional environments, the interested reader is referred to reports by Mellon (1967), Mellon and Wall (1963), Schultheis (1970), McLean (1977), Schultheis and Mountjoy (1978), and Ricketts and Sweet (in press).

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APPENDIX 1

Name, Location and Palinspastic Data for Field Sections Used in this Report

SECTION NUMBER	SECTION NAME	TOPOGRAPHIC MAP 1:50,000	LOCATION U.T.M.	GEOLOGICAL MAP NAME	GEOLOGICAL MAP AUTHOR	PALINSPASTIC CORRECTION[1] km	PALINSPASTIC CORRECTION[1] mi
75-1	Grassy Mountain	Blairmore 82G/9	Base: 868 061 Top: 863 062	Blairmore 18-55	Norris	66	41
75-5	Morrissey Ridge (Mist)	Elko 82G/6	Base: 442 791 Top: 450 787	Fernie (West) 11-1960	Leech	158	98
75-6	Flathead Ridge Pipeline	Upper Flathead 82G/7	Base: 540 664 Top: 535 675	Fernie (East) 35-1961	Price	154	96
75-7	Coal Creek Mountain (Elk)	Upper Flathead 82G/7	Base: 461 840 Top: 465 850	Fernie (East) 35-1961	Price	153	95
75-8	Sparwood Ridge	Crowsnest 82G/10	Base: 535 052 Top: 547 042	Fernie (East) 35-1961	Price	158	98
75-9	Morrissey Microwave Tower (Elk)	Upper Flathead 82G/7	Base: 450 778 Top: 457 781	Fernie (East) 35-1961	Price	158	98
75-10	Adanac Strip Mine No. 3	Beaver Mines 82G/8W	Base: 875 854 Top: 872 854	Carbondale River 5-59	Norris	68	42
75-11	Adanac Strip Mine No. 4	Blairmore 82G/9	Base: 865 900 Top: 863 896	Blairmore 18-55	Norris	68	42
75-12	Marten Ridge	Crowsnest 82G/10	Base: 555 939 Top: 552 943	Fernie (East) 35-1961	Price	153	95
75-13	Cat Mountain	Maycroft 82G/16	880 225	Gap 978A	Douglas	69	43
75-14	York Creek	Blairmore 82G/9	807 973	Blairmore 18-55	Norris	74	46
75-15	Mount Taylor	Crowsnest 82G/10	Base: 639 892 Top: 631 880	Fernie (East) 35-1961	Price	154	96
75-16	Coal Creek Mountain (Mist)	Crowsnest 82G/10	Base: 450 867 Top: 454 864	Fernie (East) 35-1961	Price	153	95
75-17	Greenhills Range	Fording River 82J/2W	Base: 506 545 Top: 524 545	-	-	132	82
75-18	Cabin Creek	Lower Flathead 82G/2	780 413	Fernie (East) 35-1961	Price	153	95
75-19	Eagle Mountain	Fording River 82J/2W	Base: 539 629 Top: 539 624	-	-	132	82
75-20	Leach Creek	Upper Flathead 82G/7	Base: 640 829 Top: 635 827	Fernie (East) 35-1961	Price	154	96

SECTION NUMBER	SECTION NAME	TOPOGRAPHIC MAP 1:50,000	LOCATION U.T.M.	GEOLOGICAL MAP NAME	GEOLOGICAL MAP AUTHOR	PALINSPASTIC CORRECTION[1] km	PALINSPASTIC CORRECTION[1] mi
75-21	Grassy Mountain D.D.H.	Blairmore 82G/9	-	Blairmore 18-55	Norris	66	41
75-23	Fording Coal D.D.H. 392	Fording River 82J/2W	531 612	-	-	132	82
75-24	Fording Coal D.D.H. 307	Fording River 82J/2W	531 612	-	-	132	82
75-25	Fording Coal D.D.H. 68	Fording River 82J/2W	-	-	-	132	82
75-27	Morrissey Ridge (Type)	Elko 82G/6 Upper Flathead Valley 82G/7	Base: 450 757 Top: 452 757	Fernie (East) 35-1961	Price	158	98
76-1	Oldman River Gap	Maycroft 82G/16	Base: 925 288 Top: 930 266	Gap 978A	Douglas	68	42
76-2	Cabin Ridge	Fording River 82J/2E	775 456	Beehive Mountain 14-1958	Norris	71	44
76-2A	Cabin Ridge	Fording River 82J/2E	782 477	Beehive Mountain 14-1958	Norris	71	44
76-2B	Cabin Ridge	Langford Creek 82J/1W	794 440	Livingstone River 5-1958	Norris	71	44
76-3	Ridge Creek	Langford Creek 82J/1W	885 541	Livingstone River 5-1958	Norris	66	41
76-4	Plateau Mountain	Fording River 82J/2E	Base: 737 663 Top: 733 660	Beehive Mountain 14-1958	Norris	64	40
76-5	Sentinel-Highwood Ranger Station	Mount Head 82J/7E	Base: 668 859 Top: 662 865	Mount Head 1052A	Douglas	71	44
76-6	Picklejar-Utah	Mount Rae 82J/10W	544 001	-	Allan & Carr 1947	66	41
76-7A	Mount Allan (Elk)	Evans Thomas Creek 82J/14E	Base: 269 485 Top: 264 481	-	Crockford 1949	71	44
76-7B	Mount Allan (Mist)	Evans Thomas Creek 82J/14E	Base: 268 495 Top: 267 492	-	Crockford 1949	71	44
76-8	Banff Traffic Circle	Banff 82O/4E	035 733	Banff 1294A	Price & Mountjoy	71	44
76-9	Mount Lipsett (Pocaterra)	Mount Rae 82J/10W	445 024	-	Allan & Carr 1947	68	42
76-10	Mist Mountain West	Mount Rae 82J/10W	Base: 459 024 Top: 459 016	-	Allan & Carr 1947	68	42
76-11	Mount Lipsett	Mount Rae 82J/10W	Base: 446 031 Top: 441 028	-	Allan & Carr 1947	68	42
76-12	Trap Creek	Dyson Creek 82J/10	701 968	Dyson Creek 827A	Hage	61	38

SECTION NUMBER	SECTION NAME	TOPOGRAPHIC MAP 1:50,000	LOCATION U.T.M.	GEOLOGICAL MAP NAME	AUTHOR	PALINSPASTIC CORRECTION[1] km	mi
76-13	Wilkinson Summit	Fording River 82J/2E	707 654	Beehive Mountain 14-1958	Norris	71	44
76-14	Isolation Ridge	Fording River 82J/2E	763 533	Beehive Mountain 14-1958	Norris	71	44
76-15	Weary Ridge	Mount Head 82J/7W	507 822	-	-	130	81
76-15A	Weary Creek	Mount Head 82J/7W	488 839	-	-	130	81
76-16	Line Creek	Tornado Mountain 82G/15W	Base: 593 337 Top: 597 334	Fernie (East) 35-1961	Price	135	84
76-17	Barrier Mountain	Barrier Mountain 820/12E	984 294	Barrier Mountain 1273A	Price & Mountjoy	71	44
76-17A	Barrier Mountain	Barrier Mountain 820/12E	Base: 979 290 Top: 979 287	Barrier Mountain 1273A	Price & Mountjoy	71	44
76-17B	Barrier Mountain	Barrier Mountain 820/12E	Base: 981 285 Top: 985 280	Barrier Mountain 1273A	Price & Mountjoy	71	44
76-17C	Barrier Mountain	Barrier Mountain 820/12E	Base: 015 264 Top: 011 261	Barrier Mountain 1273A	Price & Mountjoy	71	44
76-18	Limestone Mountain	Limestone Mountain 820/14	087 527	Limestone Mountain	Ollerenshaw	27	17
76-19	Bragg Creek	Bragg Creek 82J/15	540 465	Moose Mountain & Morley	Beach	48	30
EV-1	Elk Valley D.D.H.	Kananaskis 82J/11	369 047	-	-	129	80
EV-2	Elk Valley D.D.H.	Kananaskis 82J/11	371 038	-	-	129	80
EV-3	Elk Valley D.D.H.	Kananaskis 82J/11	369 029	-	-	129	80
EV-4	Elk Valley D.D.H.	Kananaskis 82J/11	368 020	-	-	129	80
77-1	Gladstone-Mill Creek	Beaver Mines 82G/8E	063 768	Beaver Mines 739A	Hage	-	24
77-2	Raspberry Ridge	Mount Head 82J/7E	685 733	Mount Head 1052A	Douglas	71	44
77-3	Cutoff Creek	Cripple Creek 83B/4E	985 622	Fall Creek 883A	Henderson	27	17
77-4	Prairie Creek	Tay River 83B/3	051 773	Tay River 840A	Henderson	-	-

SECTION NUMBER	SECTION NAME	TOPOGRAPHIC MAP 1:50,000	LOCATION U.T.M.	GEOLOGICAL MAP NAME	GEOLOGICAL MAP AUTHOR	PALINSPASTIC CORRECTION[1] km	PALINSPASTIC CORRECTION[1] mi
77-5	Gap Lake	Saunders 83B/5W	805 996	Alexo 884A	Erdman	-	-
77-6	Thompson Highway	Nordegg 83C/8	492 044	Nordegg 55-34	Douglas	-	-
77-7	Wapiabi Creek (Lower)	Nordegg 83C/8	Base: 382 136 Top: 382 128	Nordegg 55-34	Douglas	-	-
77-12	Wapiabi Creek Upper	Nordegg 83C/8	345 151	Nordegg 55-34	Douglas	-	-
77-13	Cox Hill	Bragg Creek 82J/15	469 511	Moose Mountain & Morley	Beach	48	30
77-14	Volcano Creek	Mount Rae 82J/10E	613 211	Dyson Creek 827A	Hage	-	-
77-17D	Barrier Mountain	Barrier Mountain 820/12E	980 288	Barrier Mountain 1273A	Price & Mountjoy	71	44
77-17E	Barrier Mountain	Barrier Mountain 820/12E	020 264	Barrier Mountain 1273A	Price & Mountjoy	71	44

[1]Palinspastic correction values modified from Norris (1971; pers. comm., 1981). For palinspastic corrections, Turner Valley is considered fixed.

APPENDIX 2

Thickness Data for Formations and Members, Kootenay Group

SECTION NUMBER	KOOTENAY GROUP Metres	ELK FORMATION Metres	MIST MOUNTAIN FORMATION Metres	MORRISSEY FORMATION Metres	MOOSE MOUNTAIN MEMBER Metres	WEARY RIDGE MEMBER Metres	NIKANASSIN FORMATION Metres
75-1	139.9	-	115.9	23.9	18.5	5.4	-
75-5	-	-	455.3	45.4	22.5	22.9	-
75-6	702.5	279.5	382.6	40.4	8.0	32.3	-
75-7	-	462.6	-	-	-	-	-
75-8	1111.8	482.4	599.1	30.3	12.8	17.5	-
75-9	-	521.9	120.1 ±	-	-	-	-
75-10	93.6	-	73.9	19.6	3.9	15.8	-
75-11	89.1	-	67.8	21.3	6.3	14.9	-
75-12	-	105.9+	539.9+	-	-	-	-
75-13	122.5	-	99.1	23.5	-	-	-
75-14	-	-	108.8+	-	-	-	-
75-15	702.8	253.5	402.9	46.4	26.9	19.4	-
75-16	-	-	610.7	33.9 ±	15.6	18.3 ±	-
75-17	-	-	665.2	69.0	14.1	55.0	-
75-18	257.2	-	236.8	20.4	8.2	12.2	-
75-19	-	304.8 ±	-	-	-	-	-
75-20	-	-	-	47.6 ±	19.6	28.0 ±	-
75-21	105.2	-	81.9	-	-	-	-
75-23-25	-	-	484.6	53.8	15.0	38.8	-
75-27	-	-	-	41.2	18.3	22.9	-
76-1	122.5	-	81.0	41.5	-	-	-
76-2A	228.8	27.8	169.6	31.4+	10.6	20.8	-
76-2B	-	32.9	-	-	-		-
76-3	156.3	-	119.8	36.5	14.8	21.7	-
76-4	-	56.1	148.0	-	-	-	-
76-5	286.4	119.3	112.1	55.0	9.0	46.0	-

SECTION NUMBER	KOOTENAY GROUP Metres	ELK FORMATION Metres	MIST MOUNTAIN FORMATION Metres	MORRISSEY FORMATION Metres	MOOSE MOUNTAIN MEMBER Metres	WEARY RIDGE MEMBER Metres	NIKANASSIN FORMATION Metres
76-6	-	-	-	41.4+	5.5	35.9+	-
76-7	1014.6	589.4	404.1	21.1	16.6	4.5	-
76-8	-	-	-	35.9	8.0	27.9	-
76-9	-	89.2+	-	-	-	-	-
76-10	-	-	380.4	79.2	35.5	43.7	-
76-11	-	360.2	-	-	-	-	-
76-12	178.8	-	128.2	50.6	6.9	43.7	-
76-13	-	205.9	101.9	-	6.8+	-	-
76-14	263.5	47.1	173.6	42.8	9.8	33.0	-
76-15	-	-	-	68.7	23.6	45.2	-
76-15A	-	-	187.5+	-	-	-	-
76-16	-	-	120.9+	64.8	28.8	36.0	-
76-17	843.3	409.2	361.2	72.8	39.2	33.6	-
76-18	84.9	-	24.6	60.3	-	-	-
76-19	91.7	-	71.8	19.9	9.2	10.7	-
EV1-4	1006.0	457.2	483.7+	-	-	-	-
77-1	-	-	31.7+	-	-	-	-
77-2	-	206.4	-	-	-	-	-
77-3	54.3	-	32.5	21.8	-	-	-
77-5	64.3	-	40.4	23.9	-	-	-
77-13	137.2	-	110.6	26.6	17.0	9.6	-
77-14	230.3	-	188.1	42.2	25.3	16.9	-
77-4	-	-	-	-	-	-	?3.7?
77-6	-	-	-	-	-	-	48.4+
77-7	-	-	-	-	-	-	446.4
77-12	-	-	-	-	-	-	50.9+

APPENDIX 3

Palynology

by A.R. Sweet

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.

Flathead Ridge, Sec. 75-6

Mist Mountain 75-6-6 — C-57046

Comments: A very small residue with some unidentifiable spores was recovered: hence no age determination is possible.

Sparwood Ridge, Sec. 75-8

Cadomin, 75-8A-103 — C-57047

Vitreisporites pallidus (Reissinger) Nilsson 1958
Cycadopites sp.
Eucommiidites minor Groot and Penny 1960
Gleicheniidites sp. cf. *G. circinidites* (Cookson) Dettmann 1963
Verrucosisporites cf. *V. rotundus* Singh 1964
Distalanulisporites spurius (Bolkh) Pocock 1970
Schizosporis reticulatus Cookson and Dettmann 1959
Schizosporis parvus Cookson and Dettmann 1959

Comments: Recovery low but good; relatively low degree of carbonization. Together, *Schizosporis reticulatus* and *S. parvus* indicate an Early Cretaceous age. None of the above forms are indicative of a post Neocomian age.

Elk, 75-8A-80 — C-51953

Alisporites grandis (Cookson) Dettmann 1963 (common)
Podocarpidites sp.
Vitreisporites pallidus (Reissinger) Nilsson 1958
Classopollis spp. (abundant)
Cycadopites sp. (abundant)
Ginkgocycadophytus spp.
Cerebropollenites mesozoicus (Couper) Nilsson 1958
Sigmoipollis sp.
Eucommiidites minor Groot and Penny 1960
E. troedssonii Erdtman 1948
Cyathidites minor Couper 1953
Laevigatosporites ovatus Wilson and Webster 1946
Callialasporites verrucosus Pocock 1970
Inaperturopollenites cf. *I. australis* (Cookson) Pocock 1970
Ginkgoretectina ferrei Pocock 1970
Exesipollenites tumulus Balme 1957
Undulatisporites fossulatus Singh 1971
Cicatricosisporites carlylensis Pocock 1962
Acanthotriletes sp.
dinoflagellate sp.
Schizaeoisporites delcourtii Pocock 1964
Manumia irregularis Pocock 1970
Microreticulatisporites sp.
Ischyosporites punctatus Cookson and Dettmann 1958

Comments: Recovery excellent; low degree of carbonization. This sample contains a mixture of forms known only from the Jurassic (e.g. *Cicatricosisporites carlylensis*) and those previously reported only from the Cretaceous (e.g. *Schizaeoisporites delcourtii*); hence no definite age determination is possible. Note the record of three dinoflagellate specimens.

Elk, 75-8A-68 — C-45100

Comments: Recovery very poor; no identifiable palynomorphs observed; age indeterminate.

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Elk, 75-8A-26	*Alisporites grandis* (Cookson) Dettmann 1963 *Classopollis* sp. *Inaperturopollenites dettmannii* Pocock 1970 *Osmundacidites wellmanii* Couper 1953 *Cycadopites* sp. *Lycopodiumsporites* sp. *Distyotriletes pseudoreticulatus* (Couper) Pocock 1962 *Concavissimisporites variverrucatus* (Couper) Brenner 1963 *Cicatricosisporites australiensis* (?) (Cookson) Potonié 1956 Comments: Recovery good; relatively high degree of carbonization. Age indeterminate unless one assumes an Early Cretaceous age based on the one observed fragment of what is probably *Cicatricosisporites australiensis*.	C-45095
Elk, 75-8A-"Needle Coal"	*Alisporites grandis* (abundant) *Cycadopites* sp. *Deltoidospora* sp. *Eucommiidites minor* Comments: Recovery good; relatively low to average degree of carbonization. Age indeterminate.	C-68006
	Morrissey Microwave Tower, Sec. 75-9	
Elk 75-9-13	*Alisporites grandis* (Cookson) Dettmann 1963 (scarce) *Cyathidites* sp. (rare) *Ginkgocycadophytus* sp. (rare) *Granulatisporites* sp. (scarce) *Perinopollenites elatoides* Couper 1958 (rare) *Osmundacidites wellmanii* Couper 1953 (scarce) Comments: Organic debris brown; preservation relatively good; recovery sparse to good; age indeterminate.	C-68007
Elk, 75-9-20	*Alisporites grandis* (Cookson) Dettmann 1963 (scarce) *Classopollis* sp. (scarce) *Cyathidites* sp. (rare) *Osmundacidites* sp. (scarce) *Vitreisporites pallidus* (Reissinger) Nilsson 1958 (rare) Comments: Organic debris brown; preservation poor; recovery very sparse; age indeterminate.	C-68007
Elk, 75-9-27	*Alisporites grandis* (Cookson) Dettmann 1963 (abundant) *Alisporites* spp. (abundant) *Cerebropollenites mesozoicus* (Couper) Nilsson 1958 *Cicatricosisporites* sp. (1 fragment) *Cyathidites* sp. *Ginkgocycadophytus* sp. *Lycopodiumsporites* sp. *Osmundacidites wellmanii* Couper 1953 *Perinopollenites elatoides* Couper 1958 *Pityosporites* sp. *Podocarpidites* sp. *Steriosporites antiquasporites* (Wilson and Webster) Dettmann 1963 *Steriosporites regium* Drozhastichich 1961 *Verrucosisporites* cf. *V. rotundus* Singh 1964 Comments: Organic debris brown; preservation good; recovery abundant; age possibly Cretaceous, based on the occurrence of a single specimen of *Cicatricosisporites*.	C-68008

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Elk, 75-9-30	*Cyathidites* sp. (common) *Laevigatosporites ovatus* Wilson and Webster 1946 (rare) *Lycopodiumsporites* sp. (scarce) *Osmundacidites wellmanii* Couper 1953 (scarce) Comments: Organic debris brown; preservation poor; recovery sparse; age indeterminate.	C-68009
Elk, 75-9-44	*Alisporites* sp. (common) *Cerebropollenites mesozoicus* (Couper) Nilsson 1958 (rare) *Deltoidospora psilotoma* Rouse 1959 (scarce) *Lycopodiumsporites* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (scarce) *Steriosporites antiquasporites* (Wilson and Webster) Dettmann 1963 (scarce) ?*Trilobosporites* sp. Comments: Organic debris brown; preservation average; recovery sparse; age indeterminate.	C-68010
Elk, 75-9-51	*Deltoidospora psilostoma* Rouse 1959 (rare) *Lycopodiumsporites* sp. (rare) Comments: Organic debris brown; preservation poor; recovery very sparse; age indeterminate.	C-68011
Elk, 75-9-74	*Concavisporites verrucosus* var. *minor* Pocock 1962 (rare) (?) *Contignisporites* sp. (rare) *Cyathidites* sp. (scarce) *Deltoidospora psilostoma* Rouse 1959 (rare) *Dictyotriletes southeyensis* Pocock 1962 (rare) *Granulatisporites* sp. (rare) *Lycopodiumsporites* sp. (rare) *Osmundacidites wellmanii* Couper 1958 (common) Comments: Organic debris light brown to black; preservation and recovery average; age indeterminate.	C-68012
Elk, 75-9-85	Comments: Except for some fragments of bisaccate pollen no identifiable palynomorphs were observed in this sample.	C-68013
Elk, 75-9-90	*Alisporites grandis* (Cookson) Dettmann 1963 (common) *Classopollis* sp. (smooth, rare) *Cyathidites* spp. (scarce) *Ginkgocycadophytus* (rare) *Osmundacidites wellmanii* Couper 1953 (rare) *Steriosporites antiquasporites* (Wilson and Webster) Dettmann 1963 (rare) Comments: Organic debris light brown; preservation and recovery good; age indeterminate.	C-68014

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.

Marten Ridge, Sec. 75-12

Mist Mountain,
75-12-76

C-51978

Alisporites grandis (Cookson) Dettmann 1963 (common)
Podocarpidites sp.
Classopollis sp.
Vitreisporites pallidus (Reissinger) Nilsson 1958
Inaperturopollenites turbatus Balme 1957
Cyathidites minor Couper 1953
Osmundacidites wellmanii Couper 1953
Cerebropollenites mesozoicus (Couper) Nilsson 1958
Callialasporites verrucosus Pocock 1970
Bitreisporites sp.
Granulatisporites sp.
Tasmanites sp.
Trilobosporites cf. *T. apiverrucatus* Couper 1958
Trilobosporites sp.
Steriosporites antiquasporites (Wilson and Webster) Dettmann 1963
Lycopodiumsporites sp.
Dictyotriletes pseudoreticulatus (Couper) Pocock 1962
Eucommiidites troedssonii Erdtman 1948
Deltoidospora juncta (Kara-Murza) Singh 1964
Concavisporites verrucosus (Delcourt and Sprumont) Pocock 1962
Rugulatisporites sp.
Verrucosisporites cf. *Triletes verrucatus* Couper 1953
V. rotundus Singh 1964
Klukisporites variegatus Couper 1958
Cooksonites sp.
Converrucosisporites proxigranulatus Brenner 1963
Schizosporis reticulatus Cookson and Dettman 1959
?*Pilosisporites* sp.
Contignisporites glebulentus Dettmann 1963

Comments: Excellent recovery; degree of carbonization low; age Early Cretaceous based on the combined presence of *Schizosporis reticulatus*, *Contignisporites glebulentus*, and *Trilobosporites* cf. *T. apiverrucatus*.

Mist Mountain,
75-12-92

C-51980

Alisporites grandis (Cookson) Dettmann 1963
Ginkgocycadophytus sp.
Cycadopites sp.
Eucommiidites troedssonii Erdtman 1948
Cerebropollenites mesozoicus (Couper) Nilsson 1958
Osmundacidites wellmanii Couper 1953
Steriosporites antiquasporites (Wilson and Webster) Dettmann 1963
Cyathidites minor Couper 1953
Inaperturopollenites dettmannii Pocock 1970
Lycopodiumsporites austroclavatidites (Cookson) Pocock 1962
Neoraistrickia obtusispina Rouse 1959
Lycopodiacidites baculatus Pocock 1962
Deltoidospora juncta (Kara-Murza) Singh 1964
Verrucosisporites cf. *V. obscurilaesuratus* Pocock 1962
Fungal spore
dinoflagellate sp. (5 spec.)

Comments: Recovery good; relatively low degree of carbonization. There is no definite indication that this sample is younger than Jurassic (i.e. the known age range of *Verrucosisporites obscurilaesuratus* is Barremian and that of *Lycopodiacidites baculatus* is Oxfordian to Purbeckian). The dinoflagellate specimens are most probably reworked.

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.

Coal Creek Mountain, Sec. 75-16

Mist Mountain, 75-16-PP — C-68005

Alisporites grandis (Cookson) Dettmann 1963 (common)
Alisporites sp. (common)
Deltoidospora psilostoma Rouse 1959 (scarce)
Ginkgocycadophytus sp. (rare)
Osmundacidites wellmanii Couper 1953 (rare)
Pityosporites sp. (scarce)
Podocarpites sp. (scarce)

Comments: Organic debris brown to black; preservation and recovery average; age indeterminate.

Green Hills Range, Sec. 75-17

Mist Mountain, 75-17-149A — C-49024

Alisporites grandis (Cookson) Dettmann 1963
Vitreisporites pallidus (Reissinger) Nilsson 1958
Cycadopites sp.
Classopollis spp.
Osmundacidites wellmanii Couper 1953
Eucommiidites minor Groot and Penny 1960
Exesipollenites tumulus Balme 1957
Cerebropollenites mesozoicus (Couper) Nilsson 1958
Inaperturopollenites cf. *I. australis* (Cookson) Pocock 1970
Verrucosisporites rotundus Singh 1964
Dictyophyllidites sp.
Ischyosporites punctatus Cookson and Dettmann 1958
Taurocusporites sp. cf. *T. segmentatus* Stover 1962
Verrucosisporites asymmetricus (Cookson and Dettmann) Pocock 1962
Distaltriangulisporites cf. *D. irregularis* Singh 1971
Acanthotriletes sp.
Undulatisporites fossulatus Singh 1971

Comments: Recovery low; degree of carbonization relatively low. Of the species which may have some age significance *Taurocusporites segmentatus* is known from throughout the Early Cretaceous, *Verrucosisporites asymmetricus* from the Aptian and Albian and *Distaltriangulisporites irregularis* from the Middle to Late Albian. Therefore, this sample is of Early Cretaceous age.

Mist Mountain, 75-17-108 — C-49019

Alisporites grandis (Cookson) Dettmann 1963
Cedripites sp.
Podocarpidites sp.
Vitreisporites pallidus (Reissinger) Nilsson 1958
Classopollis spp.
Cycadopites sp.
Lycopodiumsporites sp.
Steriosporites antiquasporites (Wilson and Webster) Dettmann 1963
Cerebropollenites mesozoicus (Couper) Nilsson 1958
Cyathidites minor Couper 1953
Cyathidites australis Couper 1953
Exesipollenites tumulus Balme 1957
Cicatricosisporites sp.
?*Trilobosporites* sp.
Schizosporis reticulatus and Dettmann 1959 (thick walled)

Comments: Recovery good; degree of carbonization intermediate. Based on the occurrence of *Schizosporis reticulatus*, which has been widely reported from rocks of Early Cretaceous age, in addition to the absence of Aptian-Albian forms, this sample is considered to be of Neocomian age.

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Mist Mountain, 75-17-84	*Lycopodiumsporites* sp. *Cycadopites* sp. Comments: Recovery very poor; degree of carbonization appears to be high; age indeterminate.	C-49015
	Cabin Creek, Sec. 75-18	
Mist Mountain, 75-18-49	*Alisporites grandis* (Cookson) Dettmann 1963 *Cedripites* sp. *Pityosporites* sp. *Vitreisporites pallidus* (Reissinger) Nilsson 1958 *Cerebropollenites mesozoicus* (Couper) Nilsson 1958 *Cycadopites* sp. *Classopollis* spp. *Osmundacidites wellmanii* Couper 1953 *Eucommiidites troedssonii* Erdtman 1948 *Callialasporites trilobatus* (Balme) Sukh Dev 1961 *Deltoidospora juncta* (Kara-Murza) Singh 1964 *Lycopodiumsporites* sp. *Stereiosporites clavus* *Dictyotriletes pseudoreticulatus* (Couper) Pocock 1962 *Deltoidospora psilostoma* Rouse 1959 *Acanthotriletes* sp. *Reticulatisporites* cf. *R. utriger* (Bolkh) Pocock 1970 *Januasporites reticularis* Pocock 1962 *Corrugatisporites anagrammensis* (Kara-Murza) Pocock 1970 *Concavissimisporites parkinii* (Pocock) Singh 1964 *Concavissimisporites southeyensis* Pocock 1970 *Verrucosisporites* cf. *Triletes verrucatus* Couper 1953 *Manumia irregularis* Pocock 1970 *Verrucosisporites rotundus* Singh 1964 *Foramisporis dailyi* (Cookson and Dettmann) Dettmann 1963 *Cooksonites* sp. *Matthesisporites* cf. *M. tumulosus* Doring 1964 *Concavisporites verrucosus* (Delcourt and Sprumont) Pocock 1962 *Schizosporis reticulatus* Cookson and Dettmann 1959 Comments: Recovery good; relatively high degree of carbonization. The occurrence of *Schizosporis reticulatus* together with *Januasporites reticularis*, *Foramisporis dailyi* and *Cooksonites* indicates that this sample is most probably of Cretaceous age.	C-52000
	Eagle Mountain-Fording Coal, Sec. 75-19-25	
Mist Mountain, 75-24-89'-93'	*Alisporites grandis* (Cookson) Dettmann 1963 *Cycadopites* spp. *Classopollis* spp. *Deltoidospora* sp. *Vitreisporites pallidus* (Reissinger) Nilsson 1958 *Cerebropollenites mesozoicus* (Couper) Nilsson 1958 *Osmundacidites wellmanii* Couper 1953 *Inaperturopollenites* sp. Comments: Recovery low; degree of carbonization relatively high. The above species or species groups are all long ranging and nondiscriminating relative to defining floral zones within the Late Jurassic-Early Cretaceous interval. This type of assemblage is typical of the coal-bearing portion of the Kootenay Group.	C-49061

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Mist Mountain, 75-24-330.7'-337.2'	*Osmundacidites wellmanii* Couper 1953 *Deltoidospora* sp. Comments: Recovery very poor; degree of carbonization apparently high; age indeterminate.	C-49051
Elk, 75-19-55	*Classopollis* sp. *Inaperturopollenites dettmannii* Pocock 1970 *Matthesisporites* cf. *M. tumulosus* Doring 1964 *Steriosporites antiquasporites* (Wilson and Webster) Dettmann 1963 *Lycopodiumsporites* sp. *Osmundacidites wellmanii* Couper 1953 (common) *Deltoidospora* sp. *Matonisporites* sp. *Steriosporites regium* Drozhastichich 1961 *Reticulatisporites* cf. *R. utriger* (Bolkh) Pocock 1970 *Cicatricosisporites australiensis* (Cookson) Potonié 1956 *Acanthotriletes levidensis* Balme 1957 *Leptolepidites verrucatus* Couper 1953 *Dictyotriletes southeyensis* Pocock 1962 *Concavissimisporites variverrucatus* (Couper) Brenner 1963 dinoflagellates spp. Comments: Recovery good; degree of carbonization relatively low. The combined presence of *Cicatricosisporites australiensis*, *Dictyotriletes southeyensis* and *Acanthotriletes levidensis* is strongly suggestive of an Early Cretaceous (Neocomian) age for this sample. Twelve specimens of dinoflagellates were observed which suggest the paleoenvironment of the sample may have been marginally marine (estuarine?). [The very low dinoflagellate to spore-pollen ratio suggests that any environmental interpretation placed on their occurrence should be treated with caution (pers. comm., W.W. Brideaux)].	C-49039
Elk, 75-19-17	*Alisporites grandis* (Cookson) Dettmann 1963 *Classopollis* spp. *Osmundacidites wellmanii* Couper 1953 (abundant) *Deltoidospora* sp. *Steriosporites antiquasporites* (Wilson and Webster) Dettmann 1963 *Lycopodiumsporites austroclavatidites* (Cookson) Pocock 1962 *Polycingulatisporites reduncus* (Bolkhovitina) Playford Dettmann 1965 *Cycadopites* sp. *Acanthotriletes levidensis* Balme 1957 Comments: Recovery good; degree of carbonization low. Except for the presence of *Acanthotriletes levidensis*, which by itself is of dubious significance, no direct evidence for the age of this sample exists.	C-49046
	Plateau Mountain, Sec. 76-4	
Elk, 76-4-29	*Alisporites grandis* (Cookson) Dettmann 1963 (abundant) *Callialasporites damperi* (Balme) Sukh Dev 1961 (rare) *Ginkgocycadophytus* sp. (scarce) *Lycopodiumsporites* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (abundant) Comments: Organic debris brown to yellow brown; preservation and recovery good; age indeterminate.	C-64179

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.

Sentinel-Highwood Ranger Station, Sec. 76-5

Elk, 76-5B-9	*Alisporites* spp. (scarce) *Cerebropollenites mesozoicus* (Couper) Nilsson 1958 (scarce) *Concavisporites verrucosus* var. *minor* (Delcourt and Sprumont) Pocock 1962 (common) *Concavissimisporites variverrucatus* (Couper) Brenner 1963 (common) *Cyathidites* sp. (common) *Deltoidospora psilostoma* Rouse 1959 (rare) *Dictyotriletes southeyensis* Pocock 1962 (rare) *Exesipollenites tumulus* Balme 1957 (rare) *Lycopodiumsporites* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (scarce) *Pityosporites* sp. (rare) *Podocarpidites* sp. (rare) *Verrucosisporites* sp. (rare) Comments: Organic debris brown to black; preservation poor to good; recovery sparse; no evidence was found for this sample being other than Jurassic in age.	C-64184
Elk, 76-5B-15	*Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann 1961 (rare) *Classopollis* spp. (scarce) *Cyathidites* sp. (scarce) *Deltoidospora psilostoma* Rouse 1959 (rare) *Ginkgocycadophytus* sp. (scarce) *Murospora* sp. *Osmundacidites wellmanii* Couper 1953 (scarce) *Verrucosisporites* sp. Comments: Organic debris light brown to black; preservation poor; recovery very sparse; age possibly Cretaceous based on the presence of *Aequitriradites*.	C-64185

Trap Creek, Sec. 76-12

Mist Mountain, 76-12-6	*Alisporites* spp. (common) *Cyathidites* sp. (scarce) *Osmundacidites wellmanii* Couper 1953 (scarce) *Podocarpidites* sp. (scarce) *Verrucosisporites* cf. *V. rotundus* Singh 1964 (rare) Comments: Organic debris brown; preservation and recovery sparse; age indeterminate.	C-64186
Mist Mountain, 76-12-8	*Alisporites grandis* (Cookson) Dettmann 1963 (common) *Classopollis* sp. (common) *Cyathidites* sp. (scarce) *Exesipollenites tumulus* Balme 1957 (rare) *Ginkgocycadophytus* (rare) *Osmundacidites wellmanii* Couper 1953 (rare) *Podocarpidites* sp. (rare) Comments: Organic debris dark yellow to brown; preservation good; recovery sparse; age indeterminate.	C-64187

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Mist Mountain, 76-12-23	*Alisporites grandis* (Cookson) Dettmann 1963 (common) *Classopollis* sp. (rare) *Cyathidites* sp. (rare) *Ginkgocycadophytus* sp. (rare) Comments: Organic debris yellow brown; preservation poor; recovery sparse; age indeterminate.	C-64188
Mist Mountain, 76-12-26	*Callialisporites damperi* (Balme) Sukh Dev 1961 (rare) *Cerebropollenites* sp. (rare) *Classopollis* sp. (smooth, common) *Cyathidites* sp. (scarce, common) *Cicatricosisporites australiensis* (Cookson) Potonié 1956 (scarce) *Ginkgocycadophytus* sp. (scarce) *Vitreisporites pallidus* (Reissinger) Nilsson 1958 (rare) Comments: Organic debris yellow to yellow brown; preservation poor; recovery good (only unoxidized portion of sample contained *Cicatricosisporites*). Based on the presence of *Cicatricosisporites*, this sample may be of Cretaceous age, or is at least probably equivalent in age to strata younger than the C seams at Sparwood and Natal, B.C.	C-64189

Wilkinson Summit, Sec. 76-13

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Elk, 76-13-35	*Alisporites* sp. (scarce) *Callialasporites damperi* (Balme) Sikh Dev 1961 (rare) *Classopollis* spp. (common) *Cyathidites* sp. (common) *Deltoidospora juncta* (Kara-Murza) Singh 1964 (rare) *Deltoidospora psilostoma* Rouse 1959 (rare) *Dictyotriletes southeyensis* Pocock 1962 (scarce) *Exesipollenites tumulus* Balme 1957 (rare) *Ginkgocycadophytus* sp. (scarce) *Lycopodiumsporites austroclavatidites* (Cookson) Pocock 1962 (rare) *Matthesisporites* cf. *M. tumulosus* Doring 1964 (rare) *Microreticulatisporites* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (common) *Vitreisporites pallidus* (Reissinger) Nilsson 1958 (rare) Comments: Organic debris brown to black; preservation relatively good; recovery sparse; age most probably Jurassic, although the assemblage is not very definitive.	C-64181
Elk, 76-13-41	*Alisporites* spp. *Deltoidospora psilostoma* Rouse 1959 (rare) *Osmundacidites wellmanii* Couper 1953 (scarce) Comments: Organic debris brown to black; preservation poor; recovery very sparse; age indeterminate.	C-64182
Elk, 76-13-52	*Cyathidites* sp. (rare) Comments: Organic debris brown to black; preservation poor; recovery very low; age indeterminate.	C-64183

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
	Weary Ridge, Sec. 76-15	
Mist Mountain, 76-15-21	*Alisporites* spp. (scarce) *Classopollis* sp. (rare) *Cyathidites* sp. (rare) *Inaperturopollenites* sp. (rare) *Lycopodiumsporites* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (scarce) *Steriosporites antiquasporites* (Wilson and Webster) Dettmann 1963 (rare) Comments: Organic debris brown to black; preservation poor; recovery very sparse; age indeterminate.	C-68002
Mist Mountain, 76-15-23	*Cyathidites* sp. (scarce) *Neoraistrickia obtusispina* Rouse 1959 (rare) Comments: Organic debris brown to black; preservation poor; recovery very sparse; age indeterminate.	C-68003
Mist Mountain, 76-15-35	*Alisporites* sp. (scarce) *Classopollis* sp. (rare) *Cyathidites* sp. (scarce) *Lycopodiumsporites* sp. (rare) Comments: Organic debris brown to black; preservation poor; recovery very sparse; age indeterminate.	C-68004
	Barrier Mountain, Sec. 76-17	
Elk, 76-17B-2	*Alisporites grandis* (Cookson) Dettmann (scarce) *Cerebropollenites mesozoicus* (Couper) Nilsson 1958 (rare) *Concavisporites verrucosus* var. *minor* (Delcourt and Sprumont) Pocock 1962 *Cyathidites* sp. *Deltoidospora psilostoma* Rouse 1959 (rare) *Schizosporis reticulatus* fragment (?) Cookson and Dettmann 1959 (rare) Comments: Organic debris light brown to black; preservation poor; recovery very sparse; age indeterminate.	C-64190
Elk, 76-17B-6	*Classopollis* spp. (common) *Cyathidites* sp. (sparse) *Dictyotriletes southeyensis* Pocock 1962 (rare) *Ginkgocycadophytus* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (rare) Comments: Organic debris light brown to black; preservation poor; recovery very sparse; age indeterminate.	C-64191
Elk, 76-17B-17	*Deltoidospora psilostoma* Rouse 1959 (rare) Comments: Organic debris brown to black; preservation poor; recovery very sparse; age indeterminate.	C-64192

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Elk, 76-17B-19	*Alisporites* sp. (rare) *Classopollis* sp. (smooth, common) *Cyathidites* sp. (rare) *Dictyotriletes southeyensis* Pocock 1962 (rare) *Lycopodiumsporites* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (rare) Comments: Organic debris brown to black; preservation poor; recovery very sparse; age indeterminate.	C-64193
Elk, 76-17B-27	*Cyathidites* spp. (abundant) *Dictyotriletes southeyensis* Pocock 1962 (scarce) *Ginkgocycadophytus* sp. (rare) *Osmundacidites wellmanii* Couper 1953 (common) *Schizosporis reticulatus* Cookson and Dettmann 1959 (1 fragment) Comments: Organic debris brown; preservation and recovery good; age probably Early Cretaceous, based on the presence of *Schizosporis reticulatus*.	C-64194
Elk, 76-17C-13	*Alisporites* spp. (common) *Cyathidites* sp. (scarce) ?*Contignisporites* sp. (rare) *Ginkgocycadophytus* spp. (rare) *Osmundacidites wellmanii* Couper 1953 (rare) Comments: Organic debris brown; preservation and recovery poor; age indeterminate.	C-64195
Elk, 76-17C-27	*Cyathidites* sp. (scarce) *Deltoidospora psilostoma* Rouse 1959 (common) *Granulatisporites* sp. (rare) *Schizosporis reticulatus* (?) Cookson and Dettmann 1959 (fragment) Comments: Organic debris brown to black; preservation poor; recovery sparse. Some poorly preserved dinoflagellates appear to be present. These may indicate a marine influence; age indeterminate unless one takes the questionable identification of *Schizosporis* as indicating a Cretaceous age.	C-64196
Elk, 76-17C-50	*Classopollis* sp. (rare) *Cyathidites* (rare) *Ginkgocycadophytus* sp. (rare) Comments: Organic debris brown; preservation poor; recovery very sparse; age indeterminate.	C-64197
Elk, 76-17C-55	Comments: Organic debris brown; no identifiable grains observed; age indeterminate.	C-64198
Elk, 76-17C-65	Comments: Except for scarce bisaccate pollen and *Classopollis* sp. the organic debris is brown; no identifiable grains observed; age indeterminate.	C-64199

FORMATION, FIELD SAMPLE NO.	LOCATION, FLORA AND COMMENTS	GSC LOC. NO.
Elk, 76-17C-67	Comments: Except for scarce bisaccate pollen and *Classopollis* sp. the organic debris is brown; no identifiable grains observed; age indeterminate.	C-64200
Elk, 76-17C-71	Comments: Organic debris brown; no identifiable grains observed; age indeterminate.	C-68001

General Comments:

Of the 60 species recorded, 27 are known to range across the Jurassic-Cretaceous boundary, 20 have been previously reported from Cretaceous strata, and 13 from Jurassic strata. Even though the above is based on an incomplete literature survey and the flora of the Jurassic-Cretaceous boundary interval is, at present, poorly known within North America, a sufficient number of potential index species are present to justify further work on the establishment of a biostratigraphic zonation within the upper portion of the Kootenay Group.

APPENDIX 4

Micropaleontology

by J.H. Wall

FORMATION, FIELD SAMPLE NO.	LOCATION, FAUNA, AGE AND ENVIRONMENT	GSC LOC. NO.
	Marten Ridge, Sec. 75-12	
Mist Mountain, 75-12-9	*Haplophragmoides* sp. - one specimen only Age: indeterminate, Cretaceous appearance Environment: uncertain - the single foraminifer present may not be indigenous to the locality, and would be inadequate for assumption of marine conditions. Re-examination of the residue did not yield any additional foraminifers.	C-51967
Mist Mountain, 75-12-56	Ostracoda *Darwinula leguminella* (Forbes) genus indeterminate - reniform carapace, prominent longitudinal striations, apparent sexual dimorphism Age: Jurassic-Cretaceous Environment: nonmarine.	C-51975
	Greenhills Range, Sec. 75-17	
Mist Mountain, 75-17-22	Charophyta ?*Sphaerochara* sp. - one distorted gyrogonite genus indeterminate - incomplete gyrogonite Age: Jurassic-Cretaceous Environment: nonmarine.	C-49005
	Eagle Mountain-Fording Coal, Sec. 75-19-25	
Mist Mountain, 75-23-656'-679'	One or more primitive protistids, possibly "thecamoebians" Age: indeterminate Environment: probably nonmarine.	C-49027
Mist Mountain, 75-24-337.2'-340.6'	Rare shell (possibly ostracode) fragments Age: indeterminate Environment: indeterminate.	C-49050
	Barrier Mountain, Sec. 76-17	
Mist Mountain, 76-17A-1	*Ammodiscus* or *Trochamminoides* sp. - 4 specimens Age: Jurassic (?) Environment: shallow marginal marine, probably brackish.	C-65164
Mist Mountain, 76-17A-6	*Ammodiscus* sp. cf. *A. southeyensis* (Wall) - 10 specimens Age: Jurassic (?) Environment: shallow marginal marine, probably brackish.	C-65165
Mist Mountain, 76-17A-18	*Ammodiscus* or *Trochamminoides* sp. - 1 specimen Age: Jurassic (?) Environment: shallow marginal marine, probably brackish.	C-65168
Mist Mountain, 76-17A-21	*Ammodiscus* sp. cf. *A. southeyensis* (Wall) - 4 specimens Age: Jurassic (?) Environment: shallow marginal marine, probably brackish.	C-65169
	Elk Valley, Sec. E.V. 1-4	
Mist Mountain, E.V. 2-25'-32'	Ostracoda - genera indeterminate - 2 partial carapaces Age: indeterminate Environment: probably nonmarine.	C-65171

FORMATION, FIELD SAMPLE NO.	LOCATION, FAUNA, AGE AND ENVIRONMENT	GSC LOC. NO.
Mist Mountain E.V. 2-236'-238.8'	?*Cyzicus* sp., a brachiopod - 1 partial, pyritized specimen Age: indeterminate Environment: probably nonmarine.	C-65170
	Gap Lake, Sec. 77-5	
Fernie, 77-5-1	*Haplophragmoides* sp. - 2 specimens *Ammobaculites* sp. - 1 incomplete specimen Age: indeterminate Environment: probably marginal marine.	C-68040
	Prairie Creek, Sec. 77-4	
Mist Mountain, 77-4-4	*Ammodiscus* sp. cf. *A. southeyensis* (Wall) - 12 specimens Age: Jurassic (?) Environment: shallow marginal marine, probably brackish.	C-72252
	Wapiabi Creek, Sec. 77-7	
Nikanassin, 77-7-5	*Ammodiscus* sp. cf. *A. southeyensis* (Wall) - 10 specimens *Haplophragmoides* sp. - 1 specimen Age: Jurassic (?) Environment: shallow marginal marine, probably brackish.	C-68016
Nikanassin, 77-7-6	*Haplophragmoides* sp. - 1 specimen Age: Jurassic (?) Environment: shallow marginal marine, probably brackish.	C-68017
Nikanassin, 77-7-31	Sparse, indeterminate foraminifera Simple, discoidal, spumelline radiolarians One poorly preserved, indeterminate ostracode Age: indeterminate, but Jurassic indicated. The radiolarians appear similar or identical to some illustrated by Weihmann (1964, Pl. 1, figs. 8-10) from the Middle Jurassic part of the Fernie Formation. Environment: marine, probably shallow (radiolarians would not be expected this high in the section - their presence may be due to removal from their original environment).	C-68030
Nikanassin, 77-12-6	Siliceous protistids belonging to either the hippocrepininid foraminifera or to the thecamoebians Age: indeterminate Environment: uncertain, probably brackish water.	C-68035

General Comments:

Most samples from the coal-bearing Mist Mountain Formation are largely unfossiliferous, generally yielding only sporadic nonmarine microfossils. Section 76-17A, Barrier Mountain, however, yielded foraminifera of a simple agglutinated form, probably identical with *Ammodiscus southeyensis* (Wall) described from the Shaunavon Formation of Saskatchewan and generally regarded as being of Bathonian age. Based on this tenuous piece of evidence, the Mist Mountain Formation is given a questionable Jurassic age. Such a primitive foraminifer, however, could well have an extensive geologic range. Chamney, in Jansa (1972, p. 3202) mentioned the occurrence of *Ammodiscus* and *Haplophragmoides* in the "Passage Beds" of the Fernie Formation, which were considered to be indicative of a Kimmeridgian age, although no species were identified nor was any corroborative evidence offered. The barren samples which were processed are assumed to be of nonmarine origin, lacking as they do any indicators of a marine association.

The microfauna obtained from the Nikanassin Formation at Wapiabi Creek is inadequate for the purpose of dating. The low faunal recovery may be in part caused by the indurated character of the shales, which resulted in an incomplete disintegration of the samples. It also seems probable that much of this sequence is of shallow, brackish water origin, which would tend to inhibit the development of a diversified foraminiferal fauna. The meagre microfauna that was recovered at this and other northern localities would seem to favour a Jurassic age for the Nikanassin, which is in agreement with the assignments by Warren and Stelck (1958) and Gussow (1960).

APPENDIX 5

Coal Rank Determination by Vitrinite Reflectance

by A.R. Cameron, P.R. Gunther and D.M. Bardwell

FORMATION, FIELD SAMPLE NO. OR FOOTAGE	MEAN MAXIMUM REFLECTANCE %Ro	% VM OF VITRINITE (FROM KOTTER'S CURVE)	COMPARABLE ASTM RANK	GSC LOC. NO.
Sparwood Ridge, Sec. 75-8				
Elk, 75-8A-90	0.58 ± .02	42.0	HVB-C	C-51957
Coal Creek Mountain, Sec. 75-16				
Mist Mountain, 75-16-7, 112.4'	1.24 ± .07	25.7	MVB	C-59992
Mist Mountain, 75-16-34, 1185.4'	1.14 ± .05	28.0	MVB	C-59993
Mist Mountain, 75-16-ww, 1844.1'	0.97 ± .04	32.0	HVB-MVB	C-59994
Morrissey Microwave Tower, Sec. 75-9				
Elk, 75-9-13, 262.0'	1.13 ± .05	28.2	MVB	C-59997
Elk, 75-9-27, 619.3'	1.01 ± .05	30.6	HVB-MVB	C-59998
Elk, 75-9-85, 1703.2'	0.64 ± .07	41.0	HVB-B	C-59999
Elk, 75-9-90, 1764.8'	0.66 ± .03	40.3	HVB-B	C-60000
Mount Taylor, Sec. 75-15				
Mist Mountain, 75-15-13, 981.4'	1.02 ± .06	30.8	HVB-MVB	C-59995
Mist Mountain, 75-15-28, 1434.9'	1.19 ± .04	26.8	MVB	C-59996
Eagle Mountain-Fording Coal, Sec. 75-19-25				
Elk, 75-19-15	0.81 ± .03	36.0	HVB-A	C-49048
Elk, 75-19-50	0.62 ± .04	42.0	HVB-B	C-49040
Mist Mountain, 75-23, 245'-247'	1.15 ± .04	29.0	MVB	C-49037

FORMATION, FIELD SAMPLE NO. OR FOOTAGE	MEAN MAXIMUM REFLECTANCE %Ro	% VM OF VITRINITE (FROM KOTTER'S CURVE)	COMPARABLE ASTM RANK	GSC LOC. NO.
		Oldman Gap, Sec. 76-1		
Mist Mountain, 76-1-13, 76.6'	1.06 ± .06	29.9	MVB	C-59962
Mist Mountain, 76-1-25, 175.0'	1.09 ± .05	29.2	MVB	C-59963
Mist Mountain, 76-1-34, 248.5'	1.19 ± .06	26.8	MVB	C-59964
		Cabin Ridge, Sec. 76-2		
Mist Mountain, 76-2A-5, 67.2'	1.25 ± .06	25.4	MVB	C-59965
Mist Mountain, 76-2A-12, 170.1'	1.26 ± .04	25.2	MVB	C-59966
Mist Mountain, 76-2A-28, 354.1'	1.32 ± .06	23.7	MVB	C-59967
Mist Mountain, 76-2A-42, 595.5'	1.36 ± .07	22.8	MVB	C-59968
Mist Mountain, 76-2B-12, 133.8'	1.26 ± .07	25.2	MVB	C-59970
Mist Mountain, 76-2-24, 251.8'	1.28 ± .04	24.7	MVB	C-59971
		Ridge Creek, Sec. 76-3		
Mist Mountain, 76-3-29, 369.8'	1.16 ± .05	27.5	MVB	C-59972
Mist Mountain, 76-3-40, 512.1'	0.99 ± .04	31.6	HVB-MVB	C-59973
		Trap Creek, Sec. 76-12		
Mist Mountain, 76-12-20, 299.5'	1.59 ± .06	17.8	LVB	C-59978
		Wilkinson Creek, Sec. 76-13		
Mist Mountain, 76-13-7, 127.9'	1.37 ± .04	22.5	MVB	C-59974
Mist Mountain, 76-13-17, 305.9'	1.10 ± .09	28.9	MVB	C-59975
Elk, 76-13-35, 634.4'	1.16 ± .07	27.5	MVB	C-59976
Elk, 76-13-42, 736.3	1.20 ± .06	26.6	MVB	C-59977

FORMATION, FIELD SAMPLE NO. OR FOOTAGE	MEAN MAXIMUM REFLECTANCE %Ro	% VM OF VITRINITE (FROM KOTTER'S CURVE)	COMPARABLE ASTM RANK	GSC LOC. NO.
		Mist Mountain-Mount Lipsett, Sec. 76-9-10-11		
Elk, 76-9-24, 292.7'	0.89 ± .04	34.0	HVB-A	C-49081
Elk, 76-9-22, 268.5'	1.08 ± .04	29.0	MVB	C-49080
Elk, 76-11-39, 782.0'	0.98 ± .07	31.0	HVB-A	C-49075
Elk, 76-11-26, 528.4'	1.11 ± .03	29.0	MVB	C-49070
Elk, 76-11-14, 223.9'	1.29 ± .04	24.0	MVB	C-49065
Elk, 76-11-7, 168.8'	1.15 ± .05	26.0	MVB	C-49063
Mist Mountain, 76-10-96, 1466.5'	1.16 ± .05	26.5	MVB	C-49085
Mist Mountain, 76-10-84, 1376.0'	1.18 ± .05	26.5	MVB	C-49086
Mist Mountain, 76-10-72, 1265.8'	1.53 ± .07	19.5	LVB	C-49087
Mist Mountain, 76-10, 1093.0'	1.54 ± .06	19.5	LVB	C-49093
Mist Mountain, 76-10-54, 798.1'	1.61 ± .06	18.0	LVB	C-49088
Mist Mountain, 76-10-43, 666.1'	1.38 ± .20	22.0	MVB	C-49089
Mist Mountain, 76-10-29, 524.1'	1.63 ± .15	17.0	LVB	C-49090
Mist Mountain, 76-10-21, 403.0'	1.79 ± .05	14.5	LVB	C-49091
Mist Mountain, 76-10-13A, 271.0'	1.74 ± .06	15.0	LVB	C-49092

FORMATION, FIELD SAMPLE NO. OR FOOTAGE	MEAN MAXIMUM REFLECTANCE %Ro	% VM OF VITRINITE (FROM KOTTER'S CURVE)	COMPARABLE ASTM RANK	GSC LOC. NO.
		Barrier Mountain, Sec. 76-17		
Mist Mountain, 76-17A-3, 278.2'	2.09 ± .05	11.2	SA	C-59982
Mist Mountain, 76-17A-9, 359.7'	2.25 ± .05	9.8	SA	C-59983
Mist Mountain, 76-17A-28, 493.9'	2.27 ± .05	9.6	SA	C-59984
Mist Mountain, 76-17A-36, 566.1'	2.23 ± .07	9.9	SA	C-59985
Mist Mountain, 76-17A-58, 794.7'	2.12 ± .07	10.2	SA	C-59986
Mist Mountain, 76-17B-2, 62.8'	1.84 ± .05	13.9	SA-LVB	C-59987
Mist Mountain, 76-17B-18, 343.0'	1.80 ± .07	14.4	LVB-SA	C-59988
Elk, 76-17C-5, 106.4'	1.82 ± .06	14.1	LVB-SA	C-59989
Elk, 76-17C-22, 402.4'	1.82 ± .04	14.1	LVB-SA	C-59990
Elk, 76-17C-62, 1040.8'	1.60 ± .10	1.6-1.7	LVB	C-59991
		Bragg Creek, Sec. 76-19		
Mist Mountain, 76-19-8, 133.4'	1.90 ± .06	13.0	SA	C-59979
Mist Mountain, 76-19-13, 167.5'	1.91 ± .06	12.9	SA	C-59980
Mist Mountain, 76-19-24, 261.5'	1.68 ± .07	16.3	LVB	C-59981

SA - Semi-anthracite
LVB - Low volatile bituminous
MVB - Medium volatile bituminous
HVB - High volatile bituminous

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