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FIELD GUIDE TO THE TRIASSIC AND JURASSIC STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE ROCKY MOUNTAIN FOOTHILLS AND AND FRONT RANGES IN THE BANFF, JASPER AND CADOMIN AREAS OF ALBERTA

D.W. Gibson and T.P. Poulton

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

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TRIASSIC AND JURASSIC STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE ROCKY MOUNTAIN FOOTHILLS AND FRONT RANGES IN THE BANFF, JASPER AND CADOMIN AREAS OF ALBERTA

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PREFACE

Participants on the field trip to the Banff, Jasper and Cadomin areas will have an opportunity to examine in detail seven Triassic and Jurassic siliciclastic and carbonate outcrop localities which originally formed part of a passive margin and succeeding orogenic foredeep basin. Over the next three days rocks will be examined which were deposited in the western part of the Western Canada Sedimentary Basin, and which are characteristic of distal to proximal shelf and peritidal environments.

ITINERARY

PLEASE NOTE: The use of rock hammers and the collecting of rock samples are not allowed in Banff and Jasper National Parks.

Day 1.

Depart Calgary Convention Centre at 8:00 A.M. by bus travelling westward via the Trans-Canada Highway to Stop 1 near Banff. Here we will examine mid-to proximal-shelf and shoreface siliciclastics of the Jurassic Fernie and Morrissey formations. Mid-to distal-shelf marine siliciclastics of the Triassic Sulphur Mountain Formation will next be examined in the Banff area, first along Mount Norquay ski access road, next at our lunch locality at Bow Falls and finally along the Trans-Canada Highway near Vermilion Lakes. The latter locality represents geographically one of the most western exposures of Lower Triassic rocks in the Banff and Jasper areas.The remainder of the day will consist of a drive along the spectacular Icefields Parkway (Highway 93) to Jasper, and then along Highway 16 to Overlander Lodge near the east gate of Jasper National Park. Dinner and accommodation will be provided by Overlander Lodge.

Day 2.

Following an early morning breakfast, a short drive southward along Highway 16 and then southeastward along the Miette Hotsprings access road will take us to our first outcrop locality at the confluence of Fiddle River and Morris Creek. A short traverse down Morris Creek to Fiddle River will lead participants to exposures of the Phroso Siltstone and Vega Siltstone members of the Sulphur Mountain Formation. Although exposed, strata of the Whitehorse Formation will not be examined at this locality. In order to see the best exposures it will be necessary to cross the cold but shallow waters of Fiddle River. Sneakers or hip waders are advised. Return to the Miette Hotsprings access road, and proceed to the second outcrop locality, the former Miette Hotsprings garbage disposal site. The site is now used to store culverts and other Jasper Park Highways maintenance equipment.

Descend storage site embankment and proceed a short distance through the trees to Fiddle River, and down a steep gully to river level. At this locality, strata of the upper Sulphur Mountain (Vega Siltstone and Llama members), and Whitehorse formations (Starlight Evaporite and Winnifred members) will be examined in detail. Next, strata of the Red Deer, Poker Chip and Rock Creek members of the Jurassic Fernie Formation will be examined. As before, several crossings of Fiddle River are necessary to see the best and most continuous exposures.

Return to bus and proceed to the Miette Hotsprings for a brief visit. Return to Yellowhead Highway (16). Proceed to Stop 5 to examine exposures of the Sulphur Mountain Formation. Continue to Jasper for dinner. Evening return to Overlander Lodge.

Day 3.

Depart Overlander Lodge 8:00 A.M. and proceed northward a short distance along Highway 16 to the junction with Highway 40. Proceed eastward past the two large coal mine operations of Gregg River and Cardinal River Mines to Highway 47, then southward to our Foothills locality along McLeod River south of Cadomin. The first part of the morning will be spent examining mid- to proximal shelf, and shoreface strata of the Triassic Sulphur Mountain Formation, including an exposure of the Mackenzie Dolomite Lentil which contains hydrocarbons in the subsurface. Shallow water peritidal carbonates of the upper Whitehorse Formation will also be briefly examined. The remainder of the morning and early afternoon will be spent looking at basin/shelf and shoreface cherts, carbonates and siliciclastics of the Jurassic Nordegg, Red Deer and Rock Creek members of the Fernie Formation. In addition, early foredeep strata of the "Passage Beds" of the upper Fernie Formation and shoreface siliciclastics of the lower Nikanassin Formation will be examined along the northwest side of Prospect Creek.

Our return to Calgary beginning in mid afternoon will be via the Alberta Forestry Trunk Road System to the junction with Highway 11 near Nordegg. If there is sufficient interest and time permits, a brief stop (Stop 7) will be made to examine the Jurassic Nordegg Member east of the town of Nordegg. Triassic rocks have been eroded in the area of this outcrop. The Jurassic is unconformably underlain by Carboniferous strata of the Rundle Group.

Proceed westward along Highway 11 past Abraham Lake to North Saskatchewan River Crossing and the Icefields Parkway, then southward to Lake Louise, Banff and Calgary. Arrival at the Convention Centre will be early evening.

BACKGROUND

This Field Guide originated as the Guidebook for Field Trip #3, prepared for the 1993 Annual Convention of the Canadian Society of Petroleum Geologists, held jointly with the Global Sedimentary Geology Program, August 15-19, 1993: Carboniferous to Jurassic **PANGEA** - A Global View of Environments and Resources.

The same trip, with guidebook, was offered for the 1993 meeting of the Geological Association of Canada.

ACKNOWLEDGEMENTS

The trip leaders would like to thank Brian Cormier and Denise Then for drafting some of the figures, Bill Sharman for reproducing the many photographs, and Len Wardle for his excellent reproduction of the figures. Monica Bernard read and improved proofs of the manuscript and collated the finished guide. Dianne Cornelius assisted with corrections and provided the layout of the report. Thanks are extended to Mary McDonald and Alex Poulton for assisting Dave Gibson and Terry Poulton respectively with describing and sampling some of the outcrop localities in the Cadomin and Jasper areas. Several individuals, but particularly Graham Davies assisted with the identification and interpretation of the Nordegg chert thin sections, which were prepared by Roger Michie. Dave McNeil and Jenny Wong assisted with SEM analysis of the cherts. Karen Paull, Ram Kalgutkar, and Denise Then processed Jurassic palynological and micropaleontological samples. Tony Hamblin, Doug Cant and Gerry Reinson assisted with interpretation of the Banff Traffic Circle Jurassic section. John Wall identified and interpreted Jurassic microfossils from the McLeod River section.

INTRODUCTION

The Triassic and Jurassic rocks that will be seen during this field trip (Fig. 1), serve to illustrate most of the major rock types of both systems that have been described in other areas of the Alberta and British Columbia Foothills and Front Ranges of the Western Canada Sedimentary Basin. Access to the field stops is relatively easy, with most exposures located near major roadways. Some stratigraphically thicker and marginally better exposed field sections occur in the area, but require a helicopter or long and sometimes arduous treks through forested areas or up mountain ridges. The exposures seen on this field trip, particularly those in the Cadomin area, may be used to illustrate the lithologic character of equivalent rocks in the adjacent subsurface in the outer Foothills and Plains. Some of the units contain or may contain potential hydrocarbon resources (e.g. Mackenzie Dolomite, Bainey, 1990). Some of the Jurassic units, especially the Nordegg, Red Deer and Poker Chip Members are potential source rocks.

PREVIOUS WORK

Triassic

Triassic rocks in the area of the field trip were first described by McConnell (1887) during a geological investigation of part of the Rocky Mountains near Banff, although he considered the strata to be of Carboniferous age. Dowling (1907) studied the same succession and assigned a Permian-Triassic age. Later, Lambe (1916), on the basis of fossil identifications, proved the rocks to be of Triassic age. Kindle (1924) subsequently named this rock sequence the Spray River Formation. In 1927, Warren described a section of the Spray River Formation in Spray River gorge near Banff, and in 1945, divided the formation into two members, a lower, Sulphur Mountain Member and an upper, Whitehorse Member, with the type section of the Sulphur Mountain Member assigned to Spray River gorge. Warren in his report (op.cit.) also indicated the occurrence of a well exposed section of the Spray River Formation on McLeod River near Cadomin (Stop 6, Fig. 1). MacKay (1929a, b) mapped the distribution of Triassic rocks in the Foothills Belt near Cadomin and Mountain Park. Best (1958), described and designated a type section for the Whitehorse Member of the Spray River Formation on Whitehorse Creek near Cadomin. He recognized three new facies units in the Sulphur Mountain Member, all of which can be seen on this field trip. Irish (1951) and Mountjoy (1960,1962) elevated the two members to formational status in their respective map areas north of Athabasca River. This nomenclature has been adopted and extended to other areas of southern Alberta and southeastern British Columbia and to the outcrop belt in part of northeastern British Columbia. Shaffiudin (1960), examined and briefly described a Triassic section at Cadomin which he correlated with the type section of the Sulphur Mountain Member at Banff. A synthesis of all published Triassic stratigraphic information in western Canada, including the Cadomin and Jasper areas, was made by Barss et al., (1964). Gibson (1968a, b, 1971, 1974, 1975), as part of a regional study of Triassic rocks in the Rocky Mountain Front Ranges and Foothills of Alberta and British Columbia, described the stratigraphy, petrology and depositional environments in the field trip area. This regional investigation resulted in the redefinition and designation of new members in the Sulphur Mountain and Whitehorse formations, recognized by earlier workers. Bainey (1990), briefly described the geology and provided reservoir data for gas-bearing strata equivalent to the Mackenzie Dolomite of this guidebook. Recently, a synthesis of all available Triassic stratigraphic and biostratigraphic information in the Rocky Mountain Foothills and Front Ranges of the Western Canada Basin, including the field trip area, has been prepared by Gibson (in press) and Edwards et al., (in press).

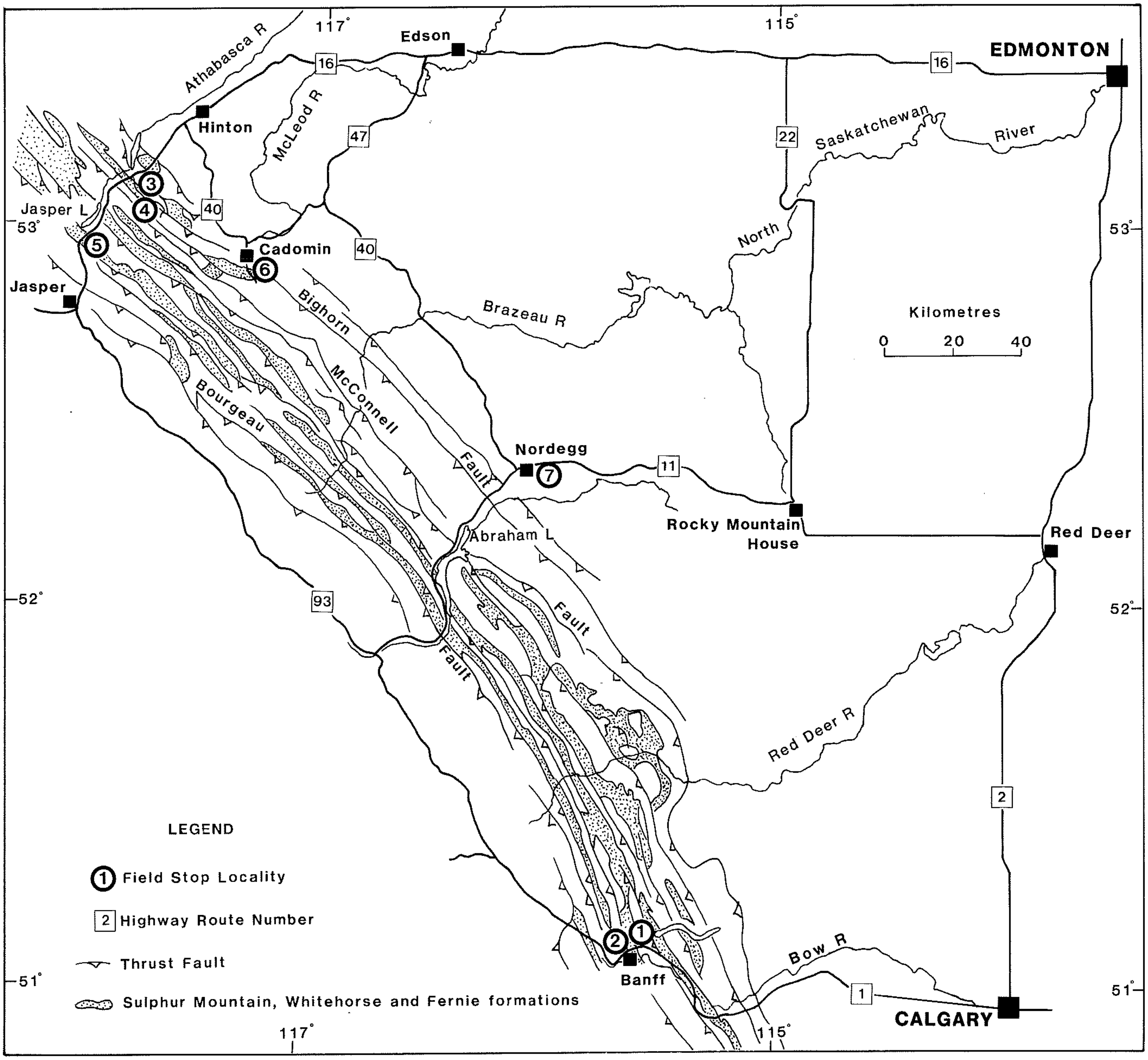

Fig. 1. Index map illustrating distribution of Triassic Sulphur Mountain and Whitehorse formations and Jurassic Fernie Formation, and field trip stops in the Banff, Jasper, Cadomin and Nordegg areas (Geology and thrust faults after Wheeler and McFeely, 1992).

Jurassic

The first detailed work on the Jurassic in Banff area was by Frebold (1957, 1962) who recognized the overturned character and tectonic significance of a Jurassic roadside exposure (Stop 1, Fig. 1) in an overturned syncline below a major thrust fault (Rundle Thrust). Previous workers, including Dowling (1907) had considered the Mesozoic sandstones in the Cascade Coal Basin to be Cretaceous, and misinterpreted the stratigraphic position of the Jurassic shales in this structurally complicated area. The section near the former Banff Traffic Circle (Stop 1, Fig. 1) formed part of a regional study on the Fernie-Kootenay transition interval published by Hamblin and Walker (1979). This Jurassic section has been the subject of previous field trips, with guidebooks published by Hamblin (1978, 1983), Walker and Hamblin (1982) and Hall and Stronach (1982). The Kootenay succession, the lowest part of which is well exposed in this section, was studied in detail on a regional scale by Gibson (1985).

In addition to mapping exercises demonstrating the presence and distribution of Jurassic rocks (eg. Dowling, 1912), the earliest detailed examination of Jurassic strata in the Jasper area was by Collet (1931), at Fiddle River. MacKay (1929a,b, 1930) introduced the name Nikanassin for the uppermost Jurassic and lowermost Cretaceous sandstone unit in west central Alberta. Some of the fossils critical to correlation of the units in the Cadomin area were described or listed in their stratigraphic context by Warren (1932) and McLearn (1932). Warren (1934) discussed the Fernie Formation on a regional outcrop scale and recognized two distinctive lithologic units that could be used for correlation, the Rock Creek Member and the Black Chert member. Spivak (1949), in a regional discussion including subsurface and surface data, applied the name Nordegg Member to Warren's Black Chert member, and recognized the usefulness for regional correlation of a unit called the 'Brown sand' at the top of the Fernie Formation and of the Poker Chip shale. The Brown sand presumably refers to the first major sandstone above the Fernie shaley sequence, ie. the lowest Nikanassin or Kootenay. Frebold (1957) provided the first detailed description of the Jurassic sequences at McLeod and Fiddle Rivers, in a volume that represented the first synthesis of the Fernie Formation (he called it the Fernie Group) and its members. Kryczka (1959) produced the only detailed description of the Nikanassin Formation in the area. Mellon (1966) also gave a summary of the formation in the Cadomin area. Hall (1984) discussed the Fernie Formation and its members on a regional scale. Rosenthal (1989) described some of the Fernie outcrops in the Jasper-Cadomin area, and their subsurface correlations in a regional study that included the Jurassic and Lower Cretaceous of west central Alberta. The regional distribution and mutual relationships of the Nordegg Member and the Red Deer Member (known as the "Nordegg" in northern Alberta), and of the Rock Creek Member and sandstones basal to the Upper Fernie were described and revised by Poulton et al., (1990). Major regional syntheses of the Jurassic of the Western Canada Sedimentary Basin were published by Springer et al., (1964), Stott (1970), Poulton (1984, 1988, 1989) and Poulton et al., (in press), the last publication containing regional distribution maps of most Jurassic units.

TRIASSIC STRATIGRAPHY

GENERAL

The following discussion briefly outlines the paleogeography, geological and tectonic setting, lithostratigraphy, correlation and depositional environments of Triassic formations and members in the Banff, Jasper and Cadomin area. For a more comprehensive discussion of Triassic rocks in the field trip area and other areas of Alberta and British Columbia, the interested participant is referred to reports by Gibson (1968a,b, 1971, 1974, 1975, in press), Gibson and Barclay (1989), Gibson and Edwards (1990) and Edwards et al., (in press).

PALEOGEOGRAPHIC AND TECTONIC SETTING

Triassic rocks in the Rocky Mountain Front Ranges and Foothills consist of a relatively thick, eastward thinning sequence of marine to marginal marine siliciclastics, carbonates and evaporites, forming part of the Western Canada Sedimentary Basin. In the field trip area, however, the Triassic succession is relatively thin although it still displays a conspicuous eastward thinning profile.

Triassic sediments were deposited on a topographically low, tectonically stable continental shelf and shoreline along a generally passive margin of the western North American Craton. Deposition along the cratonic margin began prior to the break-up of the super continent Pangea. During mid-to-late Triassic time, rifting within the supercontinent began, resulting in the separation of new continental masses, including western North America and the area of the Western Canada Basin. The initial break-up of Pangea may have been partly responsible for global sea-level fluctuations which are evident in some Triassic and younger strata of the Western Canada Basin. Deposition along the cratonic margin between latitudes 30° and 60° N, appears to have preceded the arrival and docking of several allochthonous or exotic terranes, which today occupy much of the central and western Cordillera of British Columbia (Monger, 1989). During initial deposition of the Triassic, the oceanic area west of the cratonic margin was known as Panthalassa, a region dotted with volcanic islands, archipelagos, shoals and carbonate banks with intervening deep water basins and troughs (Tozer, 1982). Some of these islands and archipelagos were fringed with coral reefs and faunas characteristic of warm shallow tropical seas. In response to the Triassic event, these oceanic land masses began their movement northward and eastward toward the stable craton. Docking and collision of the terranes carrying these island land masses with the craton appears to have begun in mid-to-late Jurassic time (e.g. Stikinia and Quesnellia). Some of the allochthonous terranes are postulated to have travelled between 1500 and 3000 km (Tozer, op. cit.). At present, no convincing evidence has yet been provided in support of some earlier suggestions of a western volcanic land mass area immediately offshore from the cratonic margin, and separated by a marine embayment or epicontinental sea. During Triassic time the southern proximity and movement of these exotic or allochthonous terranes, may also have been partly responsible for some of the major and smaller scale transgressive-regressive sea-level cycles, reflected in the shallow and deep water lithofacies of the Western Canada Sedimentary Basin and part of the field trip area.

PROVENANCE AND PALEOCLIMATE

Stratigraphic and sedimentologic evidence indicates that the Triassic sediments were derived mainly from the north and northeast from a cratonic source area of low relief, consisting of mainly quartz-rich siliciclastic rocks of possible Permian, Carboniferous and older ages (Barss et al., 1964, Gibson, 1975). As noted above, no convincing evidence in support of a western or oceanward sediment source area has yet been found.

Triassic strata of the Western Canada Sedimentary Basin are interpreted to have been deposited in a paleoclimate ranging from mid-temperate to subtropical (Gibson and Barclay, 1989). The occurrence of Upper Triassic evaporites and evaporitic sediments throughout most areas of the basin is indicative of deposition within an arid and probably hot subtropical climate. However, the absence of these evaporite sediments in Lower and Middle Triassic rock units suggests a more temperate and less arid climatic regime. Marine waters in the basin, even during Late Triassic time appear to have been too cold to support the growth of corals or other warm water faunas such as megalodonts and sponges (Tozer, op. cit.). These normally warm water faunas have, however, been recovered from Late Triassic rocks in the Yukon (Reid and Ginsburg, 1986), in allochthonous terranes accreted to the North American craton during early Middle Jurassic time.

REGIONAL FRAMEWORK

Triassic rocks of the Spray River Group in the Banff, Jasper and Cadomin region are divided into two distinct and contrasting formations, a lower, Sulphur Mountain and an upper, Whitehorse. Each formation displays internal lithologic variation that generally facilitates subdivision into members (Figs. 2, 3). The Sulphur Mountain Formation comprises a sequence of medium to dark grey, to rusty brown weathering, dolomitic and calcareous, siltstone, sandstone, and shale, with locally, calcareous and silty to sandy dolostone. In the field trip area the formation ranges in thickness from 400 m at the type locality in Spray River gorge near Banff to 156 m at the junction of Fiddle River and Morris Creek (Fig. 3), then to an eastern erosional pinch-out in the vicinity of Township 48 Range 19 W5. At Mount Greenock on the north side of Athabasca River the formation is 222 m thick (Fig. 3). In most of the field trip area, the Sulphur Mountain Formation is divided into three members, which in ascending order are Phroso Siltstone, Vega Siltstone and Llama. At Spray River gorge near Banff and at Mount Greenock near Jasper Lake and other more western localities, the Vega Siltstone Member is abruptly overlain by the Whistler Member (Figs. 2, 3). The Whistler Member is not exposed or does not occur at any of the field stop localities. Where strata of the member are absent, they are assumed to have graded laterally into facies of the Llama Member, or alternatively, have been erosionally removed prior to Llama deposition. Between the Cadomin area, and the Snow Pass-Cascade River area northeast of Banff (Gibson, 1974), the Vega Siltstone Member is characterized by an additional unit called the Mackenzie Dolomite Lentil (Fig. 3).

The Whitehorse Formation in most areas of the field trip is divided into two members, a lower, Starlight Evaporite and an upper, Winnifred. However, at Mount Greenock and most other western areas north of Athabasca River, the Starlight Evaporite Member is overlain abruptly by carbonate of the Brewster Limestone Member (Figs. 2, 3). The Brewster Limestone Member does not occur south of Athabasca River, a result of a lateral facies change into strata more typical of the Winnifred Member. In the Front Ranges between Athabasca and Brazeau rivers, and possibly farther south, the Starlight Member is characterized by a distinct quartz sandstone called the Olympus Sandstone Lentil (Gibson, 1968a, 1974, in press). The Whitehorse Formation, with type section near Cadomin and Stop 6 (Fig. 1), comprises an assemblage of pale weathering, variegated dolostones, limestones, quartz sandstones, and intraformational and/or solution breccias. Gypsum as much as 44 m thick occurs near Athabasca River (Gibson, 1968a, 1974). In the field trip area, the Whitehorse Formation ranges in thickness from 234 m at Mount Greenock to 41 m at Mackenzie Creek Gap (Fig. 3). The formation thins rapidly eastward due to pre-Jurassic erosion and/or sedimentary convergence, such that in the subsurface east of the Mackenzie Creek Gap locality Whitehorse Formation strata are absent .

SULPHUR MOUNTAIN FORMATION

Phroso Siltstone Member

Strata of the Phroso Siltstone Member will be examined at Stops 2, 3, 5 and 6 (Fig. 1). The member comprises a generally recessive, shaly to flaggy weathering sequence of grey-brown to dark grey, quartz siltstone and silty shale, with rare, thin to medium beds of very fine grained quartz sandstone, and thin to thick parallel to wavy lamination which forms a conspicuous and diagnostic component of the member at most eastern localities. Westward, however, as will be seen at Stop 2C near Vermilion Lakes, Phroso strata consist of mainly shaly weathering siltstone with little to no sandstone. The strata are carbonaceous, ferruginous, and very dolomitic, such that locally, they may be classed as silty to sandy dolostone. At the type section of the Sulphur Mountain Formation near Banff, the Phroso Member is 46 m thick. At Stop 2C the thickness is estimated to be 180 m. In the Jasper-Cadomin area to the north the Phroso Siltstone Member varies in thickness from 72 m near Cadomin to 87 m on Fiddle River (Stops 6, 3, Fig. 1). At Mount Greenock on the west side of Athabasca River, Phroso strata are 94 m thick. In the Gulf Mobil Lovett River 10-17-47-19W5 well, the Phroso Siltstone Member thins to 17 m (Fig. 3).

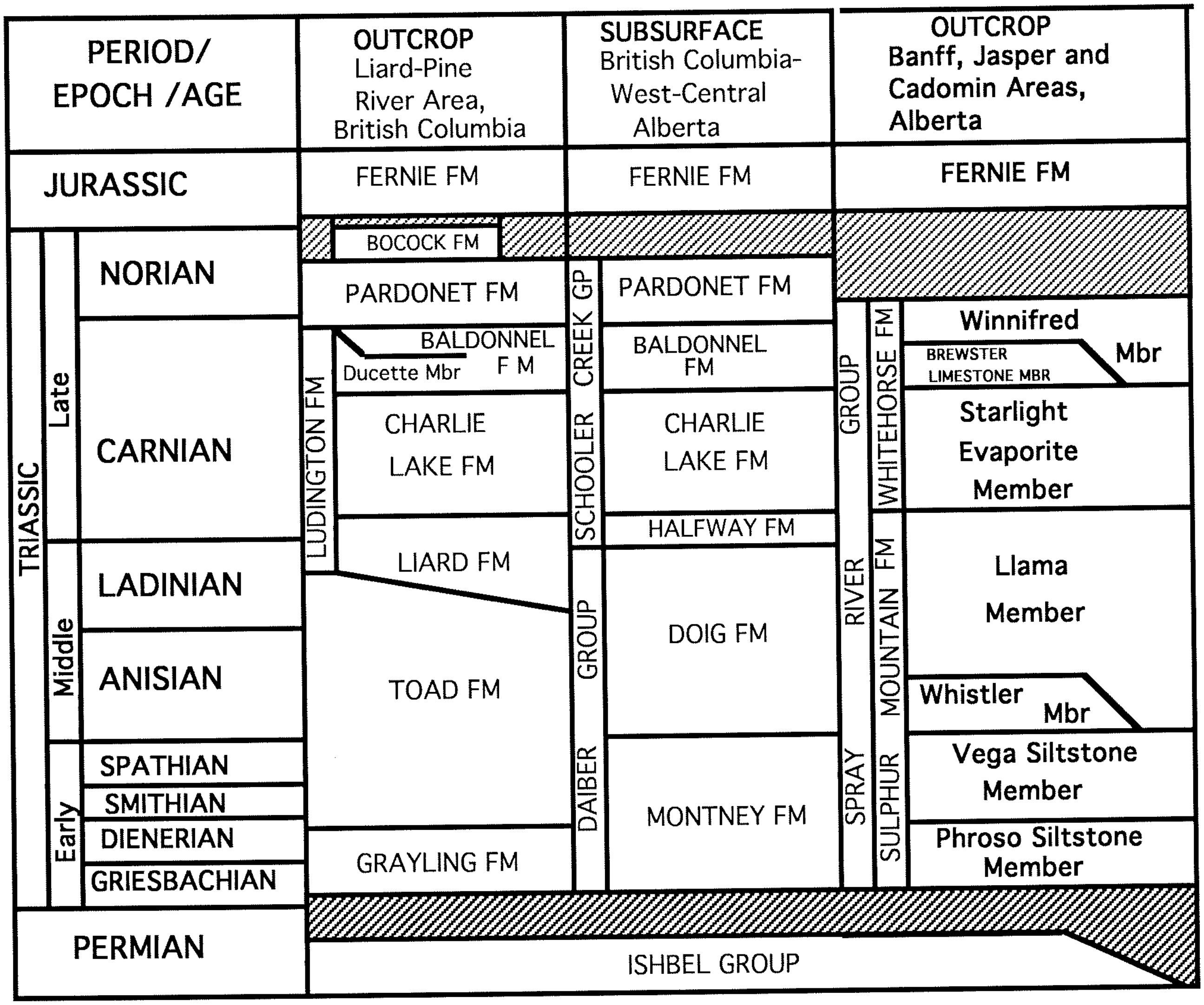

Fig. 2. Nomenclature and correlation chart illustrating relationship between Triassic formations and members in field trip area and those in outcrop and subsurface of west-central Alberta and northeastern British Columbia.

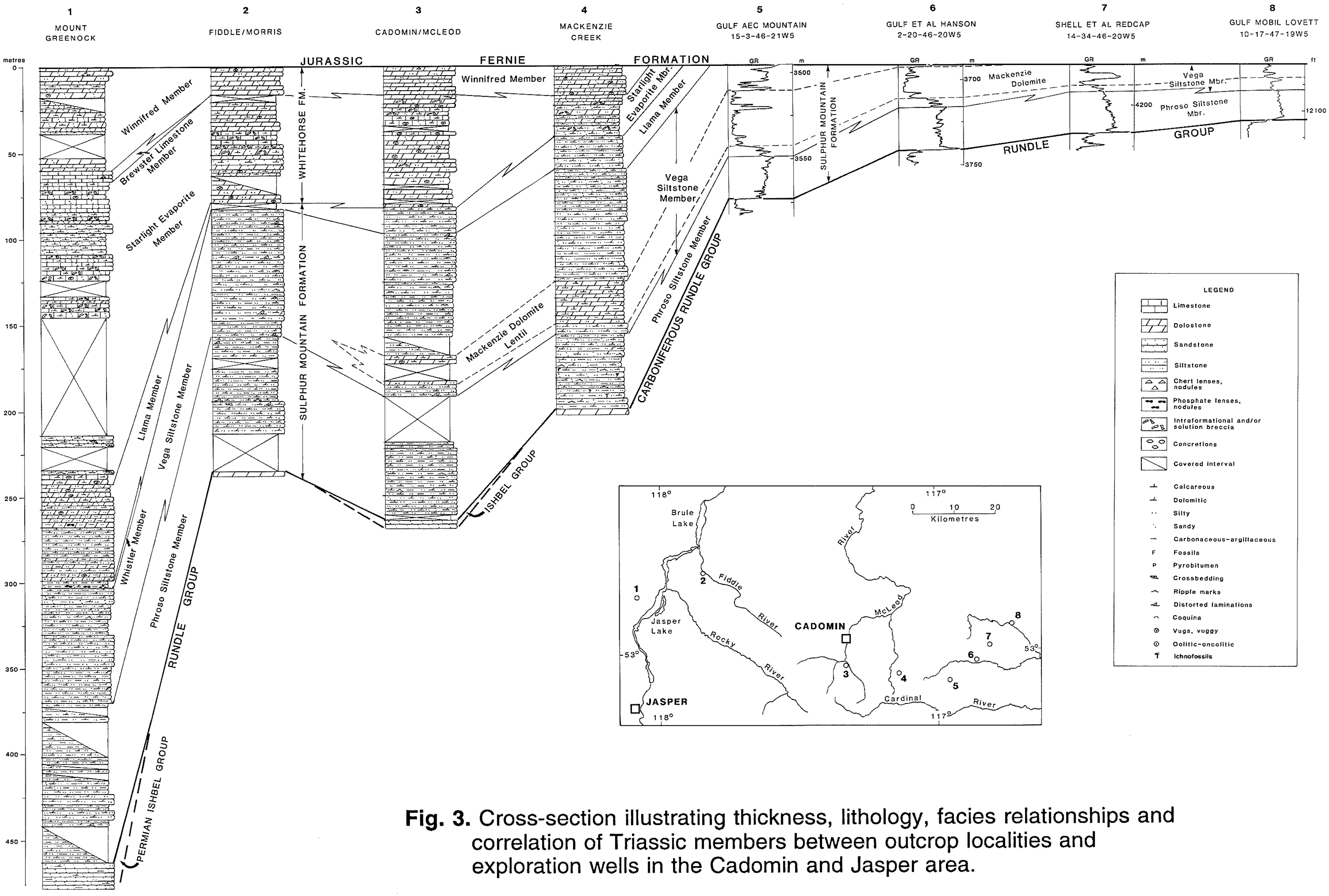

Fig. 3. Cross-section illustrating thickness, lithology, facies relationships and correlation of Triassic members between outcrop localities and exploration wells in the Cadomin and Jasper area.

Regionally, the Phroso Siltstone Member is underlain disconformably by sandstone, siltstone and cherty siltstone and chert of the Permian Ishbel Group (Fig. 3). However, at Stop 3, and most other eastern subsurface localities, the Phroso Member is underlain disconformably by light weathering dolostones of the Carboniferous Rundle Group (Fig. 3). Regionally, the contact with the overlying Vega Siltstone Member is conformable and generally distinct. However, in the field trip area the contact is gradational, with strata characteristic of the Phroso and Vega Siltstone members interdigitating over several metres.

The Phroso Siltstone Member is sparsely fossiliferous with only indeterminate, flattened ammonoids collected from near the base (e.g. Stop 2C). Northwest of Athabasca River and at Spray River Gorge, near Banff, the pelecypod *Claraia stacheyi* Bittner has been recovered and the strata assigned an Early Triassic Griesbachian age.

The Phroso Siltstone Member correlates with the Grayling Formation of the Foothills outcrop belt, and with the lower Montney Formation of the subsurface Foothills and Plains in northeastern British Columbia and west central Alberta (Fig. 2).

The thin bedded, predominantly fine parallel to wavy laminated siltstones and sandstones of the Phroso Member were deposited in a relatively deep water distal to proximal shelf environment, generally below storm wave base. Ripple lamination may be observed at the Cadomin and Jasper Highway localities (Stops 6, 5, Fig. 1), suggesting a slightly shallower water environment, in which storm activity may have modified and reworked the sediment.

Vega Siltstone Member

Strata of the Vega Siltstone Member are exposed at all Triassic field stop localities, but will be examined in detail only at Stops 2, 3, 4 and 6 (Fig. 1). The Vega Member consists of a generally distinct rusty brown weathering sequence of thin to medium bedded, dolomitic, quartz siltstone and carbonaceous shale (Fig. 3). Locally, beds of very fine grained sandstone and very sandy to silty dolostone are intercalated. The more resistant weathering, thicker bedded siltstones, alternate with the thinner bedded finely laminated shaly siltstones and shales, commonly forming conspicuous resistant-recessive weathering couplets. The resistant-recessive facies is best developed in Foothills and Front Range exposures north of Athabasca River, but also occurs in the Front Ranges of the Banff and Kananaskis area to the south. Although present, the recessive shale and/or silty shale intervals are not as common in the Cadomin and Jasper area. However, examples of these Vega-like alternating facies can be seen at or near the base of the Phroso Siltstone Member at the Cadomin Rail/McLeod River and Fiddle River localities. At the Cadomin Rail/McLeod River field stop (Stop 6), the lower Vega Siltstone Member is characterized by a distinct, buff to light grey weathering, porous dolostone called the Mackenzie Dolomite Lentil (Fig. 3). In the Cadomin and Jasper area, the Vega Siltstone Member ranges in thickness from a minimum of 65 m on Fiddle River to 95 m at the Cadomin Rail/McLeod River locality (Fig. 3). At the type locality of the Sulphur Mountain Formation near Banff the Vega Member is 330 m thick.

Like the Phroso Member, the Vega Siltstone Member contains few fossils. Those identified from other localities outside of the field trip area, include the pelagic pelecypod *Posidonia cf. P. mimer* Oeberg and the ammonite *Euflemingites cf. cirratus* (White) of Early Triassic Smithian age. The ammonite *Eumorphotis multiformis* Bittner and the pelecypod *Anodontophora* sp. have been identified as being of probable Early Triassic age.

The Vega Siltstone Member in the Cadomin and Jasper area is abruptly and possibly unconformably overlain by the Llama Member (Fig. 3). At Mount Greenock on the west side of Athabasca River, and at the type locality of the Sulphur Mountain Formation near Banff, the Vega Siltstone is abruptly overlain by the Whistler Member, a transgressive, deep water calcareous siltstone and shale (Fig. 3). As noted previously, the Whistler Member at the Fiddle River and Cadomin localities grades laterally into siltstones of the Llama Member, or alternatively, may be interpreted as having been eroded.

The Vega Siltstone Member correlates with exposures of the Lower Toad Formation, and the middle and upper Montney Formation of the subsurface Foothills and Plains in northeastern British Columbia and west central Alberta (Fig. 2).

Strata of the Vega Siltstone Member form part of a regressive or progradational, upward coarsening stratigraphic succession, as can be seen in some of the exploration wells in Figure 3. The strata are interpreted to have been deposited in a mid to proximal shelf and shoreface environment. Sedimentary structures which will be seen at the field stop localities, include ripples and ripple cross lamination, hummocky cross stratification, flute and groove casts, channel scour and well developed large-scale load casts or flow rolls. Fine parallel and lenticular lamination are common in many of the shaly siltstone interbeds. The distinct resistant and recessive weathering alternation generally shows a decrease in the thickness and frequency of the shaly siltstone and shale interbeds in an easterly direction, suggesting a proximity to shallower water and a higher energy shoreface environment. The predominantly fine parallel and wavy lamination, particularly in the shaly weathering and lower part of the member, suggests deposition for most part below storm wave base. The occurrence of groove and flute casts and distinct alternation of siltstone and shale, may indicate deposition in part by turbidity currents. However, strata of the upper Vega Member in the easternmost sections, where shale interbeds are thin and less common, and when combined with the occurrence of hummocky cross stratification, ripple lamination and shallow scour channels, suggest deposition in a higher energy shoreface environment, probably between fair weather and storm wave base. Some of the thicker siltstone beds may represent deposition by turbidity currents, but most are considered to have been deposited by storm generated offshore currents, and accordingly, may be classed as tempestites.

Mackenzie Dolomite Lentil

Strata equivalent to the Mackenzie Dolomite Lentil were first recognized and described by Best (1958) and called the "Middle Dolomite Unit" of the Sulphur Mountain Member. He first recognized the dolomite facies in the Athabasca-North Saskatchewan River area. The Mackenzie Dolomite, with type locality at Mackenzie Creek Gap (Fig. 3), comprises a relatively thin succession of medium bedded, light grey to yellowish grey, slightly calcareous dolostone, with locally, interbeds of very silty to sandy dolostone, very dolomitic quartz siltstone and very fine grained sandstone, near the upper and lower contacts. The main facies of the lentil consists of medium to coarsely crystalline dolostone with thin intervals or beds consisting of fragmented dolomitized bivalve shells. The dolostone is very vuggy and porous, a feature readily apparent at Stop 6 near Cadomin. As can be seen in cross section Figure 3, the dolostone lithofacies is easily recognized in exploration wells, where it occurs as a distinct stratigraphic marker. Facies assumed equivalent to the Mackenzie Dolomite have been observed in outcrop as far south as Cascade River in Banff National Park (Gibson, 1974). Like the Vega Siltstone Member, the carbonate lentil appears to have been deposited mainly within a proximal shelf or shoreface environment. The Mackenzie Dolomite at the Cadomin locality appears to have been deposited farther offshore. The dolostone lentil does not occur at any of the other Triassic field stops.

The Mackenzie Dolomite Lentil is assigned a thickness of 17 m at the Cadomin Rail/McLeod River locality. The base or lower half of the lentil is talus covered. However, because of its recessive weathering character, the covered interval is assumed to be underlain by porous and poorly indurated dolostone. In the field trip area the Mackenzie Dolomite ranges in measured thickness from 4 m near the headwaters of Fiddle River near the boundary of Jasper National Park to 24 m at the type locality at Mackenzie Creek Gap (Fig. 3).

The contacts of the lentil with the main facies of the Vega Siltstone Member are generally sharp and distinct, and are placed at a prominent lithological change, where the light weathering dolostones change to the more thickly bedded, and darker weathering siltstones and shaly siltstones of the main Vega Siltstone Member.

Whistler Member

The Whistler Member does not occur at any of the five Triassic field stops (Fig. 3). As noted above, the strata of the member may be interpreted to have graded laterally into shallower water facies of the Llama Member, or possibly have been eroded prior to deposition of the Llama Member. The Whistler Member is exposed at the type section of the Sulphur Mountain Formation near Banff where it is 13 m thick, and at the Mount Greenock locality near Jasper (Fig. 3), where it attains a thickness of 4 m. The member consists of recessive, shaly-weathering, dark brownish grey to dark grey dolostone and siltstone. The strata are very carbonaceous, locally pyritiferous, and are commonly thin to indistinctly bedded, characterized by fine, regular to slightly wavy, light grey lamination. The base is marked at many localities by a highly radioactive phosphatic pebble conglomerate or conglomeratic sandstone (Gibson, 1974).

Regionally, the contact with the underlying Vega Siltstone Member is abrupt and represents a major transgression and probable parasequence boundary. The base of the Whistler Member and base of the stratigraphically equivalent subsurface Doig Formation (Fig. 2), can readily be recognized in most outcrop areas of the Rocky Mountain Foothills and Front Ranges, and on gamma-ray logs in exploration wells in the Foothills and Plains of west central Alberta and northeastern British Columbia.

The Whistler Member is sparsely fossiliferous, containing compressed, generally indeterminate ammonoids of the family *Beyrichitidae*. However, ammonoids and thin shelled pelagic bivalves collected from the member at other localities in the vicinity of and north of Smoky River (Gibson, 1975), indicate an Anisian age. The contact between the Whistler and underlying Vega Siltstone members represents the boundary between the Lower and Middle Triassic rock succession.

The Whistler Member is correlative with the middle part of the Toad Formation of the Foothills outcrop belt of northeastern British Columbia, and to the lower Doig Formation in the subsurface Foothills and Plains of northeastern British Columbia and west central Alberta (Fig. 2).

Llama Member

The uppermost member of the Sulphur Mountain Formation comprises a generally resistant weathering assemblage of silty to sandy dolostone and dolomitic quartz siltstone, with locally, intercalated beds of carbonaceous, silty shale and very fine grained sandstone (Fig. 3). Strata of the Llama Member will be examined at Cadomin Rail/McLeod River and Fiddle River field stops. In the field trip area, the Llama ranges in thickness from 3 m at Stop 4, to 15 m at Stop 6. The Llama Member attains a maximum thickness of 150 metres near Smoky River (Gibson, 1968b). Near Banff the Llama attains a thickness of 6 m.

In most areas of the Front Ranges northwest of Athabasca River, the Llama Member is gradationally underlain and overlain by strata of the Whistler and Starlight Evaporite members, respectively. However, in the Cadomin and Jasper and other Foothills areas to the east and northeast, the contacts are generally abrupt. Barss et al., (1964) suggested the possibility of a disconformity between the Sulphur Mountain (Llama Member) and Whitehorse formations (Starlight Evaporite Member). As can be seen in Figure 3, strata of the Llama Member thin rapidly in the field trip area of Fiddle River (3-4 m) in comparison to the Llama Member at Mount Greenock to the west . The pronounced thinning trend may be cited as evidence in support of erosional truncation and the presence of a disconformity. Alternatively, the thinning may be due to sedimentary convergence toward the basin or shoreline margin. The contact with the underlying Vega Siltstone Member in the Fiddle River-Cadomin area is very abrupt, and likewise, may represent a disconformity. No fossil collections have been obtained from Llama or adjacent strata in the field trip area, and parasequence boundaries between the units or members in question are not obvious. The presence or absence of the unconformities remains unresolved.

The Llama Member correlates with the Liard and upper Toad formations in the outcrop belt of northeastern British Columbia and to the subsurface Halfway and upper Doig formations of northeastern British Columbia and west central Alberta (Fig. 2).

Strata of the Llama Member form part of a major transgressive-regressive cycle which began with deposition of the Whistler Member (Gibson and Barclay, 1989). The conspicuous upward increase in dolomite content and dolostone interbeds in the member, the general absence of carbonaceous and ferruginous matter and resulting light coloration, and the development of local pockets of intraformational breccia, suggest sediments of the member were deposited in a well-oxygenated, upward shallowing environment. Accordingly, strata of the Llama Member in the field trip area are interpreted as having been deposited within an upper shoreface and/or lagoonal environment. At the more western localities in the Front Ranges, where the strata are thicker, less dolomitic, and more carbonaceous and ferruginous, available evidence suggests sediment deposition in a relatively deeper water, mid to lower shoreface environment.

During Llama time, the climate appears to have changed from one with an average or relatively high rainfall, to one of low rainfall and consequent arid to semi arid climatic conditions. The vertical reduction in concentration of siliciclastic minerals and carbonaceous-ferruginous matter, may suggest that river systems were greatly reduced in their capacity to carry and transport siliciclastics into the depositional basin. Alternatively, one might argue that the dispersal energy in the marine or shallow-water environment increased greatly, thereby removing most of the detrital siliciclastic material. However, the nature and composition of the strata do not support this latter hypothesis. Most Llama strata are thick and structureless, with little to no evidence of strong current activity.

The Sulphur Mountain period thus ended with the Banff, Jasper and Cadomin areas showing a complete paleoclimate reversal, from one of moderate or high rainfall and moderate to high river discharge and siliciclastic detrital input in Early Triassic time, to one of low rainfall and low river discharge in late Middle and Late Triassic time.

WHITEHORSE FORMATION

Starlight Evaporite Member

The lowermost member of the Whitehorse Formation contains the largest variety of rock types of any member in the Spray River Group. Starlight Member strata comprise a sequence of variegated, buff, yellow, light to medium grey and reddish brown weathering dolostone and limestone, sandstone, siltstone and intraformational and/or solution breccia (Fig. 3). Locally, the breccia and dolostone contain beds and lenses of gypsum, which in the Athabasca River area attain thicknesses up to 44 m. Strata of the Starlight Member will be observed at Stops 4 and 6 (Fig. 1). The solution/collapse breccias form a conspicuous component of the member in all areas of the Front Ranges and Foothills of Alberta and northeastern British Columbia. In the field trip area, the breccias are generally medium to thick to indistinctly bedded, porous and poorly indurated, and commonly weather as recessive, partly talus covered intervals (Fig. 3). The breccias on Fiddle River and elsewhere, are composed of angular clasts of sandy quartzose, finely to medium crystalline dolostone, with lesser amounts of coarsely crystalline sandy to silty limestone, cemented by sandy to silty medium to coarsely crystalline calcite and dolomite. At the Fiddle River locality the carbonate clasts are reddish brown to buff, in a light grey finely to medium crystalline cement and matrix. The carbonate clasts are up to 8 cm in diameter. At Stops 4 and 6 the member is 66 m thick (Fig. 3). In contrast, at Mount Greenock on the west side of Athabasca River, the Starlight Evaporite Member is 177 m thick (Fig. 3). In the Banff area and the region south of Bow River strata of the Whitehorse Formation are not amenable to stratigraphic subdivision. Most of the Whitehorse facies are however, lithologically similar to the Starlight Member strata of other areas. Regionally, the Starlight Member shows a pronounced thickness increase from east to west.

Facies changes are very abrupt in the Starlight Evaporite Member over short horizontal and vertical distances, so that, except for the Olympus Sandstone Lentil (Gibson, 1974), lithologic correlation between most section localities is not possible.

Fossils are rare in the Starlight Member. Those collected from other localities in the region include indeterminate gastropods, rhynchonelloid brachiopods, and the pelecypods *Alectryonia*? sp. and *Hoernesia* sp. The bivalves are suggestive of a Middle to Late Triassic age.

The Starlight Evaporite Member is generally abruptly overlain by cliff-forming limestones of the Brewster Limestone Member. However, as can be seen in Figure 3, strata of the Brewster Member do not occur in the Fiddle River or Cadomin areas, nor in any outcrop areas south of Athabasca River (Gibson, 1974). Regionally, the contact between the Starlight and Brewster Limestone members represents a transgression and probable parasequence boundary. In the field trip area, the Starlight Member is gradationally overlain by resistant weathering dolostones of the Winnifred Member (Fig. 3). In this area, strata of the Brewster Limestone Member are interpreted to have laterally changed facies into shallower water, predominantly dolostones of the Winnifred Member.

The Starlight Evaporite Member correlates with the Charlie Lake Formation in both the outcrop belt and subsurface of northeastern British Columbia and west central Alberta (Fig. 2).

The contrast in composition and sedimentary character between the Whitehorse and Sulphur Mountain formations suggests a significant change in the depositional environment at the end of Sulphur Mountain time. The seas continued to regress at the end of Llama time, such that during Starlight Evaporite time, the depositional environment consisted of shallow water coastal inlets, tidal flats, hypersaline restricted lagoons, and sabkhas containing possible coastal dunes and playas or salt pans.

Olympus Sandstone Lentil

At many outcrop localities between Athabasca and Bow Rivers, the Starlight Member contains a distinct, cliff-forming sequence of buff to yellow weathering, slightly dolomitic quartz sandstone facies called the Olympus Sandstone Lentil (Gibson, 1974). Strata of the Olympus Sandstone are not present at any of the field stops. However, at the top of the Whitehorse Formation at its type locality at the junction of Drummond and Whitehorse creeks, near Cadomin and Stop 6 (Best, 1958), there is a clean quartzitic sandstone very similar in appearance and composition, to the Olympus Sandstone in the Starlight Member in the more westerly sections south of Athabasca River. At this locality, the quartzitic sandstone is unconformably overlain by the Jurassic Fernie Formation. The Olympus Sandstone attains a maximum thickness of 140 m in the Banff area (Gibson, 1974).

Strata of the Olympus Sandstone, because of their association with the very shallow water and sabkha facies of the Starlight Evaporite Member, are also interpreted as a product of a very shallow water environment. The sandstones may represent the sediments of a coastal offshore bar or possibly part of a barrier island system. Medium to large scale crossbedding and ripple lamination occur in the sandstone facies. The sands may in part represent coastal dunes.

Brewster Limestone Member

The Brewster Limestone Member as noted above, does not occur south of Athabasca River. It has been recognized at the Mount Greenock locality (Fig. 3). In the Front Ranges north of Athabasca River, the Brewster Member consists of cliff-forming limestone with minor beds of dolostone, and locally, beds of intraformational breccia. Its absence south of Athabasca River and the eastern Foothills is interpreted herein to be a result of a lateral facies change into the shallower water strata of the Winnifred Member (Fig. 3). The Brewster Limestone contains bivalves of the *Mysidioptera poyana* Zone and is therefore of Carnian age. Strata of the Brewster Member are correlative with the Baldonnel Formation in the outcrop belt and in the subsurface of northeastern British Columbia and west central Alberta.

Regionally, the contact with both the underlying Starlight Evaporite and overlying Winnifred members is sharp and abrupt. The lower contact is interpreted to be transgressive and represents a probable parasequence boundary.

The Brewster Limestone Member represents deposition mainly within a mid to proximal shelf coastal environment.

Winnifred Member

The Winnifred Member, the uppermost unit of the Whitehorse Formation, is well exposed at Stops 4 and 6 (Fig. 1). It comprises a medium to light grey to buff, medium to thick bedded sequence of medium to light grey to buff, sandy to silty to slightly calcareous dolostone, with minor interbeds of dolomitic quartz siltstone and very fine grained sandstone (Fig. 3). The Winnifred member is generally cliff-forming as will be seen at the outcrop localities. In the northern field trip area, the Winnifred displays a relatively constant thickness of 16 and 17 m, whereas at Mount Greenock to the west, it is 60 m thick (Fig. 3). The member thins rapidly eastward mainly due to pre-Jurassic erosion, but also partly to sedimentary convergence with the eastern shoreline and edge of the basin.

The Winnifred Member is disconformably overlain by the Jurassic Fernie Formation, with the contact well exposed at Stops 4 and 6.

The Winnifred contains few identifiable fossils. The pelecypod *Pleuromya*? sp. was collected at Stop 4 on Fiddle River, however, it was not useful as an indicator of age.

The correlation of the Winnifred to formations or units in northeastern British Columbia and west central Alberta is speculative. Because of its stratigraphic position above the Brewster Limestone Member, it is correlated with the Baldonnel Formation of the surface and subsurface (Fig. 2).

Strata of the Winnifred Member form part of another transgressive-regressive cycle which began with the deposition of the underlying Brewster Limestone Member. In the Cadomin and Jasper area, Winnifred strata were deposited in a relatively shallow-water, intertidal to subtidal environment. Water depths however, were generally deeper than those postulated for strata of the underlying Starlight Evaporite Member.

In summary, most sediments of the Whitehorse Formation are postulated to have been deposited in an arid to semi-arid, shallow-water, subtidal to intertidal, lagoonal and sabkha environment.

JURASSIC STRATIGRAPHY

PALEOGEOGRAPHIC AND TECTONIC SETTING, AND PALEOCLIMATES

The Jurassic strata in western Canada contain the record of eustatic and epeirogenic events in the Early and Middle Jurassic, and of the collisions of allochthonous terranes in the eastern Pacific with the westerly drifting North American continent in the Middle or Late Jurassic. In western Alberta and eastern British Columbia, compressional tectonics associated with the terrane collisions resulted in uplift of the Columbian (eastern Cordilleran) Orogen. Initial western uplifts of the orogen yield Middle and Late Jurassic radiometric dates in southeastern British Columbia (Archibald et al., 1983). More easterly phases of overthrusting are younger, extending into the earliest Tertiary in southwestern Alberta. In the Sinemurian (Early Jurassic), phosphorite deposition in what is now southeastern British Columbia and southwestern Alberta indicates the presence of upwelling oceanic currents that suggest access to a deep ocean to the west of the platform edge (Poulton and Aitken, 1989). Only minor, thin bentonite layers in the Early and Middle Jurassic epicratonic strata may be evidence for pre-Late Jurassic western tectonic and volcanic activity. By Late Jurassic time, the region had undergone a reversal of tectonic polarity, as western areas were uplifted during early phases of the Columbian Orogeny and were eroded. The resulting detritus filled the newly depressed foreland trough, superposed on the pre-orogenic sedimentary pile of the western part of the pre-existing stable platform.

A Middle Jurassic increase in subsidence rates for the western Canada platform and Williston Basin (and perhaps also Moose River Basin in Ontario and Michigan Basin in Michigan) may be ultimately related to the increase in central Atlantic and Gulf of Mexico spreading rates about the same time (Vogt and Tucholke, 1986, Plate 1; Bally, 1989). Some of the poorly known Middle Jurassic fine-grained siliciclastic units in the Fernie Formation of southwestern Alberta have been suggested to be westerly sourced, perhaps earliest epicratonic products of the Columbian Orogeny (e.g. Poulton, 1984) although most of the Lower and Middle Jurassic siliciclastics were undoubtedly derived from the craton exposed to the east. Similarly, the regional uplift of the Western Canada Sedimentary Basin in the Late Jurassic may have had some common causal relationship with uplift of western orogenic source terranes and the subsidence of the orogenic foreland trough.

Overall northward drift of the continent during the Jurassic, as indicated by paleomagnetic data (e.g. May and Butler, 1986) may have moved its western margin out of the depositional zone of, first phosphorites, then carbonates, accounting for their loss upward in the Jurassic column and northward in the western Canadian epicratonic basins. The predominance of boreal molluscs, such as cardioceratid ammonites and the bivalve *Buchia* in Upper Jurassic strata, as compared with the East Pacific and other generally southern ammonites in the Early and Middle Jurassic of the western Canadian craton, conforms with such movement.

Increased precipitation throughout the Jurassic period in western Canada is also suggested by the strata. Arid or semi-arid conditions indicated by the upper Watrous and Amaranth evaporites in Williston Basin (and lower Watrous and Amaranth red beds if they are Jurassic in age) give way to the humid coal-forming swamp conditions indicated for the Kootenay Group in the Late Jurassic. Such an increase in precipitation might be expected with the change in wind patterns and physiography associated with both uplift of a major orogenic belt to the west, and northward transport of the region as indicated by the paleomagnetic data.

There may be a concomitant increase in the quantity of storm, as opposed to tidal, activity from the Middle to the Upper Jurassic succession, suggested by the sedimentary structures of the respective sandstones.

REGIONAL FRAMEWORK

All but the uppermost Jurassic strata are assigned to the Fernie Formation (Fig. 4), a dominantly shaly unit first named in the Crowsnest Pass area of southeastern British Columbia (McEvoy, 1902). The Fernie has been treated as a group (Frebold, 1957) but no formations have been defined within it. It contains a number of members and informal units, the mutual relations and continuity of which are still subject to revision (e.g., Frebold, 1957; Stott, 1967; Hall, 1984; Poulton et al., 1990). The gradationally overlying uppermost Jurassic units, which continue into the Lower Cretaceous, belong to the Kootenay Group in southwestern Alberta and southeastern British Columbia (Gibson, 1985), the Nikanassin Formation in west central Alberta, and the Minnes Group in northeastern British Columbia (Stott, 1967).

The Jurassic strata overlie a regional unconformity, and were deposited over the eroded edges of Triassic and older strata. The Jurassic (and lowest Cretaceous) strata are themselves truncated below the regional unconformity at the base of the late Lower Cretaceous Cadomin Formation and the Mannville Group in west central Alberta (Fig. 5).

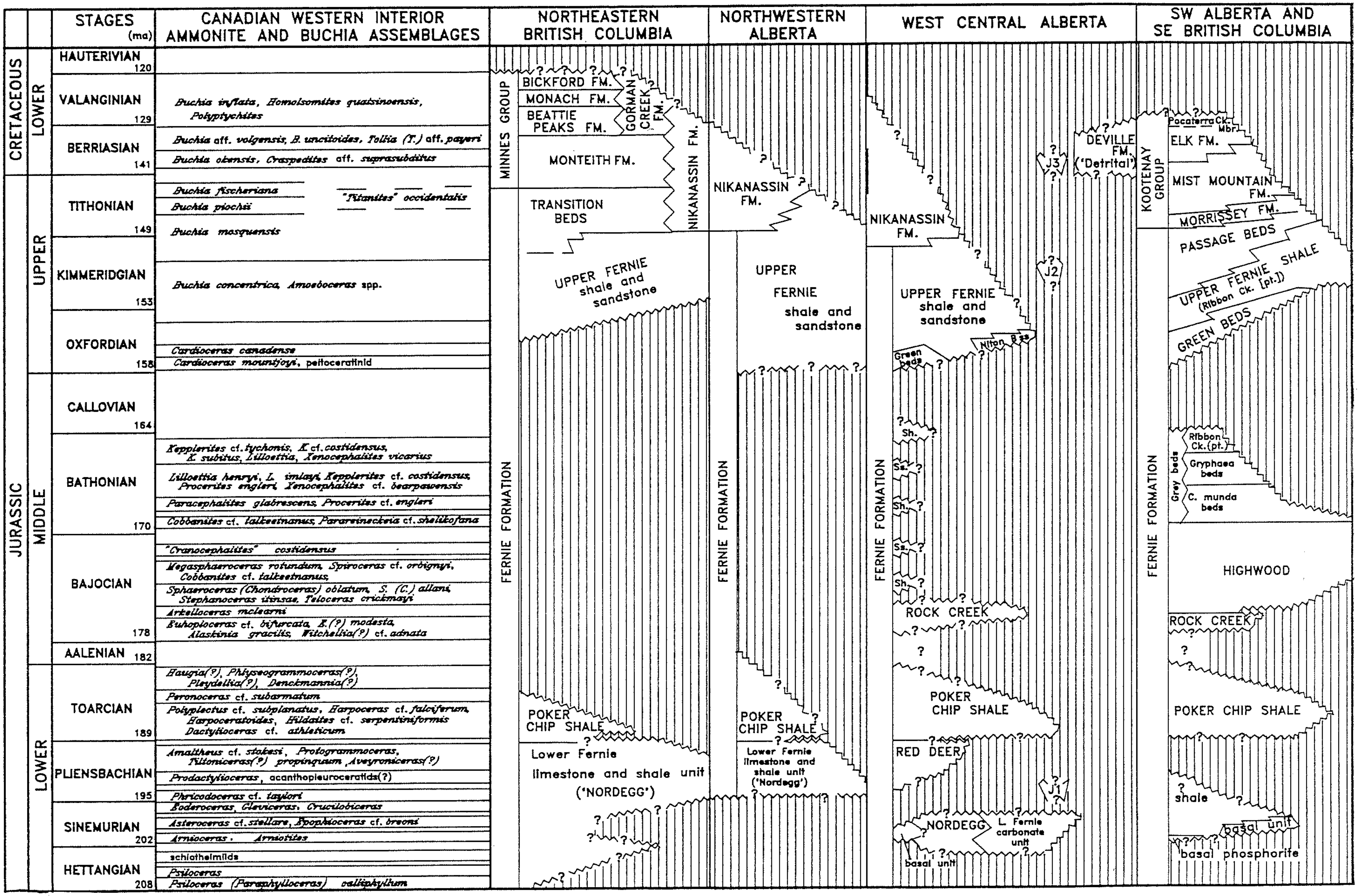

Fig. 4. Correlation chart of the Jurassic and lowest Cretaceous formations in the Western Canada Sedimentary Basin. The column for West Central Alberta is typical of the Cadomin and Jasper areas.

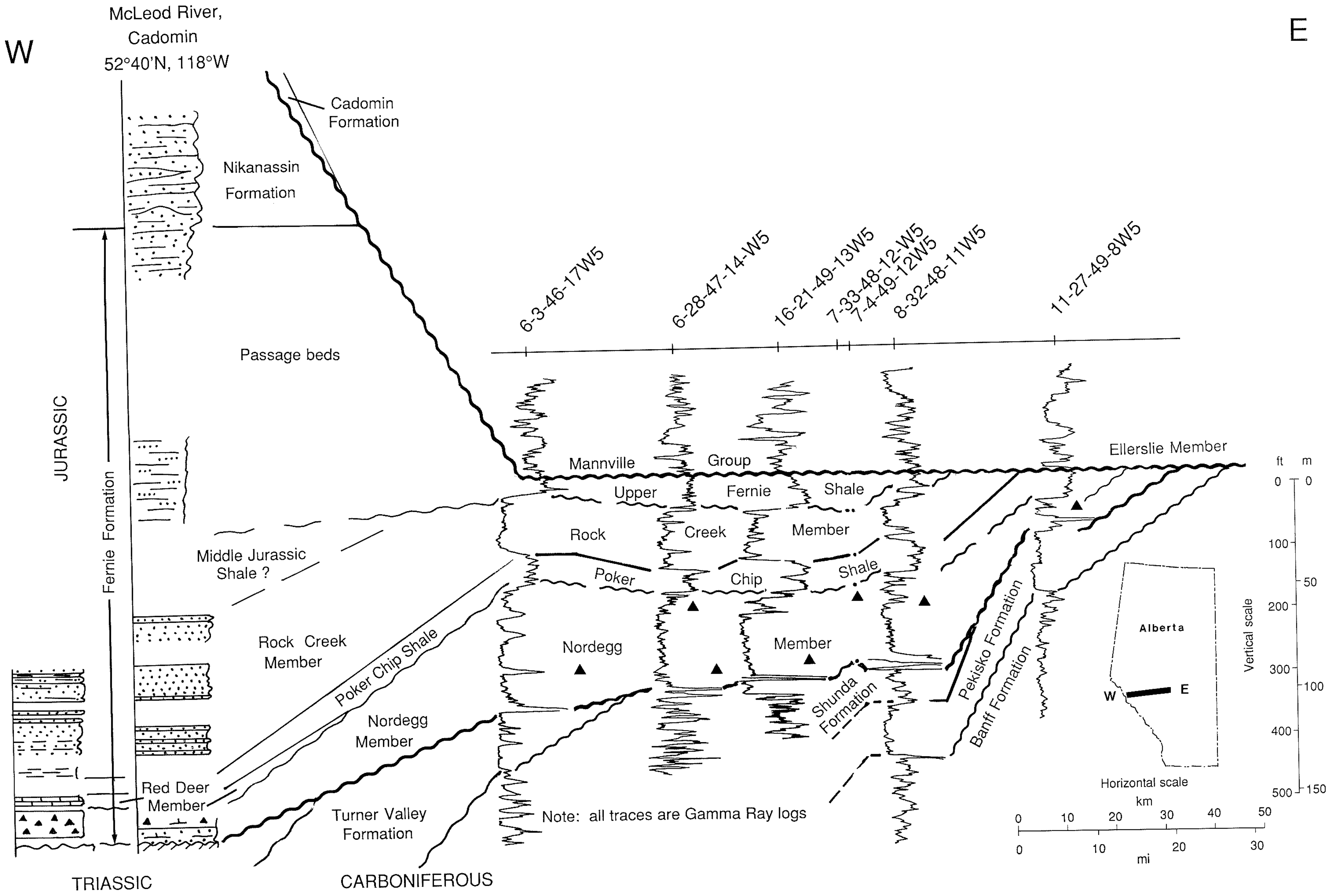

Fig. 5. West-east cross-section of Jurassic strata from the Cadomin-McLeod River-Prospect Creek section to the subsurface of central Alberta.

The Lower and Middle Jurassic parts of the Fernie Formation thicken westward gradually and become finer in that direction overall, although individual units demonstrate more complicated trends. The thickening is partly depositional, partly due to erosional truncation of units in the east.

The Lower Fernie contains regionally widespread units of shale, limestone, and chert, with a significant concentration of phosphate in some places. They are the products of deposition on a cratonic shelf starved of clastic sediment supply, but with easy access to western cold oceanic currents, at least in places (eg. Poulton and Aitken, 1989).

The Middle Fernie contains significant units of fine grained sandstone. The sandstones are quartzose except in easternmost subsurface occurrences of the lower Rock Creek Member (local equivalents of Upper Poker Chip shale), which contain significant quantities of chert grains. There is no indication of any sand source other than from the craton to the east with the possible exception of the enigmatic Grey Beds and the Pigeon Creek siltstones and fine grained sandstone members of the Fernie.

The Upper Jurassic sandstones, siltstones and shales with minor coal thicken westward abruptly, and they are truncated to the east by erosion below younger units. The sandstones contain as much as 15% chert (mainly microcrystalline quartz), and detrital mica is common on many bedding surfaces. Few if any extra-basinal clasts have been recognized in the sub-Cadomin strata in the south.

Upper Jurassic strata form the lowest major units that are ascribed to western sources. Their thickness and grain-size trends indicate approach to high-standing sources to the west, although paleocurrent data indicates mainly north-northwesterly rather than northeasterly progradation and significant basin-axial sediment transport (eg. Hamblin and Walker (1979) (see Jansa, 1972, 1981 for conflicting interpretation). Uplifted parts of the Williston Basin may have served as a southern or southeastern source for some of the detritus (Stelck et al., 1972). Thickness trends for the Nikanassin in the outcrops in west central Alberta are not well known, but the unit is continuous with subsurface and surface units farther north, where abrupt western thickening is apparent.

The initial uplift of the Columbian Orogeny to the west is generally dated by the cratonic record to its east, indicating Late Jurassic foredeep subsidence. Alternative hypotheses emphasize the Early Jurassic transgression eastward far beyond the limits of preserved Upper Carboniferous through Triassic rocks, relating these pre-Late Jurassic cratonic effects to early stages of the Columbian Orogeny. Pre-Late Jurassic cratonic Jurassic strata do not demonstrate any major western clastic sources, and the Late Jurassic and earliest Cretaceous siliciclastic wedges are the first of a series of major cratonic foredeep wedges that continue through early Tertiary in western Canada.

FERNIE FORMATION

Nordegg Member

The basal unit of the Fernie Formation in many places in west central Alberta is the Nordegg Member, a banded grey to black chert and limestone unit commonly about 15 m thick. The Nordegg is seen near Cadomin and Nordegg at Stops 6 and 7 (Fig. 1). The relative proportion of chert and limestone, and the detailed sedimentologic characteristics are somewhat variable from place to place. In the subsurface it is a massive, light grey, chert and limestone unit characterized by blocky gamma-ray logs, with a thin radioactive shale-limestone unit at its base. This basal, thin recessive unit can be seen in outcrop at McLeod River, but is poorly exposed. The Nordegg (except for the problematic *Oxytoma* bed) has not yielded any diagnostic fossils. The evidence for the widely accepted Early Sinemurian age, based on an "arietitid" from Snake Indian Falls northeast of Jasper, is not well documented; nor is the widespread character of the much cited *Oxytoma* bed 'marker' without problems (Poulton et al., 1990).

To the north (north of about 54°N latitude) and towards the west at localities farther south, the Nordegg chert and limestone facies is absent, and overlying platy limestones and shales (Red Deer Member) lie directly on or close to the Triassic (Poulton et al., 1990, Fig. 14). This is the case at Fiddle River (Stop 4; Fig. 6). The Nordegg grades to a dolomite and sandstone near-shore facies to the east, towards its erosional and depositional edge, just west of 114° W. longitude (eg. Bovell, 1969), and disappears southward at about 51°40′ N. latitude.

The banded cherts and limestones of the Nordegg are perhaps "deeper" water outer shelf deposits, deposited laterally to the more massive Nordegg platform limestones and cherts of the subsurface to the east of the outcrop belt. Locally preserved fine lamination suggests depth below storm wave base. Typical laminated cherts from McLeod River (Stop 6) and Shunda Creek (Stop 7) are dominated by organic-walled (in part), chalcedony spherules of undetermined origin, and contain significant quantities of spicules and collophane peloids, as well as minor silt-grade quartz grains, interstitial mud and organic material, and secondary carbonates. The nodular character of some of the chert at the Shunda Creek outcrop clearly indicates a secondary origin for the chert at that locality. Perhaps the Nordegg strata in the west central Alberta foothills and Rocky Mountains were deposited on a "deeper" shelf adjacent to a platform that stood higher to its east, and which is represented by the more heterogeneous array of lithologies described by Bovell (1979). Bovell interpreted the shallower(?) Nordegg just west of Edmonton to have been deposited in anoxic conditions in association with upwelling of cold water (note similar conditions indicated for equivalent phosphorites in southeastern British Columbia; Poulton and Aitken, 1989), perhaps subject to plankton blooms (acritarchs were noted in the Nordegg by Pocock, 1970). Minor small scale hummocks in the lower parts of the unit, as at Stop 6, together with the basal poorly exposed radioactive shale, may be the transgressive products of deposition at intermediate depths as the shelf subsided following post-Triassic emergence.

Red Deer and Poker Chip Shale members

The recessive, shaly interval above the Nordegg Member, or above the Triassic where the Nordegg is absent, is dominated by platy black limestone in the lower part and soft, black shale in the upper part. These two units are assigned to the Red Deer Member (of Frebold, 1969) and the Poker Chip Shale respectively. Their mutual boundary may be gradational, within the lowest Toarcian approximately, and individual small outcrops or cored intervals cannot be readily assigned to one or the other. The Red Deer Member has yielded Late Pliensbachian ammonites in its type area and the Poker Chip Shale has yielded Early and Middle Toarcian ammonites in several outcrops regionally. Both the Red Deer and Poker Chip members are largely anoxic, organic-rich, phosphatic and radioactive, fissile, black (the Poker Chip may be grey or greenish in the subsurface) recessive units with distinctive log responses. The Poker Chip Shale is seen at Stop 4 and the Red Deer Member at Stops 4 and 6.

The radioactive, high-organic, platy limestones and shales of northwestern Alberta that are commonly termed the Nordegg Member or 'Nordegg' (eg. Riediger et al., 1990) in fact probably represent the Red Deer Member (Poulton et al., 1990). This unit contains a variety of ammonites, small bivalves including small ostreiids and pectinids, brachiopods, fish fragments, and intervals rich in coccoliths, some contained in fecal pellets. Some of the macrofossils were illustrated by Crickmay (1963; erroneously as Sinemurian) and Hall (1987).

Interbedded sandstones and shales above characteristic Poker Chip shales in the subsurface to the east, arbitrarily included in the Rock Creek Member, yield Aalenian palynomorphs (G. Dolby, unpub.). These do not necessarily indicate a progradational contact between the Poker Chip and Rock Creek members, but may instead represent a coarsening-upward character of the lowest Rock Creek unit, with a lower shale-siltstone unit resting abruptly and perhaps disconformably upon underlying Poker Chip shales.

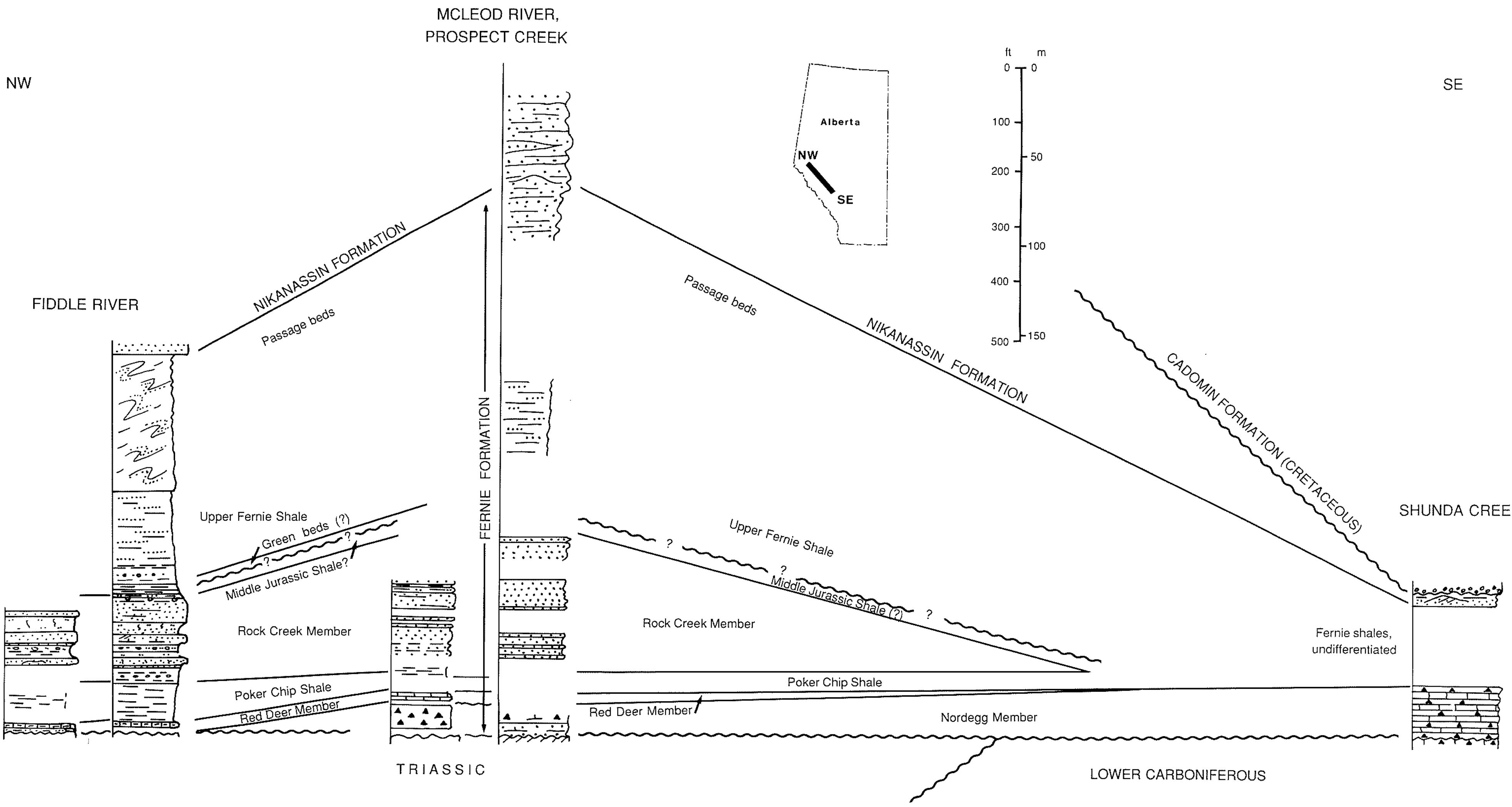

Fig. 6. Northwest-southeast cross-section showing the correlations and variation of Jurassic units between the sections visited during the field trip, from Fiddle River east of Jasper to Shunda Creek east of Nordegg.

The Red Deer and Poker Chip Shale members are starved-shelf, deeper-water, predominantly anoxic deposits. The Red Deer perhaps comprises calcisiltite laminites deposited north and west of a broad high formed by regional uplift of the Nordegg carbonate-chert bank. The more widespread Poker Chip Shale is one of a number of enigmatic, thin, widespread, epicratonic black shale units in the northern hemisphere (including *Posidonia* shales of Germany) that suggests maximum flooding of broad areas of continental crust during the Toarcian.

Rock Creek Member

What is called the Rock Creek Member in west central Alberta is not physically continuous with the Rock Creek Member in its type area in southwestern Alberta. In contrast to the single sandstone developed in the type section, it contains multiple interbedded sandstone and shale units and minor coquinas in its northern facies area. These are well displayed at Stops 4 and 6, along Fiddle River and McLeod River. The siltstones and shales gradationally underlying the lowest of the Rock Creek sandstones are included here within the Rock Creek Member as part of the same depositional sequence, whereas more conventional lithostratigraphy would include them with the underlying Poker Chip Shale to which they probably bear little relation. The Rock Creek of west central Alberta achieves a younger age than does the Rock Creek Member in its type area. The Early Bajocian ammonite *Stemmatoceras*, present in the highest Rock Creek sandstones in the Jasper area (Stop 4), occurs in the overlying basal Highwood Shale in southwestern Alberta (Fig. 4). The base of the Rock Creek Member in west central Alberta varies from abrupt to gradational (see Marion, 1984; Losert, 1986). Its isopach patterns show considerable complexity.

The Rock Creek Member exposed at Stops 4 and 6 consists of three major coarsening upward sequences. The sandstones are designated RC1, RC2 and RC3 in each of the two sections. Precise correlation of these three subunits from one section to another is not proven, although it is indeed suggested by the similarity of sedimentary structures and lithologies. The sedimentary structures and trace fossils suggest very shallow marine deposition, including the development of hard grounds and perhaps upper shoreface (even perhaps intertidal) facies. It is not clear whether the sandstones are the result of regional transgressive and regressive events on the shelf, or the product of progradational sedimentation and the shifting of sand waves and barriers on a very shallow, continuously subsiding shelf.

Middle Jurassic shales

The presence of clastic units of Late Bajocian, Bathonian and Callovian ages in west-central Alberta is suggested by palynomorphs that occur sporadically in well samples (G. Dolby, unpub.). Thes units, shown diagrammatically in the correlation chart, may be thin and locally preserved remnants of previously more widely distributed sheets, mostly removed by pre-Late Jurassic erosion. A thin unit of shales and siltstones with belemnites and the bivalve *Gryphaea* exposed at Stop 4 along Fiddle River may represent these Middle Jurassic strata.

The lowest shales and siltstones (with thin sandstones) in the section near the former Banff Traffic Circle (Stop 1) probably represent the Pigeon Creek Member, an enigmatic, turbiditic lithic sandstone developed in the Banff-Kananaskis areas. Its age and provenance are uncertain, but this uni holds promise for shedding light on the initial development of the orogenic foredeep and contemporaneous events taking place to the west. It must occupy a position in about the upper part o the Grey Beds equivalent interval (see Figure 4). Other strata at Stop 1 are probably equivalents of the Grey Beds, which is a poorly defined siltstone sequence of Bathonian and Early Callovian(?) age in southwestern Alberta and southeastern British Columbia.

Upper Fernie shales

Upper Fernie dark grey and black shales are thin but widespread in western Alberta (eg. Marion, 1984). In southwestern Alberta, they include what Hall (1984) called the Ribbon Creek Member. In some places, a thin, green and rusty, berthierine (='chamosite') -rich unit is present at the base of the shales, the Oxfordian Green beds of Frebold et al., (1959). In the subsurface west of Edmonton, the locally glauconitic Niton B sandstone (Losert, 1990) lies in the same position. These units overlie a regional disconformity below which a variety of older Jurassic units is preserved. A thin greenish shale unit above the shales and siltstones with *Gryphaea* and belemnites exposed at Stop 4 may well represent the Green beds; definitive data are not yet available.

Chondrites, conspicuous in the probable Upper Fernie Shale at Fiddle River (Stop 4) may suggest the reason for the generally unfossiliferous character of the unit: dysaerobic, deep water environments of deposition. The Upper Fernie shales grade upward, with increasing quantities of thin siltstone and sandstone beds, into the Passage beds. The Upper Fernie shales and associated facies are viewed as first transgressive (at the base) and then distal, progradational, deep-water, early deposits of the orogenic foredeep (eg. Poulton, 1984, 1989).

J.H. Wall has identified microfaunas from the Upper Fernie shales and Passage beds at Fiddle River (Stop 4) and MacLeod River (Stop 6) sections, which indicate middle to outer shelf depositional depths in the lower part of the sequence and shallower inner shelf or nearshore depths and possibly brackish salinity in the upper part approaching the contact with the Nikanassin Formation. Lower beds are probably Oxfordian, those near the top of the Passage beds may be younger Jurassic but the Foraminifera are not age-diagnostic. The lower beds contain as many as 15 species of calcareous and arenaceous Foraminifera and one Ostracode species (all with Arctic affinities) indicating normal marine shelf conditions. Microfaunas from higher in the Passage beds are progressively less diversified.

Passage Beds

The uppermost unit of the Fernie Formation in the field trip area, called the Passage Beds, is a dominantly shaly unit with conspicuous thin and planar, characteristically rusty-orange-weathering siltstone and sandstone beds (Stops 1, 4, 6). Lying closely below more competent sandstone units above, the Passage Beds are the locus for intense deformation in many places. The sandstone beds progressively increase in quantity and thickness upward within the unit, which is transitional from the Fernie shales below to the basal Kootenay or Nikanassin sandstones above. This unit is considered regionally to represent a shallowing-upward sequence, indicating north-northwesterly axial progradation in a storm-dominated foredeep (e.g., Hamblin and Walker, 1979; see also Jansa, 1981 and Hamblin and Walker, 1981 for discussion of the interpretations). The thin, planar-bedded, finely laminated and rippled (in part), very fine grained sandstones in the lower part of the unit may represent sediment introduced by a periodic mechanism onto a shelf characterized by strong bottom currents. Hamblin and Walker (1979) interpreted the Passage Beds to contain turbidites (the source of some controversy, as they lack some characteristic turbidite structures) in the lower part, and hummocky cross-stratification in upper parts, supporting the shallowing-upward interpretation. Intense bioturbation, most commonly by *Chondrites* is characteristic for at least the lower part of the Passage Beds regionally.

KOOTENAY GROUP

The Passage beds are overlain abruptly in southwestern Alberta and southeastern British Columbia by a thick, crossbedded sandstone unit, the Morrissey Formation which is the basal sandstone of the Kootenay Group (Gibson, 1985), indicating fill of the foredeep to about sea level. The lower Kootenay comprises a sequence of shoreface, beach and fluvial complexes (see Jansa, 1972; Hamblin and Walker, 1979; Gibson, 1985). The overlying Mist Mountain Formation contains immense quantities of coking coal, which are mined in southeastern British Columbia and formerly mined in southwestern Alberta (including Banff and Canmore areas), providing much of the incentive for geological mapping and exploration. The Kootenay Group has provided a characteristic flora for many years (Berry, 1929; Bell, 1946, 1956) which indicated imprecise Late Jurassic and Early Cretaceous ages. More recently, Sweet (in Poulton, 1984) has placed the Jurassic-Cretaceous boundary just below the top of the Mist Mountain Formation in the Fernie area, so that the lower Kootenay strata seen near Banff (Stop 1) are probably well within the Jurassic.

NIKANASSIN FORMATION

The uppermost Jurassic and lowermost Cretaceous strata in west central Alberta are dominantly sandstones and siltstones of the Nikanassin Formation (Gibson, 1978). This formation will be seen at Stop 6 near its type area near Cadomin. The same name is widely applied to subsurface occurrences of the Minnes Group in northeastern British Columbia (Stott, 1967). It is a northern marine to nonmarine equivalent of the essentially nonmarine Kootenay Group of southwestern Alberta. The transition from the Kootenay Group to the Nikanassin Formation occurs about the position of the North Saskatchewan River (Gibson, 1978).

The base of the Nikanassin Formation is gradational, and placed where well-developed sandstone beds dominate, above a thinner-bedded, mainly siltstone and shale interval (with thin sandstones) of the upper Fernie Formation. The Nikanassin Formation is poorly known, the subject of few studies (Kryczka, 1959; see also Mellon, 1966). The Nikanassin consists of a monotonous sequence of interbedded sandstones, siltstones and shales with thin seams of coal. The sandstones are concentrated into packages. This formation is poorly fossiliferous and reaches about 600 m thick in the Cadomin area. Regionally, the lower part consists of generally quartzose sandstones, higher parts contain chert-rich sandstone beds and thin coals.

The lower Nikanassin probably represents shelf facies from about storm-wave base to shoreface depths. There is an indication within the formation of upward variation into marginal marine, then nonmarine facies, suggested by thin coals in the upper Nikanassin. There is no clear evidence for western coarse clastic facies or source areas, as there are for the approximately equivalent Minnes and Kootenay groups to the north and south. For these reasons, west central Alberta might be viewed as containing the sought-after connection of the western interior seas with the Pacific Ocean in latest Jurassic and earliest Cretaceous times.

FIELD STOP LOCALITIES

Introduction

The Triassic and Jurassic outcrop localities selected for this field trip represent the most readily accessible exposures in the Banff, Jasper and Cadomin areas. All sections are located on or close to major and secondary roads, and require only a short traverse along the banks of shallow streams or through open forested areas. Other field sections in the area occur in thrust sheets farther to the west, which are thicker, sometimes better exposed, but require considerable effort to reach them, utilizing either a helicopter or a long walk of several kilometres along stream or river bank trails, and then up steep mountain ridges.

The following discussion outlines the most important lithologic and sedimentary features to be seen at seven localities (Fig. 1). Four localities contain part or all of the Triassic members to be examined (Fig. 1, Stops 2, 3, 4, 5, 6), and four localities contain part or all of the Jurassic members to be examined (Stops 1, 4, 6, 7). Stops 3 and 4 require crossing Fiddle River in order to see the best and most continuous exposure. Rubber hip-waders or better, running shoes or sneakers are advisable. The water is shallow, very cold and the rocks are extremely slippery. Caution is advised. Stops 1 to 5 are located in Banff and Jasper National Parks. Accordingly, the use of geological hammers and the collecting of rock specimens are not allowed without a permit.

FIELD STOP NUMBER 1

Banff-Minnewanka Interchange/Cascade River Bridge

Jurassic strata are well exposed along the north side of the Trans-Canada Highway immediately east of the bridge over Cascade River and about 600 m east of the interchange (formerly a traffic circle) with the eastern entrance to Banff townsite and access to Lake Minnewanka (Fig. 7). This is the "Banff Traffic Circle" section of Frebold (1962), which was restudied by Jansa (1972) and A. Hamblin (Hamblin and Walker, 1979), and has also been described by Hamblin (1978, 1983), Walker and Hamblin (1982), and Hall and Stronach (1982). The upper part of the section, exposing the uppermost Passage Beds and the lower Kootenay Group, has been cut by highway construction since these previous descriptions.

The section exposes Late (and Middle?) Jurassic strata of the Upper (and Middle?) Fernie Formation through the lower Kootenay Group. Lower Fernie units are exposed along Cascade River upstream where they overlie Triassic strata (Frebold, 1957), along the railroad near the Cascade River highway bridge and on the east side of Cascade Mountain just to the west, where they are in fault contact with Devonian limestones (Frebold, 1962). The strata along the highway are **overturned** below the Rundle Thrust fault, with the top to the east. Start at the west end to walk upsection. The lower parts of the Fernie in this section are somewhat folded and faulted. The highest unit, the Passage beds, are clearly much thicker than is normally exposed (350-360m), perhaps a result of the section being in a more westerly paleogeographic/tectonic setting or perhaps an indication of considerable variation from one place to another in the subsidence of the pre-orogenic foredeep trough. In general, the sequence demonstrates well the upward increase in sandstone and decrease in water depth associated with the regional Kootenay progradational wedge which initially filled the early foredeep.

The lowest few feet of Fernie strata exposed at the westernmost end of the outcrop contain planar-bedded siltstones, probably representing the **Pigeon Creek Member**. The planar bedding and sole markings suggest turbidite deposition, consistent with the member regionally. Feeding trace fossils can be seen.

The immediately overlying, faulted and folded Fernie shales and siltstones (Fig. 8) were assigned to the Grey Beds Member by Frebold (1962) and Hall and Stronach (1982). They reported the ammonites *Warrenoceras* (?=*Eurycephalites*) and *Kepplerites*, as well as bivalves and belemnites, from this unit but it is not clear from their reports whether they came from this outcrop (they may be the *Arcticoceras* and *Kepplerites* described by Frebold, 1957, from Cascade River Canyon). The ammonites indicate a Late Bathonian or possibly Early Callovian age.

The next higher (more easterly) unit comprises shales and siltstones with large concretions. Frebold (1957, 1962) reported the gastropod *"Turbo" ferniensis* Frebold from this unit nearby along Cascade River. The concretionary zone and the gastropod are characteristic regionally of an interval with large concretions that is laterally equivalent to the Green Beds Member which occurs sporadically in other areas, and is of Oxfordian age, at least in part (Frebold, 1957) (Ribbon Creek Member of Hall and Stronach, 1982, 1984). Frebold (1962) interpreted some structural repetition of units in the succeeding interval along the highway. Fine, current-oriented, carbonaceous plant debris is conspicuous on some of the bedding surfaces.

A prominent 9-10 m-thick interval within this unit, of light-weathering planar-bedded sandstones (reaching 0.5 m thick) interbedded with shales and siltstones (Figs. 8, 9) has yielded the Late Oxfordian or Early Kimmeridgian ammonite *Amoeboceras* according to Frebold (1962). It is marked "A" on Figures 7,8, and 11 and in Hamblin (1978). Hamblin and Walker (1979) identified Bouma B and BC sandstones in this and the underlying intervals. Sole marks on the bases of these planar beds are shown in Figure 10. The prominent light-colored banded interval exhibits north-northeasterly flow directions whereas those from other parts of the section are primarily north-northwesterly.

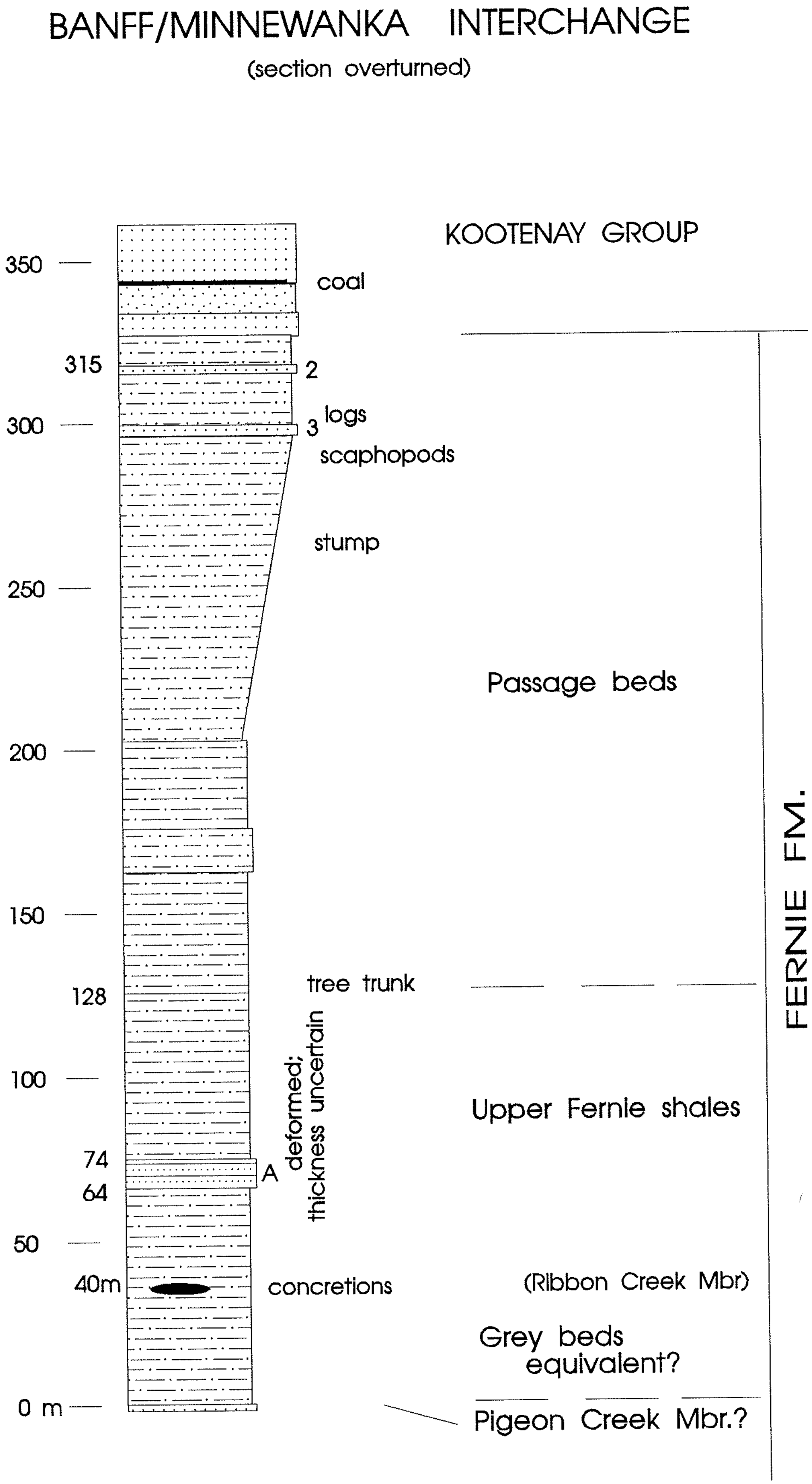

Fig. 7. The Jurassic Fernie Formation and lower Kootenay Group exposed along the Trans-Canada Highway east of the Banff-Minnewanka intersection east of Banff. Metres shown to left of lithological column refer to section of Hamblin (1978); "A" refers to *Amoeboceras* beds of Frebold (1962) and beds marked "A" by Hamblin (1978), and in Figures 9-11 below. Modified from Hamblin (1978).

The following, essentially undeformed, 260 m-thick interval comprises dark, recessive siltstones and shales with parallel-laminated and rippled, fine grained sandstone beds which increase upward in abundance, thickness and grain size. These are the **Passage Beds** of the upper Fernie Formation, which are characterized by the thin, planar, rusty orange- and brown-weathering, fine grained sandstones which impart a marked banded appearance to the outcrops (Fig. 11). The siltstones and sandstones are intensely bioturbated. Jansa (1972) identified the traces *Thalassinoides* and *Cosmorhaphe* in the strongly bioturbated thin sandstone beds in the lower part of the unit, where Hamblin and Walker (1979) identified Bouma B and C sandstones. The trace fossils other than *Chondrites*, plant debris (including tree trunks, Fig. 12), north- or north-northwest-trending sole markings, and convoluted bedding (Fig. 13) which are seen in the Banff section are not as prominent in other sections such as at Prospect Creek (Stop 6, Fig. 1). Some of the abundant fine carbonaceous plant debris on the bedding surfaces commonly is current-oriented. The first appearance of hummocky cross-stratification in the Passage Beds more or less coincides with the appearance of minor rip-ups (Hamblin and Walker, 1979). Load casts are prominent in a 3 m-thick interval high in the unit. Scaphopods litter at least one bedding surface high in the Passage Beds at this locality, now inaccessible beyond the fence. Jansa (1972) compared some of the trace fossils in the upper Passage Beds here with *Rhizocorallium* and *Planolites*. The Passage beds member is thicker here, and contains more prominent intervals of bundled and thick (in the upper part) sandstone beds than usual, similar to those of the lower Nikanassin Formation to the north (Figs. 14, 15). Some of the sandstone units resemble those of the basal Kootenay Weary Ridge facies in their grain sizes, cross bedding, and thickness, but are included within the upper Fernie because of the predominance of finer grained, more recessive lithologies with which they are interbedded. Some beds in the upper part of the unit are distinctly carbonaceous and one layer contains large wood impressions and casts. Mud-silt rip-ups occur as well. The Late Oxfordian or Early Kimmeridgian bivalve *Buchia concentrica* (Sowerby) has been reported from the unit along the Cascade River upstream.

The base of the **Kootenay Group** is placed at the base of a continuous section of often thick-bedded, chert-rich sandstone, with little interbedded siltstone (Fig. 16). The lowest 7-8 m contains conspicuous cross-beds, as does a higher unit, above a 1/2m-thick coal bed. The sedimentary structures suggest upper shoreface or beach environments for the crossbedded sandstone (Weary Ridge facies), and fluvial environments for the more irregularly bedded sandstone (Moose Mountain facies) that immediately underlies the thin coal seam (see Fig. 16). The coal seam is overlain by a 15 cm-thick quartz-chert granule conglomerate with minor limestone granules. Details of the Kootenay outcrop are beyond the limits of this field trip and guidebook (see references cited above).

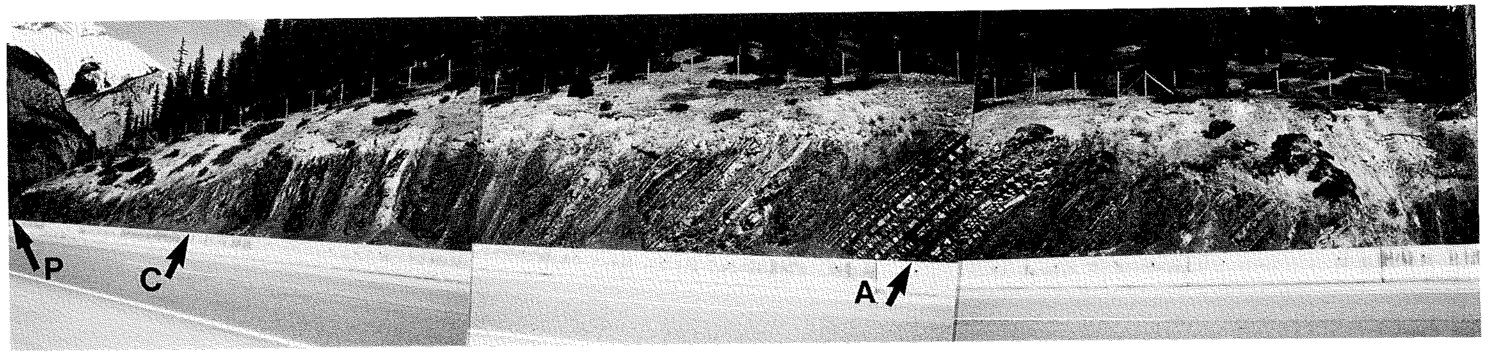

Fig. 8. Lower part of overturned Jurassic section east of Banff-Minnewanka intersection. Pigeon Creek Member of Fernie Formation occurs at extreme far left side of outcrop (P); banded unit right of centre (A) shown in detail in Figure 9. "C" marks zone of large concretions.

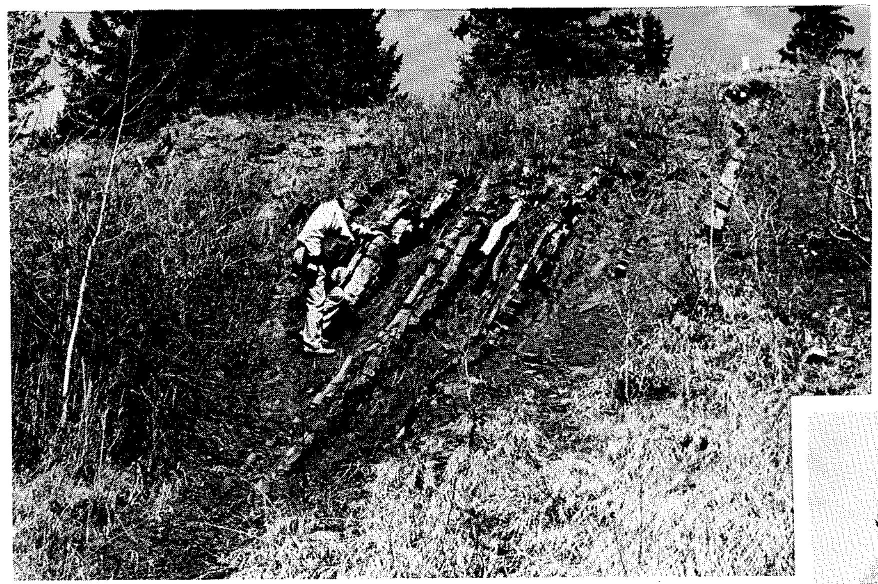

Fig. 12. Fossilized tree trunk in Passage Beds, Fernie Formation east of Banff-Minnewanka intersection.

Fig. 9. Banded sandstones and siltstones of the upper Fernie Formation east of Banff-Minnewanka intersection. This interval yielded *Amoeboceras* according to Frebold (1962).

Fig. 10. Sole marks on base of turbidites shown in Figure 9.

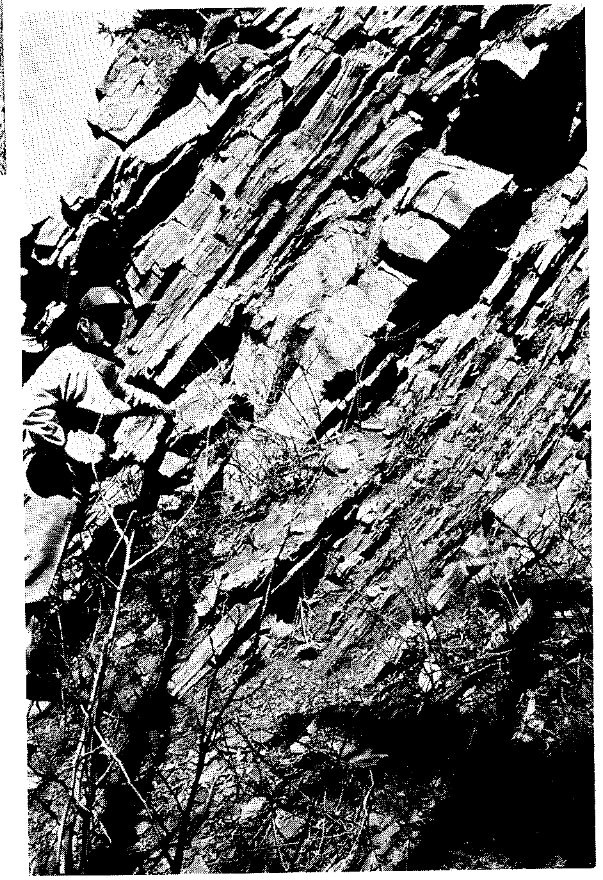

Fig. 13. Convoluted bed and load casting in upper Passage Beds, Fernie Formation east of Banff-Minnewanka intersection.

Fig. 11. Coarsening- and shallowing-upward overturned Passage Beds of the upper Fernie Formation in the middle parts of the overturned Jurassic section east of Banff-Minnewanka intersection. Banded unit shown in Figure 9 marked A. Hummocky cross stratification begins about point marked HCS→; "C" marks convoluted bed; "T" marks fossil tree stump.

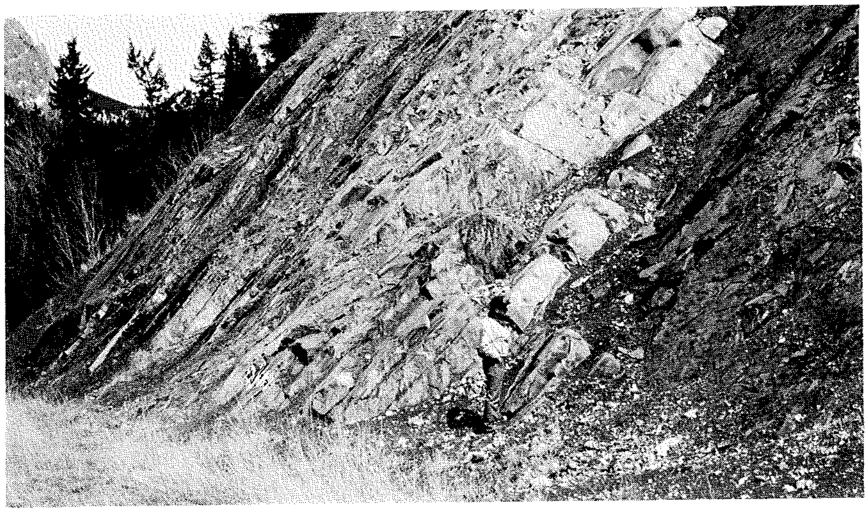

Fig. 14. Prominent 3 m thick sandstone in upper Passage beds, Jurassic section east of Banff-Minnewanka intersection. Large plant debris on dark bedding surface to right.

Fig. 15. Scour surface at base of prominent 2m-thick sandstone, near top of Passage beds east of Banff-Minnewanka intersection. Sandstone marked "3" shown in Figure 14.

Fig. 16. The lower Kootenay Group in the upper part of the overturned Jurassic section east of Banff-Minnewanka intersection, showing Fernie Formation to left (F) and basal Kootenay sandstone (K) to right, in foreground. Half-meter thick coal seam marked "C". Sandstones marked "3" and "2" are shown in Figures 14 and 15 respectively.

FIELD STOP NUMBER 2

Mount Norquay Ski Access Road (2A)

The only readily accessible Triassic rocks that can be seen in the Banff field trip area are those of the Phroso and Vega Siltstone members of the Sulphur Mountain Formation. The contact between the two members in the Banff townsite area is however gradational and sometimes difficult to assign. Excellent exposures of flaggy weathering siltstones and shales typical of the Vega Siltstone Member in the Banff area occur on both sides of the access road to the Mount Norquay Ski area. A brief stop will be made at the third major switch-back north of the Trans-Canada Highway to examine strata of the Vega Siltstone Member. This exposure as well as others in the Banff area occur in the Front Ranges of the Rocky Mountains. Figures 17 and 18 illustrate the thin-to medium-bedded, flaggy weathering siltstones of the Vega Siltstone Member. Note the predominance of fine parallel lamination in the more shaly weathering facies, and the wavy to lenticular and ripple lamination in the more resistant weathering siltstone beds. The strata represent facies of a proximal to mid-shelf marine environment. Equivalent strata will be seen at our lunch stop at Bow Falls. These exposures and those at Bow Falls occur in the footwall of the Sulphur Mountain Thrust Fault.

Return to the bus and lunch at Bow Falls.

Bow Falls (2B)

Typical exposures of both the Phroso and Vega Siltstone facies can be seen at low water at Bow Falls. However, at this time of year water levels in the Bow River are high, thus making access to some of the lowermost strata difficult. Note the abrupt and disconformable contact between the recessive weathering Phroso Siltstone Member of the Sulphur Mountain Formation and the resistant, cliff-forming strata of the Permian Ranger Canyon Formation of the Ishbel Group on the east side of the river (Fig. 19). The main part of the falls occurs within the Phroso facies. The Phroso Siltstone Member is very thin at this locality. The cliff-forming, rusty brown weathering, medium-to thin-bedded siltstones on the west side of the river beside the main parking lot are typical of the Vega Siltstone Member in most other areas within Banff National Park, Kananaskis Country to the southeast, and the Vega Member that will be seen at other Triassic field stops in the Jasper and Cadomin areas to the north. Note the fine parallel and wavy and ripple lamination in the thinner bedded siltstones on the west side of the parking lot near the Pub Staircase entrance to the Banff Springs Hotel (Fig. 20). In contrast, the thicker more resistant siltstone beds in the cliff beside the river appear to be mainly structureless.

Return to the bus and proceed back through town to the Trans-Canada Highway and Stop 2C.

Trans-Canada Highway/Vermilion Lakes (2C)

The last of the Triassic stops in the Banff area occurs beside the Trans-Canada Highway near Vermilion Lakes, and is situated palinspastically west of the Triassic exposures of Stops 2A and 2B (Fig. 21). At this locality over 300 m of siltstone typical of the Phroso Siltstone Member in the Western Canada Sedimentary Basin are well exposed adjacent to the highway. Medium grey cherty strata of the Permian Ranger Canyon Formation can be seen at the east end of the highway exposure. Unfortunately, the exact contact with the Permian, and the lower 35-40 m of the Phroso facies are not exposed. Note the dense, fine parallel lamination and shaly weathering character of the strata (Figs. 21, 22), which contrast with the wavy to ripple laminated Phroso facies that will be seen in the Jasper and Cadomin areas to the north. Distinct tempestite and/or turbidite interbeds are rare with the exception of those at the westernmost part of the outcrop. Current or other sedimentary structures are not readily obvious. The Phroso Siltstone strata at this locality are much thicker than those at Stop 2B (Bow Falls). They occur within the footwall of the Bourgeau Thrust Fault, which is the next major thrust sheet west of the Sulphur Mountain Thrust, and the Triassic exposures at Bow Falls and Mount Norquay ski hill access road. The Phroso facies at this locality are interpreted to have been deposited in a relatively deeper water mid to distal shelf environment. Some of the loose talus slabs contain poorly preserved ammonite impressions.

Return to the bus. The remainder of the afternoon will be spent driving northward along the Icefields Parkway to Jasper and our accommodation at Overlander Lodge.

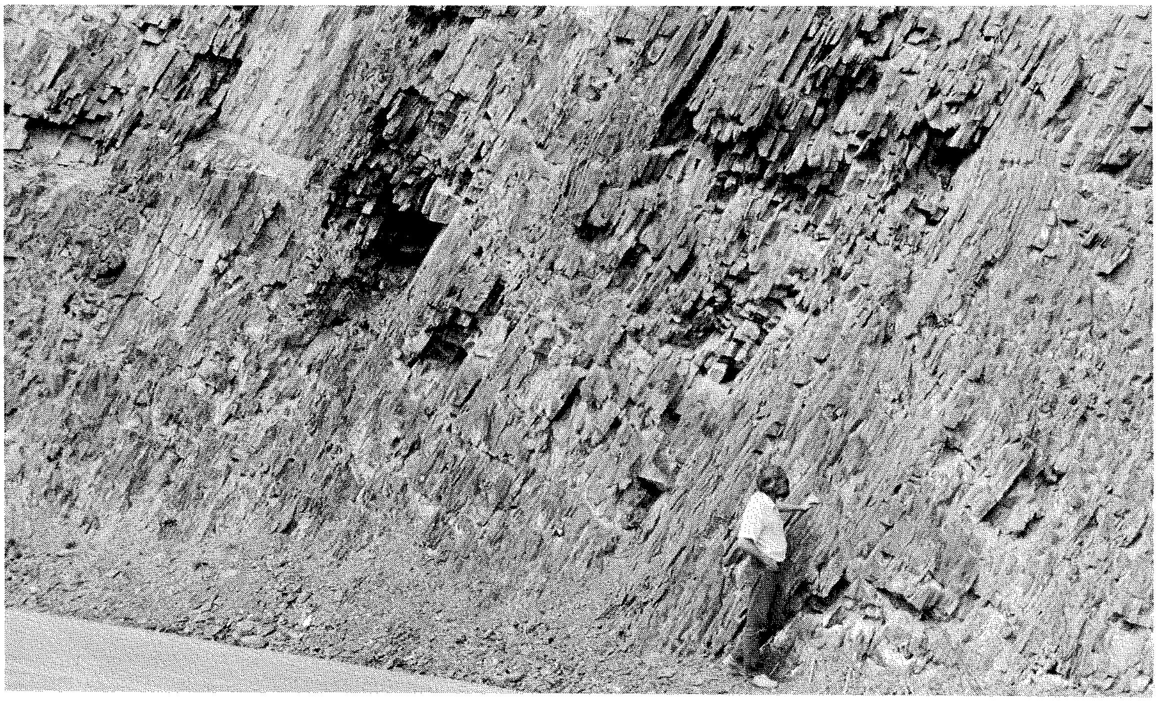

Fig. 17. Platy to flaggy weathering siltstones and shales of Vega Siltstone Member at Stop 2A, Mount Norquay ski hill access road.

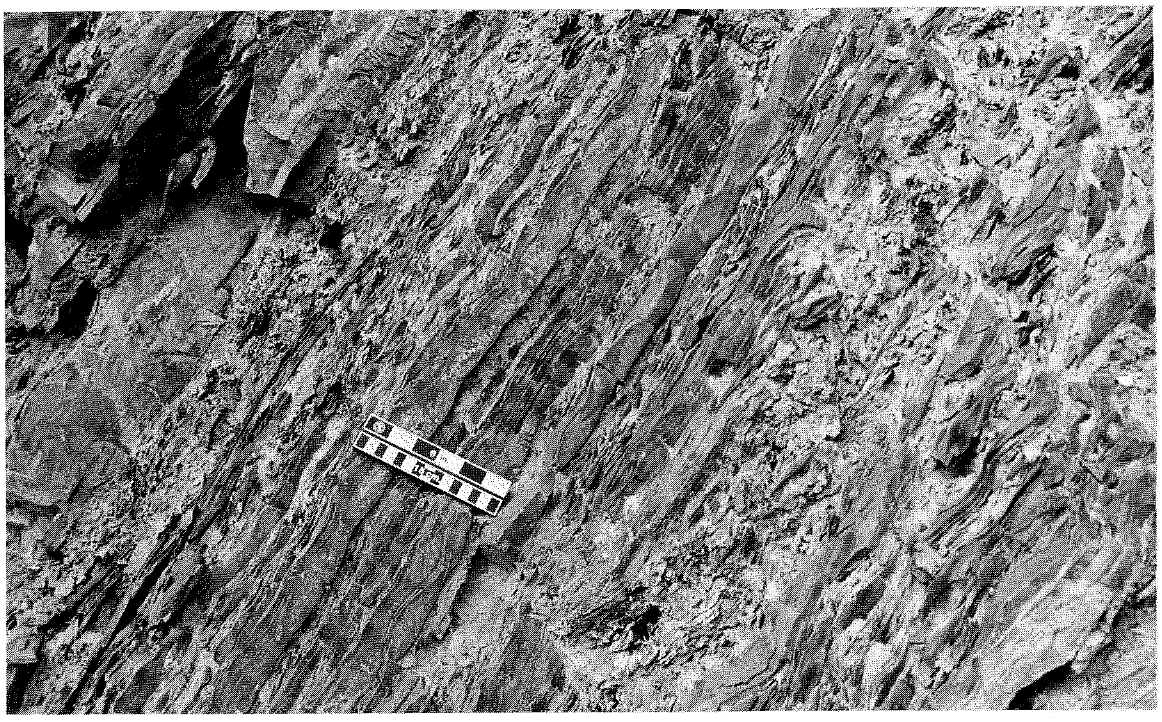

Fig. 18. Ripple laminated siltstones and fine parallel laminated shales of Vega Siltstone Member at Stop 2A.

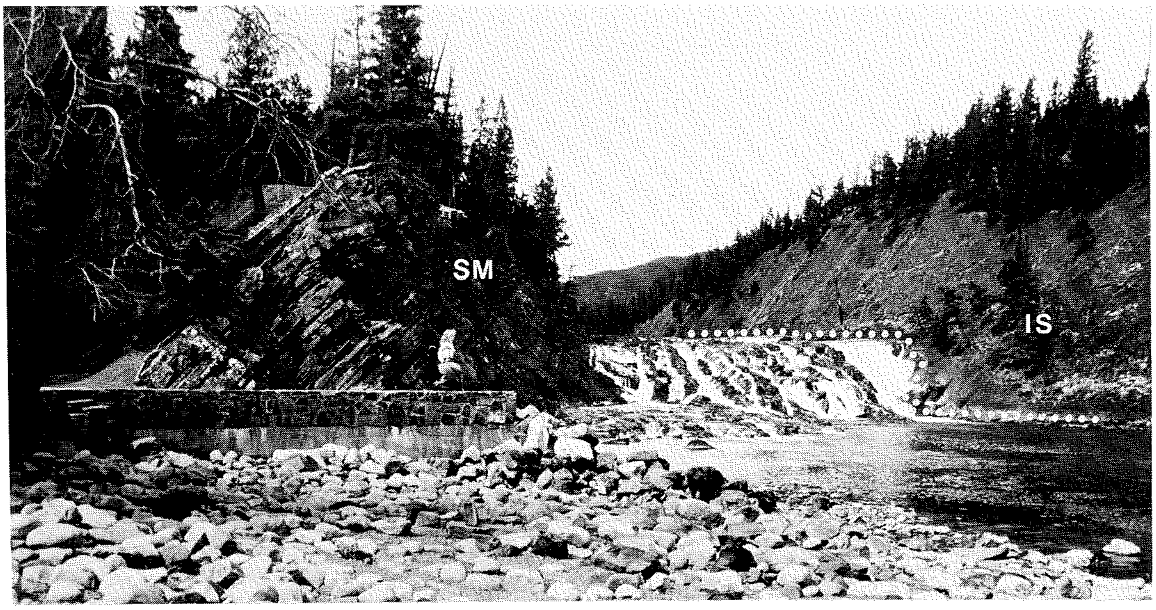

Fig. 19. Bow Falls (Stop 2B) showing abrupt unconformable contact between Triassic Sulphur Mountain Formation and Permian Ishbel Group. Note typical more resistant weathering strata of the Vega Siltstone Member on left side of falls. Falls underlain by strata of Phroso Siltstone Member. SM = Sulphur Mountain Formation; IS = Permain Ishbel Group.

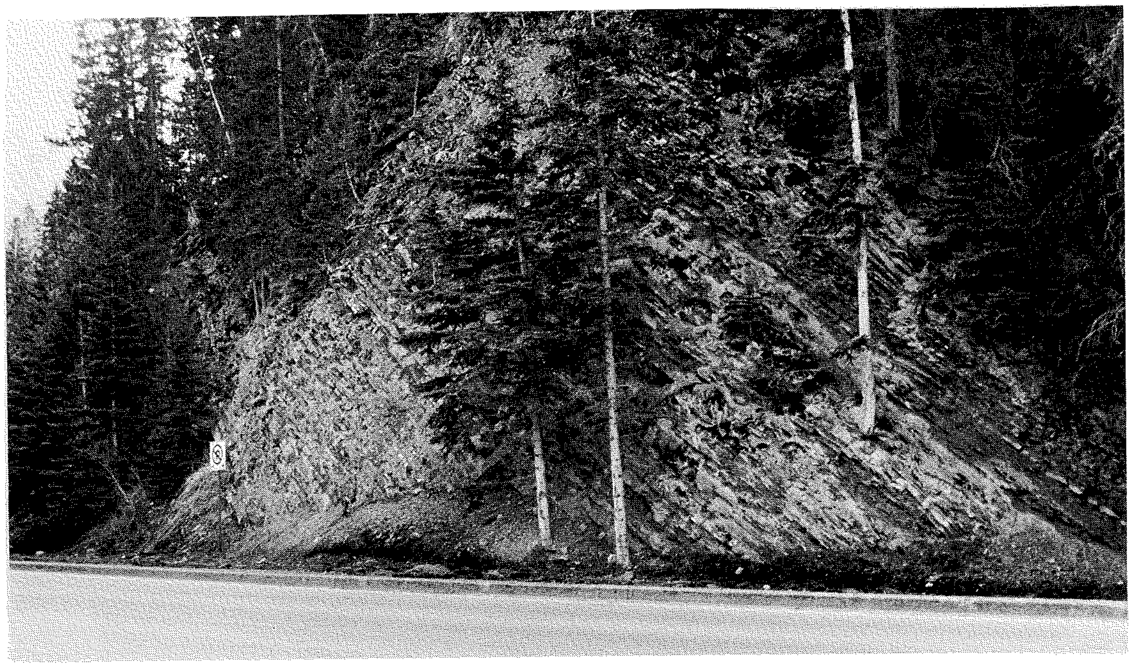

Fig. 20. Flaggy weathering, ripple laminated siltstones and shales of Vega Siltstone Member, Bow Falls parking lot (Stop 2B).

Fig. 21. Typical shaly weathering siltstones of the Phroso Siltstone Member along Trans Canada Highway near Vermilion Lakes (Stop 2C).

Fig. 22. Fine parallel lamination characteristic of Phroso Siltstone Member at most outcrop localities (Stop 2C). Contrast with wavy to ripple laminated siltstones of Phroso Member at Stops 5 and 6.

FIELD STOP NUMBER 3

Fiddle River / Morris Creek

The Fiddle River/Morris Creek section, located at the confluence of Morris Creek and Fiddle River, is reached by driving 9 km. from the Junction of Highway 16, along the Miette Hotsprings access road to Morris Creek. Proceed via a game trail along the northwest side of Morris Creek to Fiddle River.

Figure 23 is a detailed lithologic column of the Fiddle/Morris section, illustrating the thickness, members, and lithofacies of the Sulphur Mountain and Whitehorse formations. Although exposed along the river bank in the trees, the Whitehorse Formation will not be examined at this locality.

The traverse begins at the mouth of Morris Creek, where excellent examples of tempestite and/or turbidite siltstones and shaly siltstones of the lower Phroso Siltstone Member are exposed (**Unit 2**, Fig. 23). Note the well-developed rhythmicity between the finely laminated shaly siltstone and faintly to non laminated thicker beds of dolomitic siltstone. Similar resistant-recessive siltstone facies will be seen near the base of the Phroso Siltstone Member at Stop 6 near Cadomin, and can also be seen at Stop 4.The massive dip slope on the northwest side of the river consists of dolostones of the Carboniferous Rundle Group. Strata of the Permian Ishbel Group have been eroded at this locality.

Proceed downstream along the southeast side of Fiddle River to the small waterfall (**Unit 2**), which consists of lithofacies equivalent to the interbedded siltstone and shaly siltstone at the mouth of Morris Creek. Wade the river below the falls to examine the soft sediment deformation and shallow scour channel, and abrupt contact with an unusual intraformational **flat pebble conglomerate** (Figs. 24, 25, 26). The conglomerate clasts are elongate and subrounded, appear imbricated in part and occur in a dark grey, quartzose, slightly phosphatic siltstone/ sandstone matrix (Figs. 25, 26). The conglomerate may represent the basal facies of a minor transgression, and its occurrence may be related to the suggested drop in sea level during deposition of the Mackenzie Dolomite to be seen at Stop 6. Strata overlying the conglomerate consist of typical shaly siltstone of the Phroso Siltstone Member which at most localities in the region, display dense, fine parallel to locally, low angle intersecting, light grey quartz and pyritiferous lamination (Fig. 27). Similar laminated strata were seen at Stop 2C at Banff (Fig. 22). Note the absence of the distinct non-laminated interbeds seen in Unit 2. **Unit 3** looks to be part of a transgressive cycle with deposition taking place in a relatively deep water shelf environment. The contact between the Phroso Siltstone and Vega Siltstone members is conformable but relatively abrupt (Fig. 28). It is assigned to the base of an interval where dense, more resistant weathering beds of faintly to non-laminated dolomitic, quartz siltstone progressively increase upward in both frequency and thickness.The shaly and more recessive finely laminated interbeds decrease in thickness and frequency toward the top of the member (Fig. 29). *Euflemingites* ammonite impressions and small groove casts may be seen near the base of the Vega Siltstone Member. Note the very **large-scale load casts** or flow rolls in the typical cliff-forming Vega Member siltstones of **Unit 9** (Fig. 30). Units 10 and 11 of the upper Vega Siltstone Member are characterized by medium to thick beds of siltstone, some of which contain medium scale load casts, HCS bedding, ripple lamination and shallow channel scours. The contact with the overlying Llama Member is not exposed at this locality. Exposures of the Whitehorse Formation occur along the river bank, but are much better exposed at Stop 4, farther upstream.

The Vega Siltstone facies at this locality represents part of a shallowing and coarsening upward succession, interpreted to be part of a proximal shelf-shoreface environment.

Jurassic strata are exposed intermittently along the Miette Hotsprings access road from Highway 16. A sequence exposing most Jurassic units to the top of the Rock Creek Member can be seen along Morris Creek, upstream from the Miette Hotsprings access road culvert. The sequence is better exposed at Stop 4, in Fiddle River below the storage compound (below).

FIDDLE RIVER/MORRIS CREEK

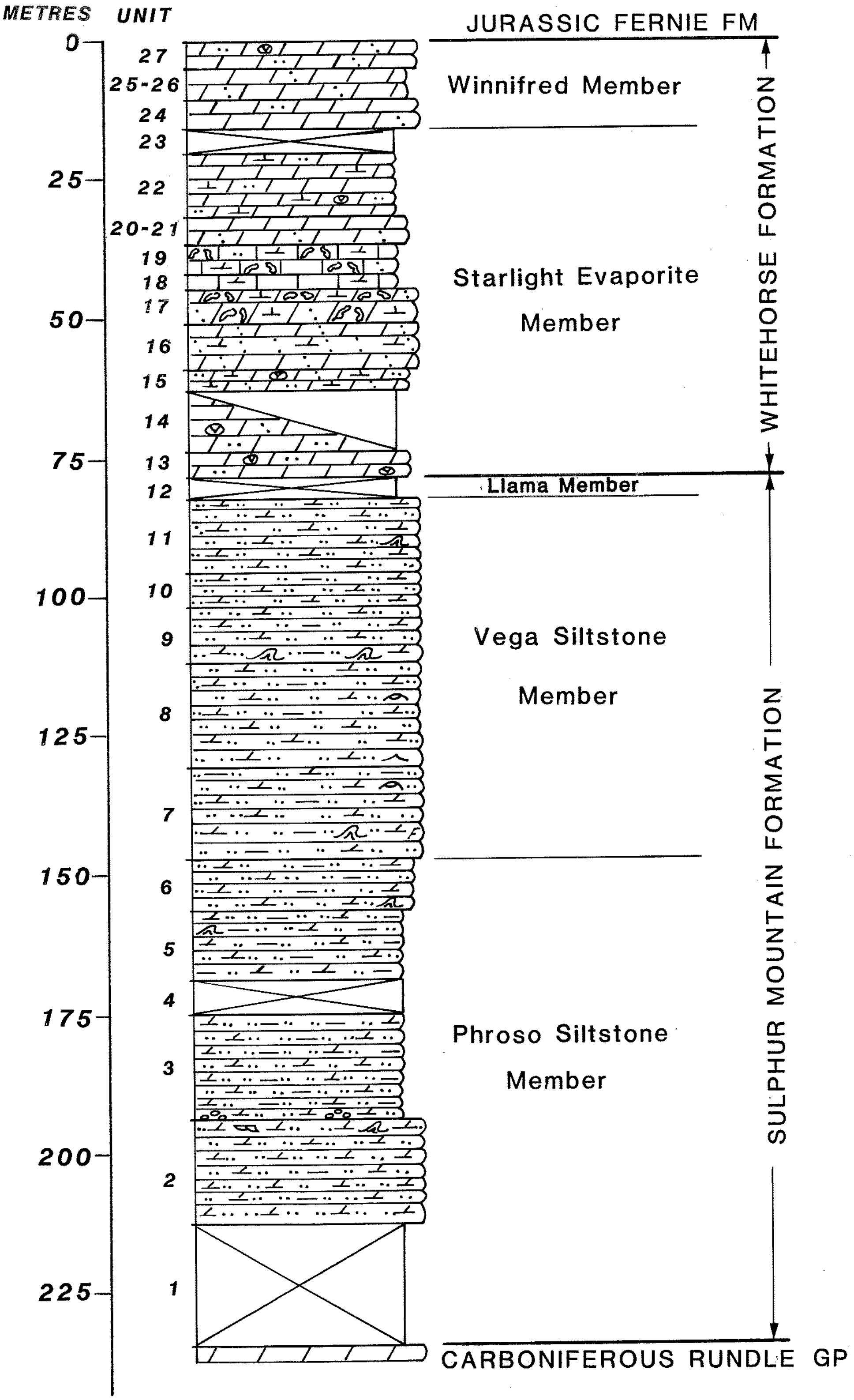

Fig. 23. Detailed columnar section of Triassic exposures at Stop 3, Fiddle River/Morris Creek (For legend see Fig. 3).

Fig. 24. Soft sediment deformation in siltstone bed of lower Phroso Siltstone Member (Unit 2) at Stop 3, Fiddle River/Morris Creek.

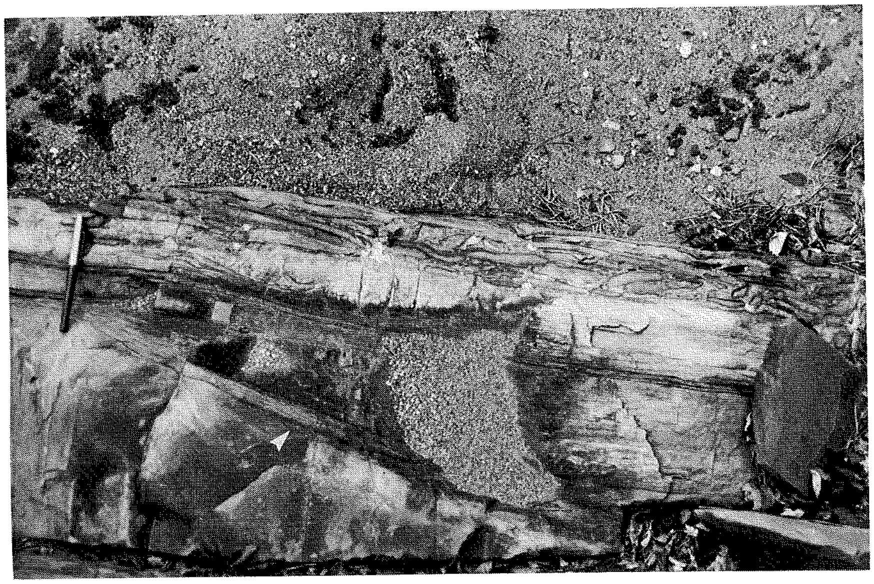

Fig. 25. Small channel infilled by finely laminated siltstone (arrow), and overlain by thin intraformational flat pebble conglomerate, in Phroso Siltstone Member at Stop 3, Fiddle River/Morris Creek.

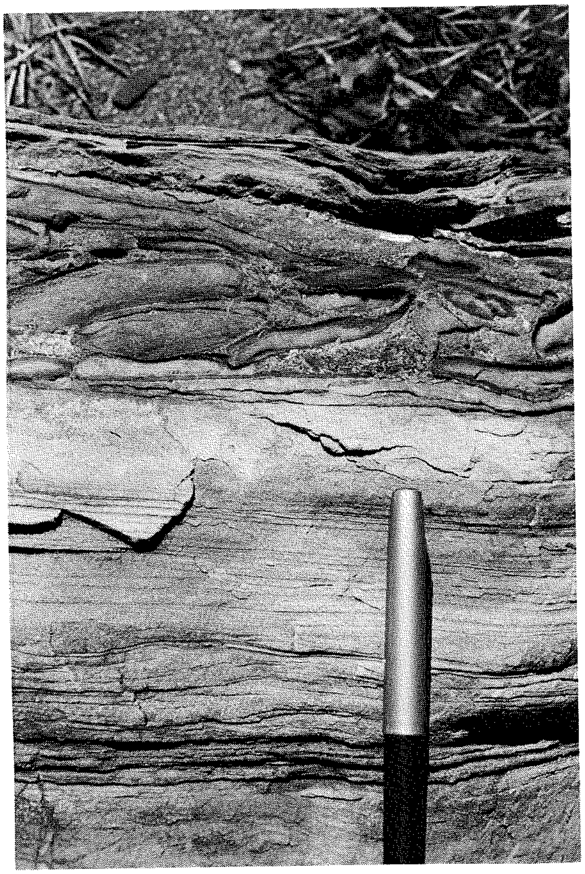

Fig. 26. Close-up of contact between flat pebble conglomerate and underlying finely laminated siltstone of Phroso Siltstone Member at Stop 3, Fiddle River/Morris Creek.

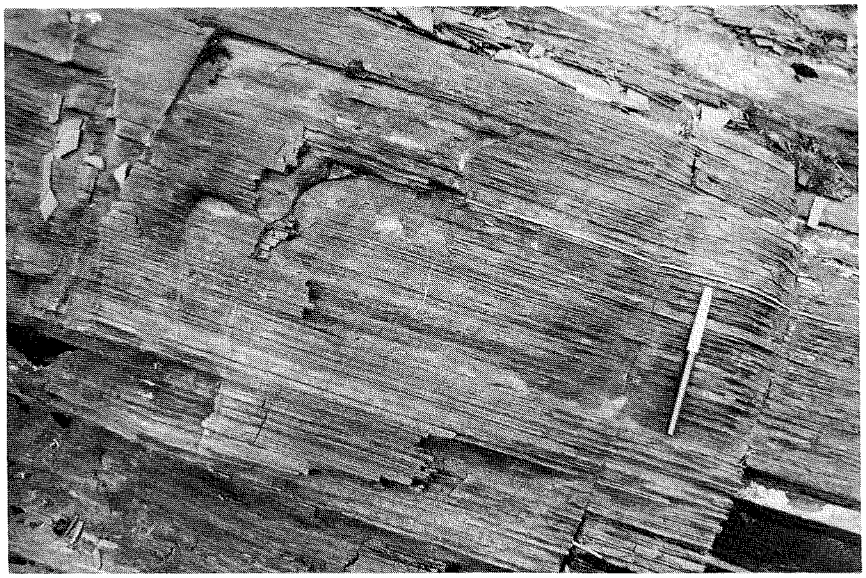

Fig. 27. Fine, parallel lamination typical of shaly siltstones of Phroso Siltstone Member at Stop 3, Fiddle River/Morris Creek.

Fig. 28. Contact between Phroso Siltstone and Vega Siltstone members at Stop 3, Fiddle River/Morris Creek. Vg= Vega Siltstone Member; Ph= Phroso Siltstone Member.

Fig. 29. Typical flaggy weathering siltstones of the Vega Siltstone Member at Stop 3, Fiddle River/Morris Creek.

Fig. 30. Large flow rolls or load casts in cliff-forming strata of Vega Siltstone Member at Stop 3, Fiddle River/Morris Creek.

FIELD STOP NUMBER 4

Jasper National Park Storage Compound

Stop 4 at the Jasper Park-Fiddle River Storage Compound (formerly a Miette Hotspring garbage disposal site) is reached by travelling southeast beyond Morris Creek and Stop 3, 14 km along Miette Hotsprings access road from the junction with Jasper Highway 16. Jurassic strata are exposed intermittently along the road, and a sequence exposing most units to the top of the Rock Creek Member can be seen along Morris Creek, upstream of the bridge near its junction with Fiddle River.

Access to the field section is via a short walk either from the Hotsprings road (if gate is locked), or from the storage site, down a small embankment, through an open forested area, to the southwest bank of Fiddle River. Descend the steep bank to river level.

Figure 31 is a detailed lithologic log of the uppermost Sulphur Mountain and Whitehorse formations.

Participants if interested and if time permits may walk upstream and examine exposures of the Phroso and Vega Siltstone members (Figs. 32, 33). These exposures are similar in character to those seen at Stop 3.

Our traverse begins on the east side of the river at the contact between the Vega Siltstone and Llama members, (Fig. 34). Note the abrupt contact and conspicuous facies change between the **Vega and Llama members**. The contact may be indicative of an **unconformity**. The Whistler Member which normally overlies the Vega Siltstone Member, is absent at this and other eastern localities (Fig. 3). Note the abrupt lithological contact between the Llama and Starlight Evaporite facies (Units 2, 3, Fig. 31; Figs. 34, 35). This contact may also represent a time or erosional gap. Small-scale soft sediment slump structures may be seen in the upper bed of Unit 2 in the Llama Member

Strata of the lower Starlight Evaporite Member consist mainly of thin to medium bedded, silty to sandy dolostone with occasional dolomitic sandstone and limestone interbeds near the base (Unit 4, Fig. 31; Figs. 34, 35). 2.4 meters above the base of the Starlight Member is a thin band of intraformational pebble conglomerate. Note the distinct light grey and olive grey banded character of the dolostone beds, and the dark grey, parallel to wavy, shale partings. Small calcite-lined vugs are common in the thinner bedded, dense dolostones. The composition, finely crystalline texture, distinct banded character and presence of ripple lamination, suggest deposition within a tidal flat or shallow water lagoonal environment. **Unit 9** (Fig. 31) represents the base of a red-weathering dolostone, limestone and solution or collapse breccia facies. For better and more continuous exposure, **cross the river**. Note the angular, red and buff dolomite clasts of the solution breccia facies (Fig. 36) . The cement and matrix of the breccia consists of limestone and calcareous dolomite. The brecciation developed as a result of evaporite dissolution and consequent collapse of overlying dolostone and sandy dolostone interbeds. **Units 9 and 10** (Fig. 31), represent deposition within a tidal flat, playa and/or sabkha environment. The contact with the resistant, cliff-forming dolostones of the Winnifred Member is abrupt (Fig. 35), and may represent a transgressive surface and slight increase in water depth. The Brewster Limestone Member, which normally overlies the Starlight Evaporite Member, does not occur at this locality. "Birds-eye"- like micro-vugs may be seen in the dolostone of **Unit 10**, near the top of the Starlight Evaporite Member (Figs 31, 35).

The Winnifred Member consists mainly of cliff-forming, finely crystalline silty to sandy dolostone, with minor dolomite intraformational breccia bands near the base (Fig. 37). In addition, weathered pyrite aggregates and small crystals, and pyritiferous shale units may be seen throughout the member. Dark grey **pyrobitumen mottling** and discontinuous colour banding occur in the upper 8 m. The Winnifred dolostones were mainly deposited in a nearshore, shallow-water intertidal to subtidal environment, however, one deeper than that postulated for underlying strata of the Starlight Evaporite Member.

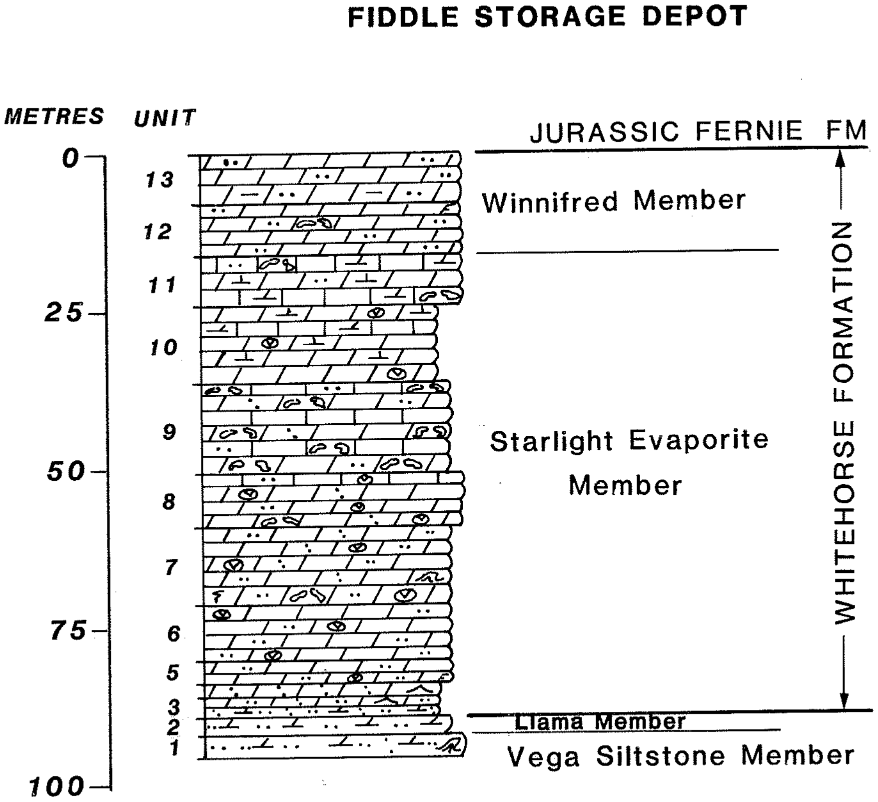

Fig. 31. Detailed columnar section of Triassic exposure at Stop 4, Fiddle River Storage Depot (For legend see Fig. 3).

Fig. 32. Cyclical resistant-recessive siltstone and silty shale in Phroso Siltstone member at Stop 4, Fiddle River Storage Depot. Pen for scale.

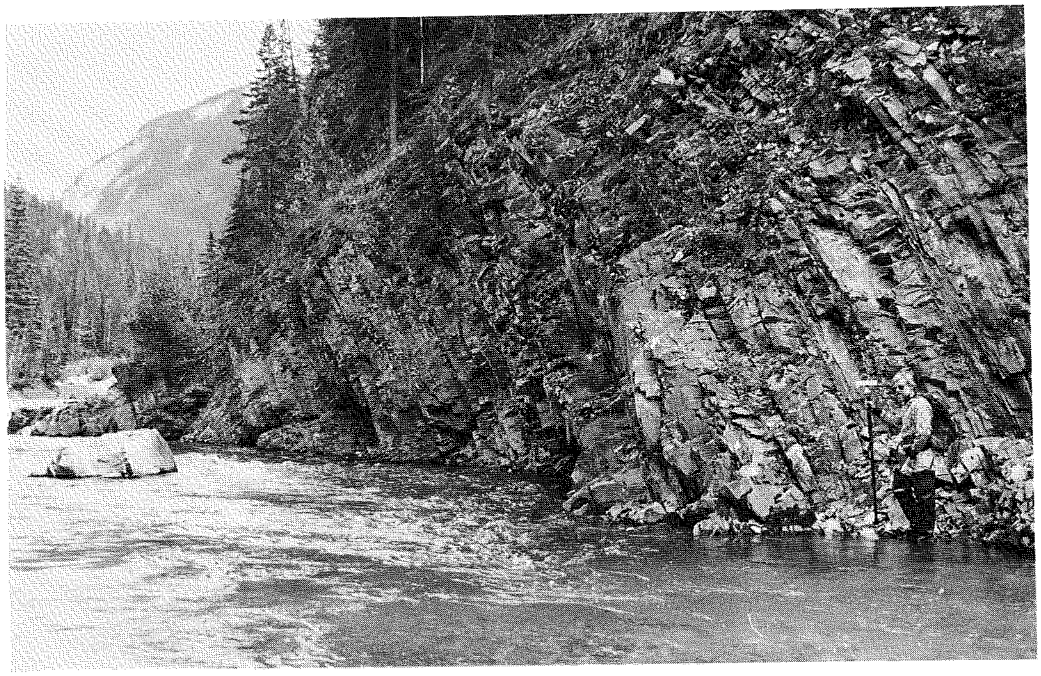

Fig. 33. Siltstones of Vega Siltstone Member at Stop 4, Fiddle River Storage Depot.

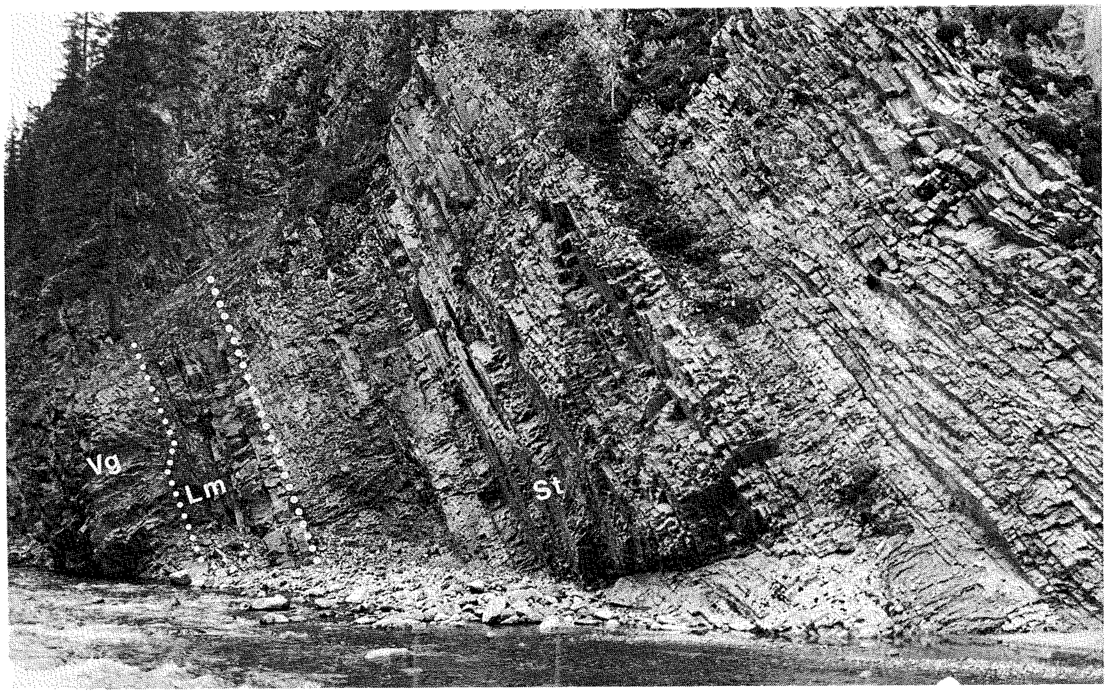

Fig. 34. Lithology and contact relationships between Vega Siltstone, Llama and Starlight Evaporite members at Stop 4, Fiddle River Storage Depot. Vg= Vega Siltstone Member; Lm= Llama Member; St= Starlight Evaporite Member

Fig. 35. Lithology and contact relationships between Vega Siltstone, Llama, Starlight Evaporite and Winnifred members of Triassic Sulphur Mountain and Whitehorse formations at Stop 4, Fiddle River Storage Depot. Vg= Vega Siltstone member; Lm= Llama Member; St= Starlight Evaporite Member; Wn= Winnifred Member; Fn= Jurassic Fernie Formation.

Fig. 36. Solution/collapse breccia in Starlight Evaporite Member at Stop 4, Fiddle River Storage Depot.

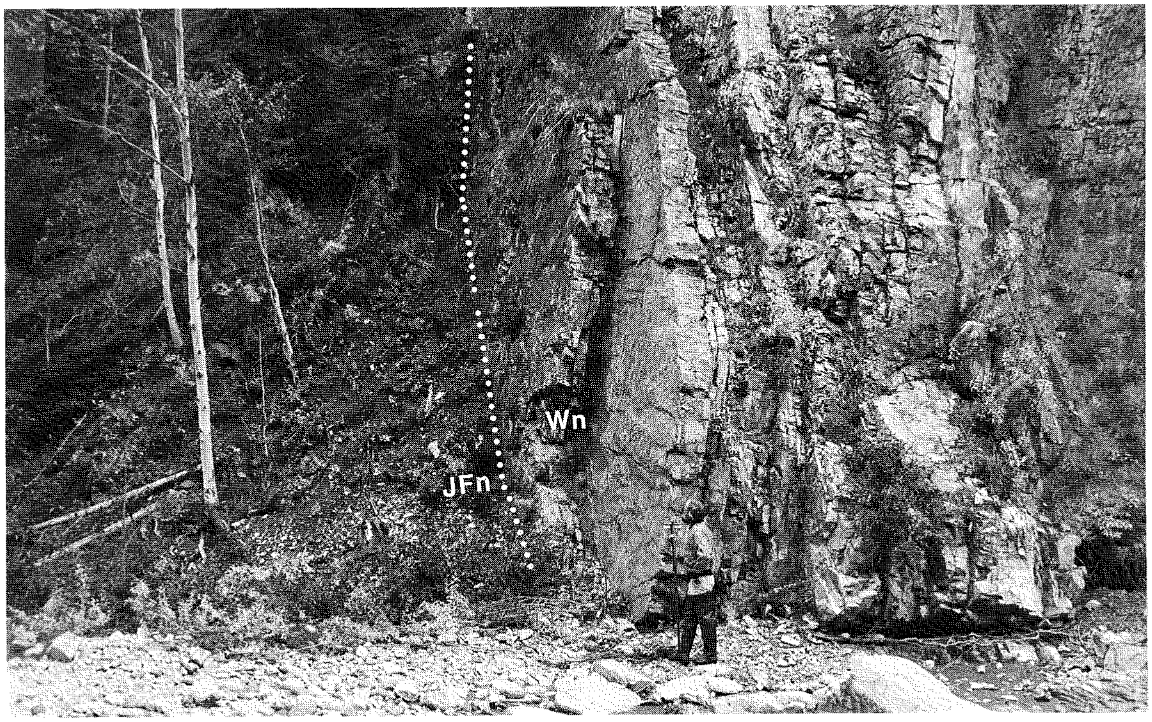

Fig. 37. Contact between cliff-forming dolostones of the Winnifred Member and recessive dark grey siltstones and shales of the Jurassic Fernie Formation (Red Deer Member) at Stop 4, Fiddle River Storage Depot. Wn= Winnifred Member; JFn= Jurassic Fernie Formation.

JURASSIC

The **contact with the Jurassic Fernie Formation** is abrupt (Fig. 37). The Fiddle River Jurassic section (Fig. 38) lies north and west of the limits of the Nordegg carbonate-chert platform, and the lowest Jurassic strata at this locality probably represent the Red Deer Member. The Poker Chip Shale and Rock Creek members are well developed. Middle Jurassic shales and Upper Jurassic Green beds may be present, but are not confidently identified. The typical Upper Jurassic gradational sequence from the Upper Fernie Shale through Passage beds to Nikanassin Formation is well developed (Figs. 4, 38). The Passage beds are contorted and may be thin for tectonic reasons.

The **upper surface of the Triassic** rocks is irregular on a small scale, with a relief of about 10 cm (Fig. 39). The Triassic surface contains abundant 1 cm-diameter vertical borings filled by sand from the overlying Jurassic unit. The Jurassic contains a 2.5 cm-thick, pebble-bearing black phosphatic sandstone irregularly distributed in shallow hollows at its base. The large clasts are angular to subrounded, and are similar to underlying Triassic lithologies, lying in a mainly quartzose matrix.

The succeeding 3.3 m thick unit comprises soft and recessive, dark grey-black fissile shale to platy siltstone, with some harder concretionary layers and calcareous concretions. Very small fragments of fish bones or scales and pectinacean bivalves occur rarely. Platy grey-black limestone, 4.6 m thick, overlies the shale. It contains very fine shell and fish fragments as well, and beds with abundant small oysters (*Ostrea ammonitides* Crickmay), various pectinacean bivalves, rhynchonellid brachiopods and rare ammonites, on some of which oysters have nucleated. The ammonites are poorly preserved but indicate a Late Pliensbachian age. The faunas and lithologies indicate assignment to the **Red Deer Member**, which has yielded other ammonites indicating equivalents of the same zone in its type area (Hall, 1987).

Most of the 27 m thick, poorly exposed, soft, recessive strata above the platy limestone comprise black, fissile, carbonaceous shale in intermittent outcrops, with minor concretionary layers, fish scales(?), marcasite and phosphate nodules, and true belemnites. The apparently abrupt base of this poorly exposed interval may be the base of the **Poker Chip Shale Member**. The Poker Chip exposed along Fiddle River contains the Early Toarcian ammonite *Dactylioceras* in its basal 20 cm, together with *Entolium* and fish fragments.

The **Rock Creek Member** at Fiddle River comprises three resistant sandstone units and associated siltstones and shales. The major sandstone units designated **RC1**, **RC2** and **RC3** are similar to those that will be seen in the Cadomin/McLeod River Section (Stop 6). The following description merges data from both banks of the river. Small scale faulting of the section is indicated by the distribution of sandstone bluffs on the southwest side of the river, but no major disruption of the sequence is suspected.

The upper 11 m of the poorly exposed interval that includes the Poker Chip Shale (Fig. 38), comprises a grey black, pyritic, rusty-weathering shale with light-grey-weathering siliceous concretions. Harder mudstone layers and siltstone laminae increase upward in number and thickness, and the latter become wavy. At least 2 thin intraformational siltstone-pebble rip-up layers occur. This is probably the lowest unit of the sequence that contains the heterogeneous Rock Creek Member. The shales of this recessive interval grade up to thin bedded, strongly bioturbated siltstone, and eventually fine grained sandstone with relict very fine lamination in the upper 1.8 m.

The lowest resistant Rock Creek unit (**RC1**; Fig. 40), 5 m thick, comprises strongly bioturbated sandstone beds 5 to 60 cm thick, with relict fine lamination, especially in the lower parts of each bed. The lamination is primarily planar, but small scale hummocks(?) occur; rippled beds occur in the upper part of the unit, and the upper surface is irregular and rusty and contains irregular phosphatic nodules, the result of a depositional hiatus and hard-ground development accompanying the succeeding relative transgression. The sandstone is very fine grained, carbonaceous and pyritic, dark grey and hard, with abundant small shale and siltstone clasts.

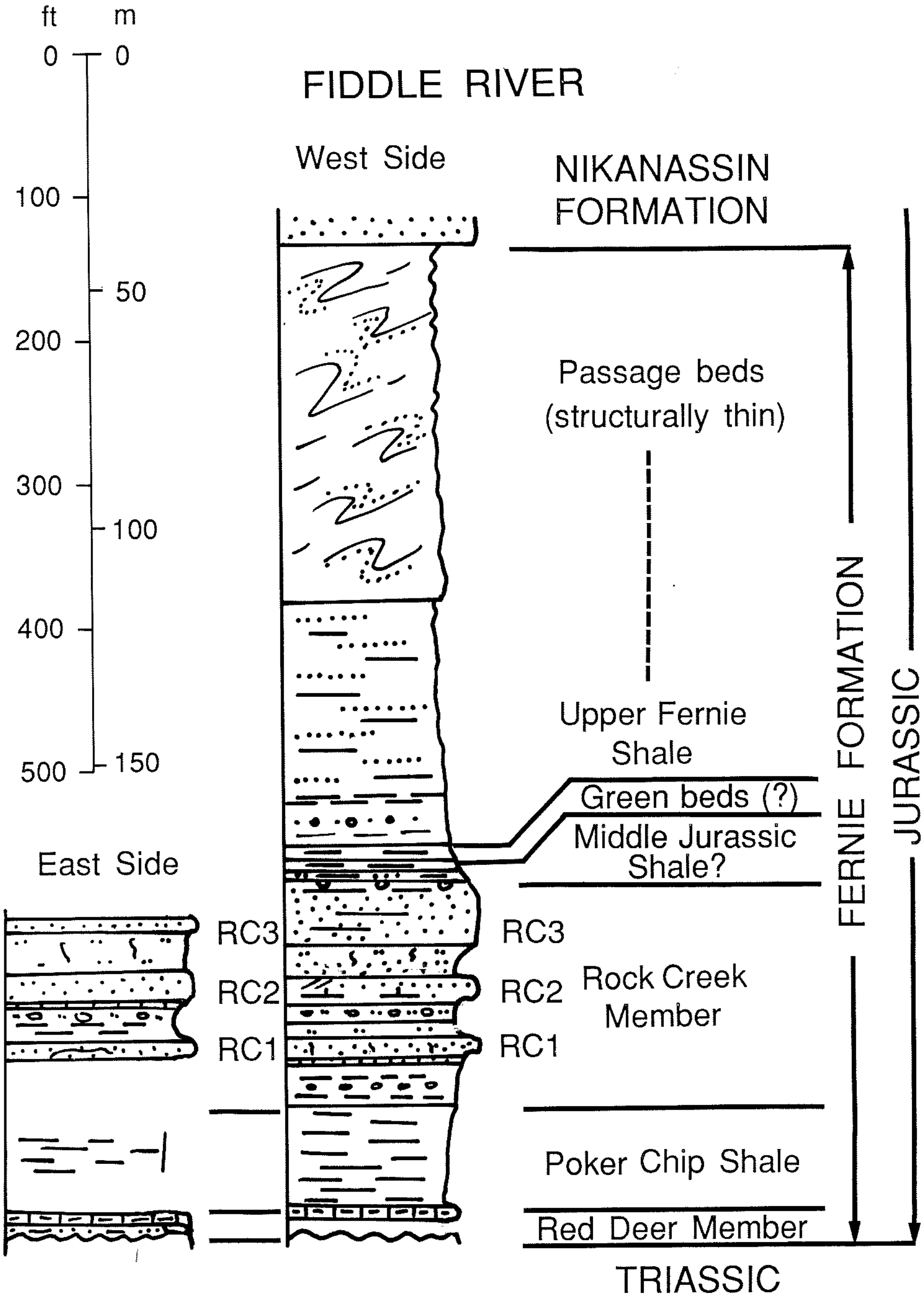

Fig. 38. Jurassic section at Fiddle River east of Jasper.

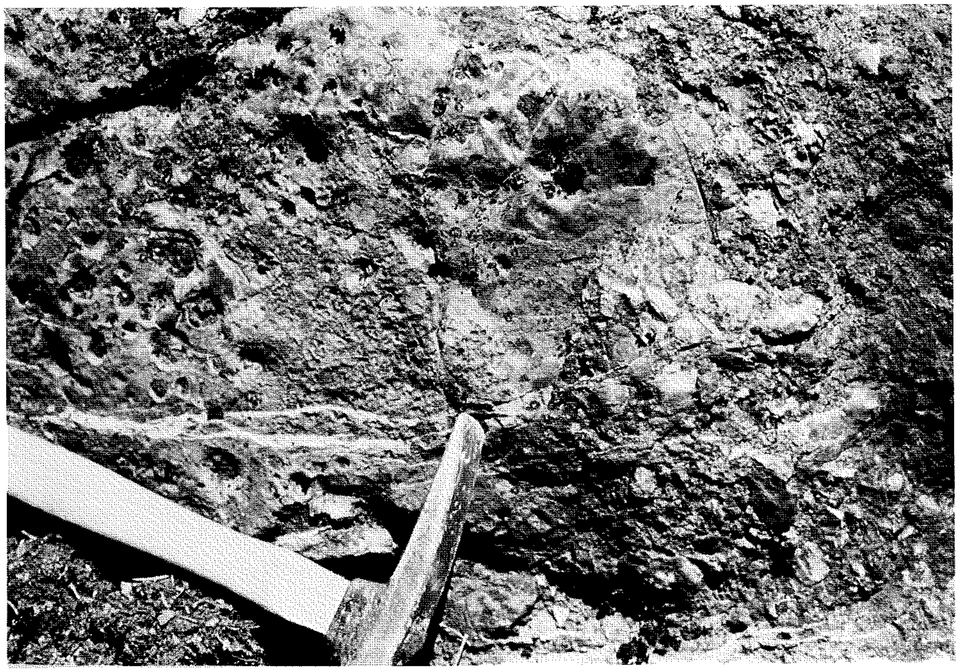

Fig. 39. The top surface of the Triassic at Fiddle River below the storage depot. The top of the Triassic has been bored and the vertical burrows filled with sandstone from overlying Jurassic unit. The very thin basal Jurassic grit-bearing sandstone is seen at bottom right.

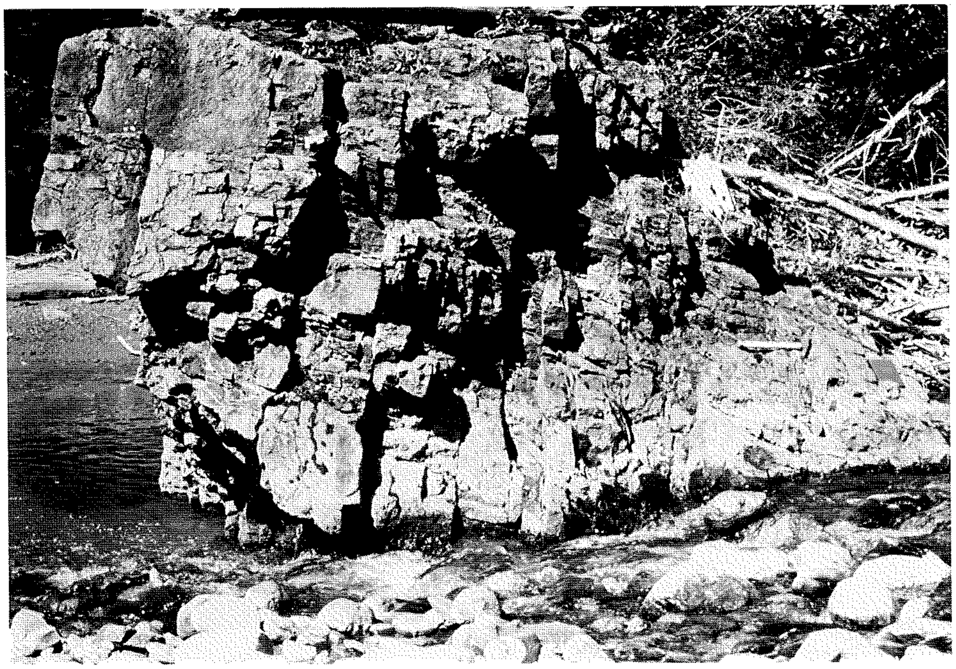

Fig. 40. The lowest Rock Creek sandstone exposed at Fiddle River east of Jasper, top to left.

At least part of the poorly exposed 9.3 m thick interval (Fig. 41) above the lowest Rock Creek sandstone (RC1) comprises soft, fissile, dark grey shale with thin, brown-weathering siltstone laminae and with sideritic concretion layers. The siltstone layers appear to become more abundant upward, and become wavy and discontinuous, reaching 2.5 cm thick. About 1.9 m below the top of the poorly exposed interval, at least one thin, flat-pebble intraformational conglomerate layer occurs, with pebbles of siltstone and sideritic concretionary material.

The second Rock Creek sandstone unit (RC2; Fig. 42), about 7.6 m thick, is very rusty weathering in its lower 30 to 45 cm, with a thin layer of siltstone and limestone pebbles, and bivalve shell hash layers. The overlying 1 - 2.5 metres comprises cross-bedded and hummocky bioclastic limestone, the latter composed of finely comminuted shell material. This grades through a 30 cm thick hummocky quartzose sandstone interval with lesser amounts of shells, small but not badly broken. The overlying, main facies of the second Rock Creek unit is well indurated, quartzose sandstone, in beds as thick as 1 m, some of which are low-angle cross stratified. Very large, low angle cross stratification can be seen high on the hillside on the southwest side of the river.

The recessive interval above RC2 consists of about 10 m of siltstone and fine grained sandstone, strongly bioturbated and rubbly-weathering, with sideritic concretions. The upper part is particularly rusty weathering.

The third Rock Creek sandstone unit (RC3) (Fig. 43), 16.8 m thick, consists of planar beds as thick as 1.5 m, probably richly but inconspicuously bioturbated, separated by thin shaly units. Some of the beds are pyritic and rusty weathering at their tops, suggesting periodic hiatuses in sedimentation, and some contain small phosphatic pebbles. The sandstone is very fine grained, quartzose, dark grey to black, carbonaceous, and locally rich in siderite and limonite. The upper 0.6 m is rusty weathering, containing two prominent bored hardgrounds, and irregular small and large, bored phosphatic nodules and patches (Fig. 44), as well as belemnites, non-calcareous "oncoids", wood impressions and casts, encrusting corals, and poorly preserved Early Bajocian ammonites (*Stemmatoceras)* and bivalves; clearly a community developed during a depositional hiatus.

The 2.9 m thick recessive interval above RC3 contains mainly soft, grey to black shale and siltstone, with belemnites, rusty weathering siltstone laminae and jarositic layers. In the lower part of the recessive internal are thin layers of siltstone and fine grained sandstone with phosphatic nodules; and a layer rich in belemnite fragments. One prominent layer, 45 cm thick and 1.5 m above the base of the unit, contains abundant *Gryphaea* as well as belemnites, and reworked phosphate pebbles, partly incorporated into carbonate concretions (Fig. 45). This graded bed with broken fossil fragments is perhaps a storm deposit. Certain characteristics of this probable **Middle Jurassic shale** unit would suggest correlation with the Highwood Member of southwestern Alberta (Fig. 4).

Soft, recessive greenish-grey shale, 3 m thick, with small reworked phosphate pebbles at its base, may represent the **Green beds** that are widespread regionally, if erratically distributed, at the base of the Upper Jurassic foredeep succession (Fig 4).

Approximately 69 m of shale represents the regionally widespread **Upper Fernie Shale** unit (Fig. 4, 46). It is mainly soft and fissile, dark grey to black, with irregular layers of sideritic concretions, and with laminae and thin beds of finely laminated and cross-laminated siltstone and fine grained sandstone. The lower 10 m of this shale yielded 15 species of arenaceous and calcareous Foraminifera which J.H. Wall (pers. com.) has interpreted as indicating an Oxfordian-Kimmeridgian age and moderate (middle or outer shelf) depositional depths. *Chondrites* is the most prominent of several trace fossils.

About 100 to 110 m of siltstone and shale with brown weathering, thin sandstone beds are characteristic of the **Passage beds** (Fig. 47). The apparent thickness of the unit is a result of the folding that characterizes this tectonically incompetent unit in many outcrops. The Passage beds are overlain high on the river bank downstream by a prominent sandstone, possible at the base of the **Nikanassin Formation.**

Fig. 41. The lowest (RC1; left) and middle (RC2; right) resistant sandstones of the Rock Creek Member, with interbedded recessive softer siliciclastics, Fiddle River east of Jasper, top to right.

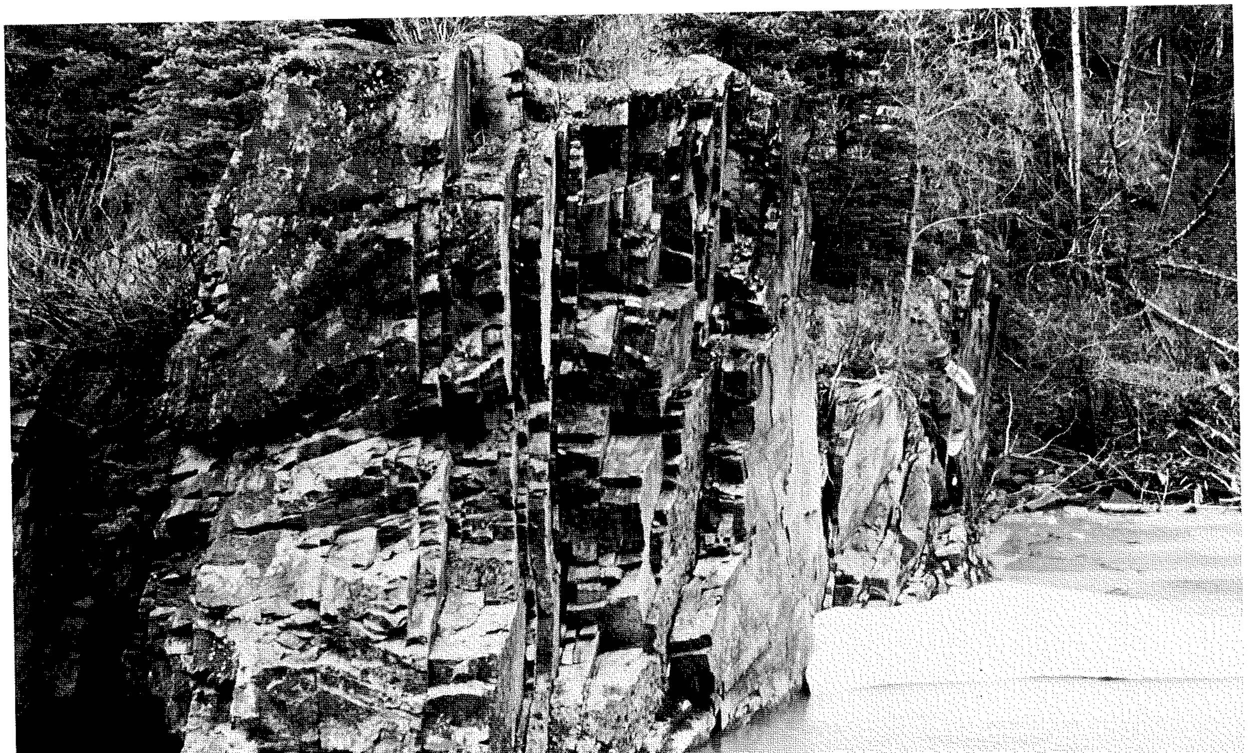

Fig. 42. The middle resistant sandstone of the Rock Creek Member (RC2) exposed at Fiddle River east of Jasper, top to left. The lower beds (right of outcrop) are crossbedded or hummocky coquinas.

Fig. 43. Highest Rock Creek sandstone unit (RC3) exposed at Fiddle River east of Jasper, top to right.

Fig. 44. Bored phosphatic nodule, top of highest Rock Creek sandstone (RC3), Fiddle River.

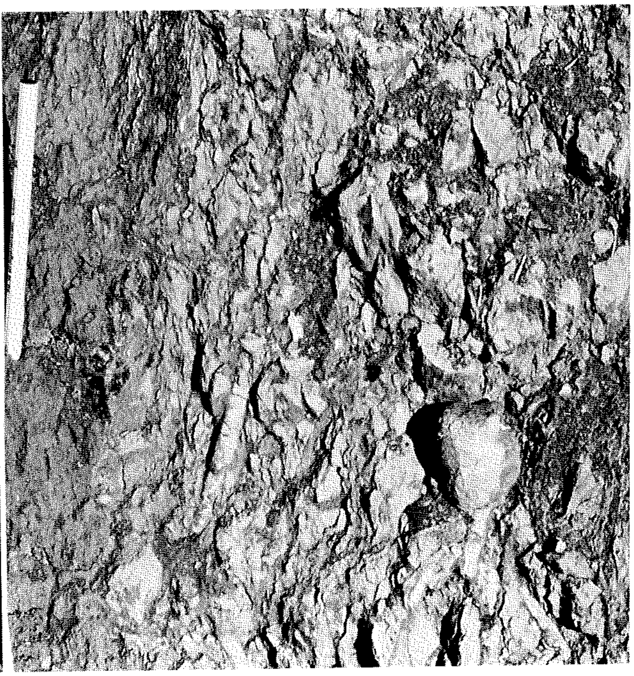

Fig. 45. Middle or Upper Jurassic siltstone bed rich in belemnites and *Gryphaea*, Fiddle River.

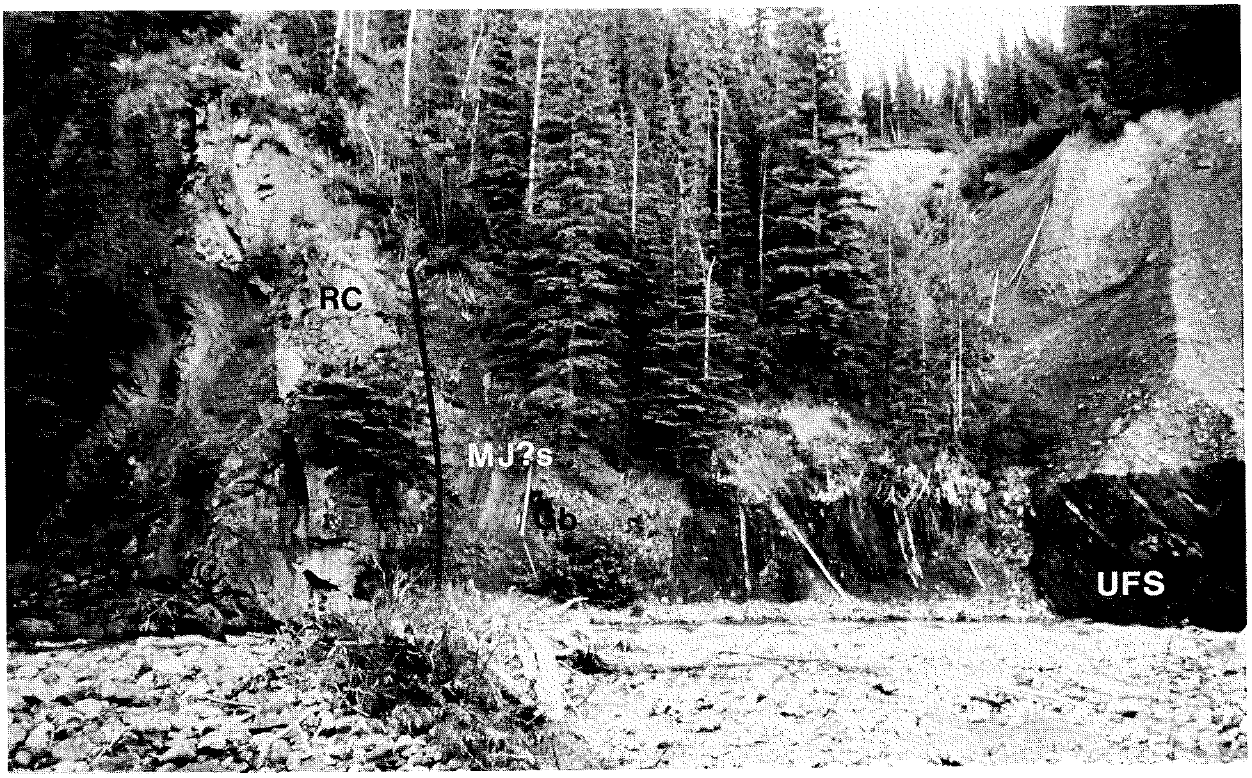

Fig. 46. Highest Rock Creek sandstone (RC) (left), overlain by Middle or Upper Jurassic shales and siltstones (MJ?s, Gb; centre), and Upper Jurassic Upper Fernie shales (UFS; right), Fiddle River east of Jasper.

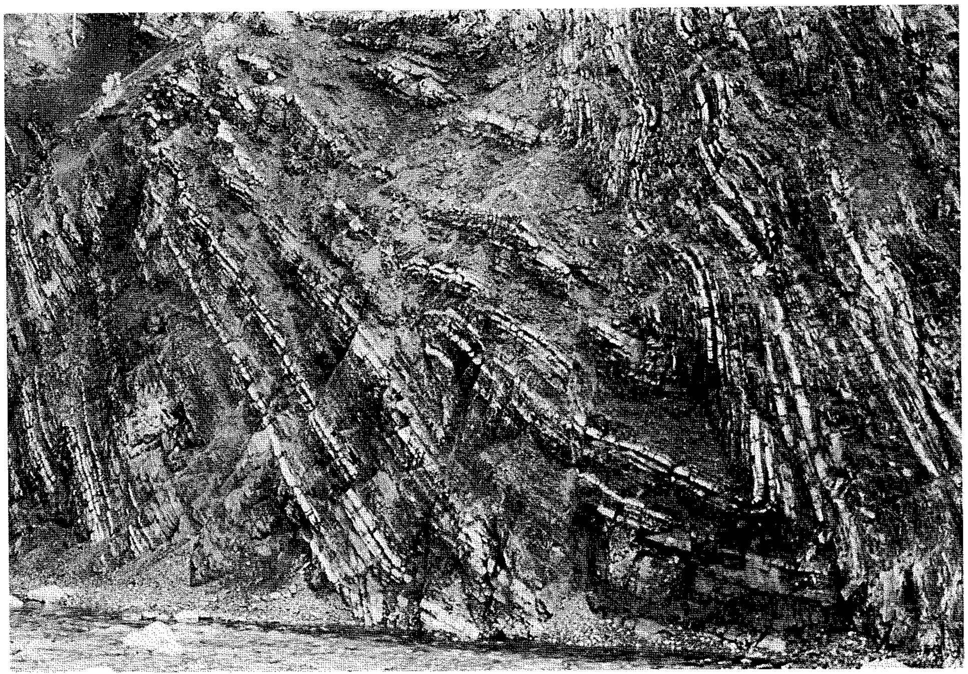

Fig. 47. Tectonically contorted siltstones and thin sandstones of the Passage Beds, Fiddle River.

FIELD STOP NUMBER 5

Jasper Highway

This Triassic exposure is located beside Athabasca River and Highway 16, 1.2 km northeast of the Cold Sulphur Spring tourist stop (Fig. 1). The Jasper Highway locality palinspastically represents the westernmost Triassic exposure in the Cadomin and Jasper area. **Figure 48** is a detailed lithologic column of the section, illustrating the lithofacies of the Phroso Siltstone and lower Vega Siltstone members.The precise contact with the underlying chert of the Permian Ranger Canyon Formation is covered. Caution is advised in crossing and walking beside the busy Yellowhead Highway.

The traverse starts at the Permian contact. Note the fine, parallel to wavy laminated character of the Phroso strata and general absence of distinct non laminated tempestite/turbidite siltstone interbeds (Fig. 49). Note the gradational nature of the contact between the Phroso and Vega facies at this locality (Fig. 50). Strata of the Vega Siltstone Member at the south end of the exposure are conspicuously thinner bedded than those seen at the other field stop localities. A complete section of the Sulphur Mountain Formation including the Whistler Member is exposed 6.1 km along strike, in an intermittent tributary on the southeast side of Jacques Creek (Gibson, 1968b).

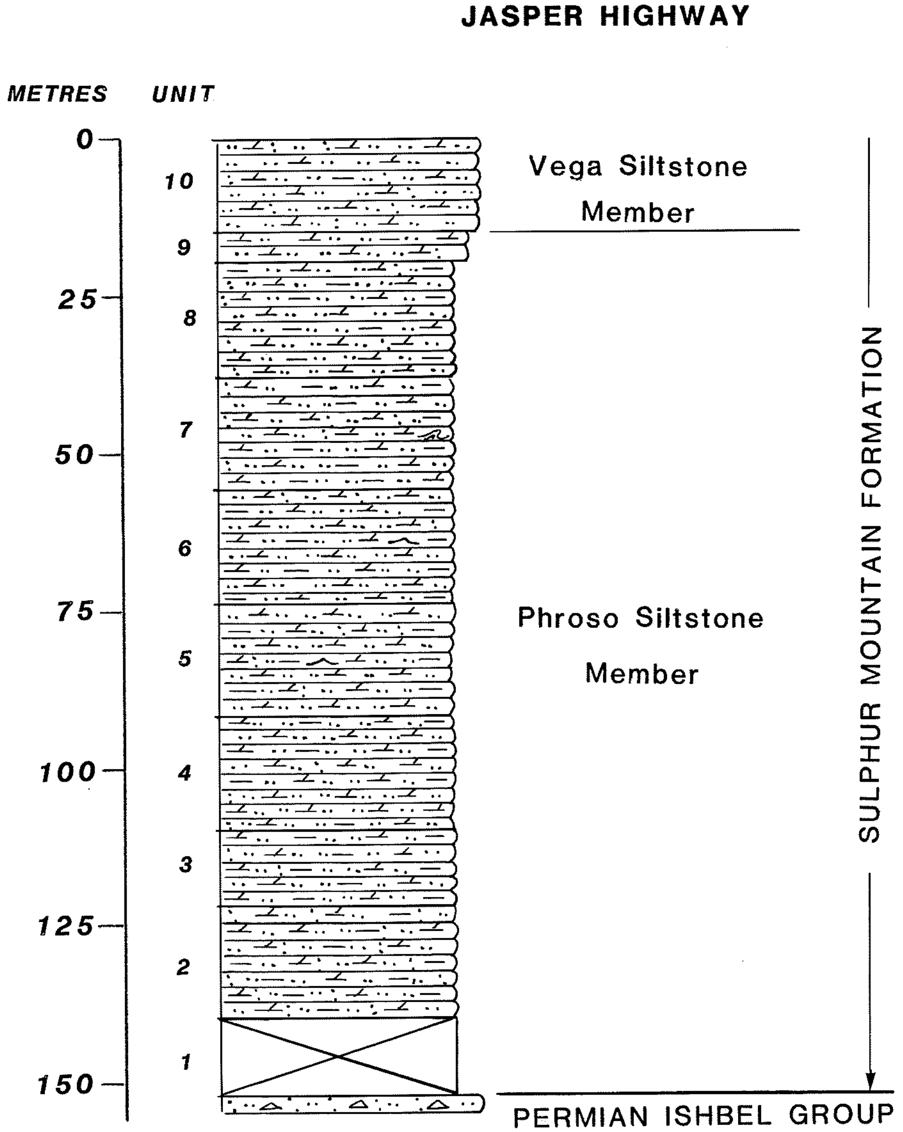

Fig. 48. Detailed columnar section of Triassic exposures at Stop 5, Jasper Highway (For legend see Fig. 3).

Fig. 49. Finely laminated shaly siltstones of Phroso Siltstone Member at Stop 5, Jasper Highway.

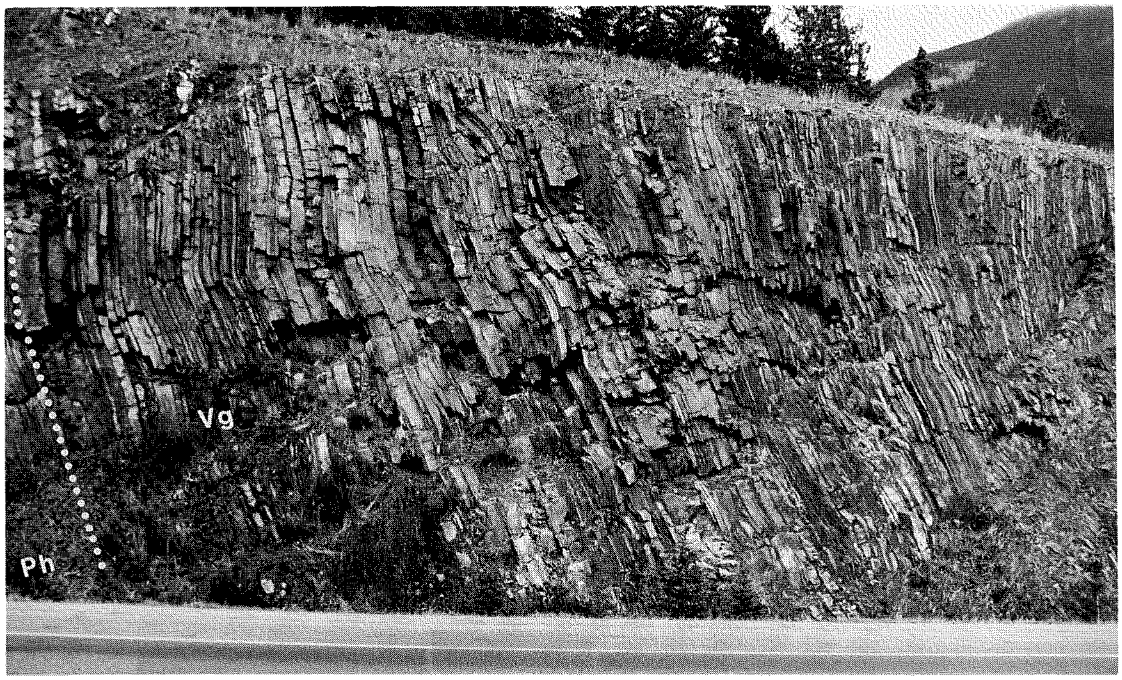

Fig. 50. Contact between Phroso Siltstone and Vega Siltstone members at Stop 5, Jasper Highway. Note the relatively thin bedded character of the lower Vega Siltstone member. Ph= Phroso Siltstone Member; Vg= Vega Siltstone Member.

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FIELD STOP NUMBER 6

Cadomin Rail / McLeod River

Access to this section locality requires driving 5 km south of Cadomin to Whitehorse Creek, crossing the bridge and proceeding 1.3 km along the secondary road to an unprepared campsite on the east side of the road. Proceed over the embankment via a fishing trail to the abandoned rail line and McLeod River.

Figure 51 is a plotted section of the Cadomin Rail-McLeod River Triassic section, illustrating thickness, field unit numbers and the lithology characteristic of the Sulphur Mountain and Whitehorse formations and each of their members. The section also has been included in cross section Figure 3.

The traverse begins on the east side of the river downstream from the wooden rail trestle, at the contact between the Permian Ranger Canyon Formation of the Ishbel Group and the Triassic Phroso Siltstone Member of the Sulphur Mountain Formation (Fig. 52). Note the phosphatic chert pebble conglomerate at the base of the Sulphur Mountain Formation. The Ranger Canyon Formation consisting of sandstone and chert, is thin at this locality, and has been eroded to the northeast, east and southeast, such that at Mackenzie Creek Gap and most exploration wells illustrated in Figure 3, the Phroso Siltstone Member and Sulphur Mountain Formation disconformably rest on dolostones of the Carboniferous Rundle Group (Mount Head Formation). Note the resistant weathering, medium to thick bedded, very dolomitic siltstone of **Unit 2**. Similar resistant weathering siltstones were seen at Stops 3 and 4 on Fiddle River. These resistant beds represent probable tempestites or turbidites deposited farther offshore during the initial Triassic marine transgression. Similar beds do not occur at Stop 5 on Jasper Highway. The Jasper Highway section is palinspastically much farther west, and accordingly, would be located farther offshore from the exposures at the Cadomin Rail/McLeod River and Fiddle River localities. Note the dense, fine to coarse, wavy and ripple laminated siltstone, sandstone and shale facies of the Phroso Siltstone Member adjacent to and below the trestle. These strata represent relatively deep water shelf facies, with deposition at times close to storm wave base. Note the general absence of conspicuous resistant weathering siltstone interbeds, a feature common in the overlying Vega Siltstone Member. The lower strata of the Phroso Member at this locality are unusually sandy and dolomitic, in comparison to Phroso facies of more western localities in the area (compare with Stop 2C).

Proceed up the small stream tributary beside the trestle, to the resistant siltstone and dolostone facies at the base of the Vega Siltstone Member. Note the soft sediment deformation at the base of the exposure (Unit 6, Fig. 51). The lower contact of the **Mackenzie Dolomite Lentil** is placed at the base of the lighter weathering silty dolostone unit at the top of Unit 6. The overlying covered interval is assumed to be underlain by dolostone facies of the Mackenzie Dolomite Lentil. **Unit 8** consists of the very vuggy and porous, calcareous dolostone typical of the light weathering lentil (Fig. 53). Elongate bivalve? shell fragments may be seen in some samples. The porous facies appears to have been recrystallized or has been subjected to moldic solution and reprecipitation, in part by calcite. As illustrated in cross section Figure 3, this distinctive dolostone facies can be seen in most exploration wells east of the Cadomin Rail/McLeod River locality. The origin of the dolomite facies is uncertain. The dolostones appear to occur within a relatively deep water shelf or lower shoreface siltstone succession. The carbonates may have been transported by storm generated currents into the offshore environment. Alternatively, the Mackenzie Dolomite may represent the capping facies of a near shore, relatively shallow water, upward coarsening sequence of siltstones and carbonates, deposited during a regional lowering of sea level. The latter interpretation is at present favoured. As noted previously, the gamma ray profile in the wells of Figure 3, suggest a shallowing and coarsening upward sequence of strata or progressive vertical increase in carbonate content. Note the finely laminated dark grey, carbonaceous siltstone and shale of **Unit 9**, overlying the Mackenzie dolostone (Fig. 53). If one assumes the Mackenzie Dolomite to be partof a shallower water, shoreface succession, the siltstone/shale facies of Unit 9, may represent a

CADOMIN RAIL/MCLEOD RIVER

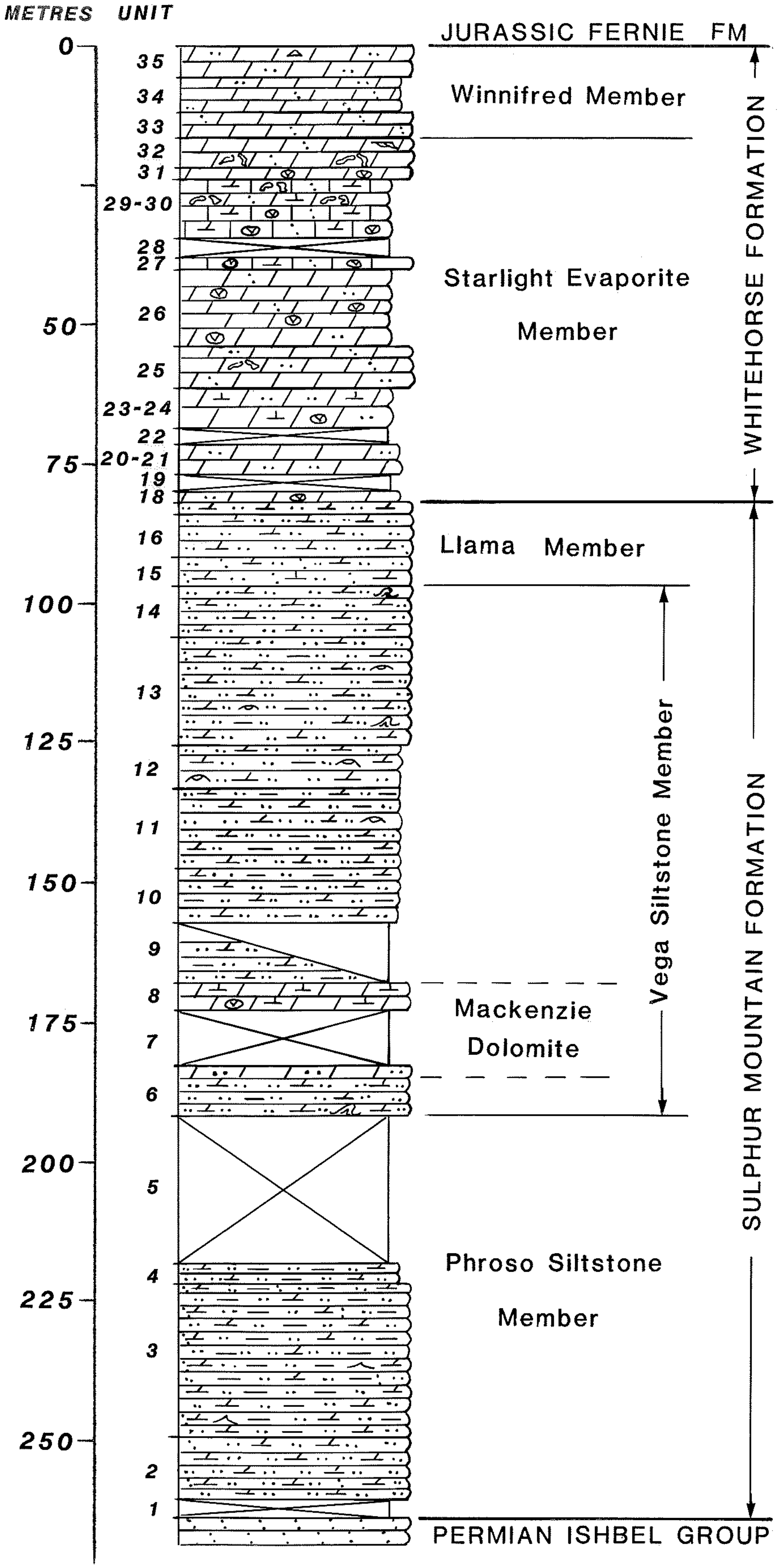

Fig. 51. Detailed columnar section of Triassic exposures at Cadomin Rail/McLeod River locality. (For legend see Fig. 3).

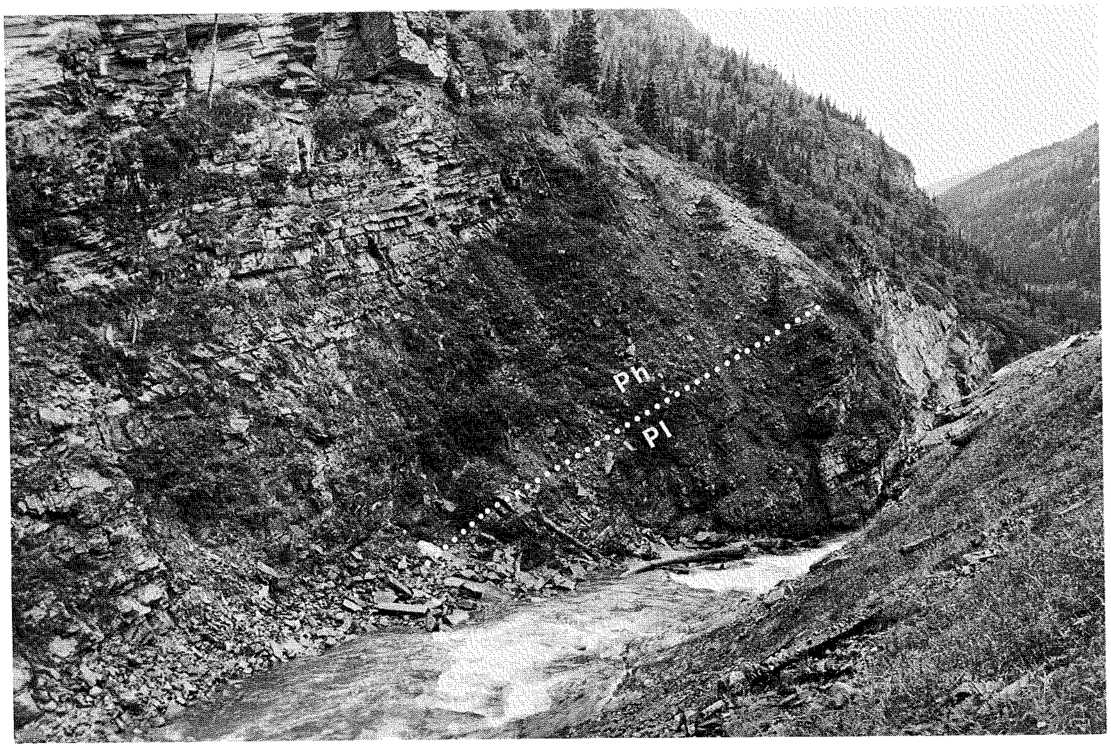

Fig. 52. Contact between Sulphur Mountain Formation (Phroso Siltstone Member) and Permian Ishbel Group (Ranger Canyon Formation) at Stop 6, Cadomin Rail/McLeod River. The thin Permian sandstone and chert facies are underlain by dolostones of the Carboniferous Mount Head Formation of the Rundle Group. Pl= Permian Ishbel Group; Ph= Triassic Phroso Siltstone Member.

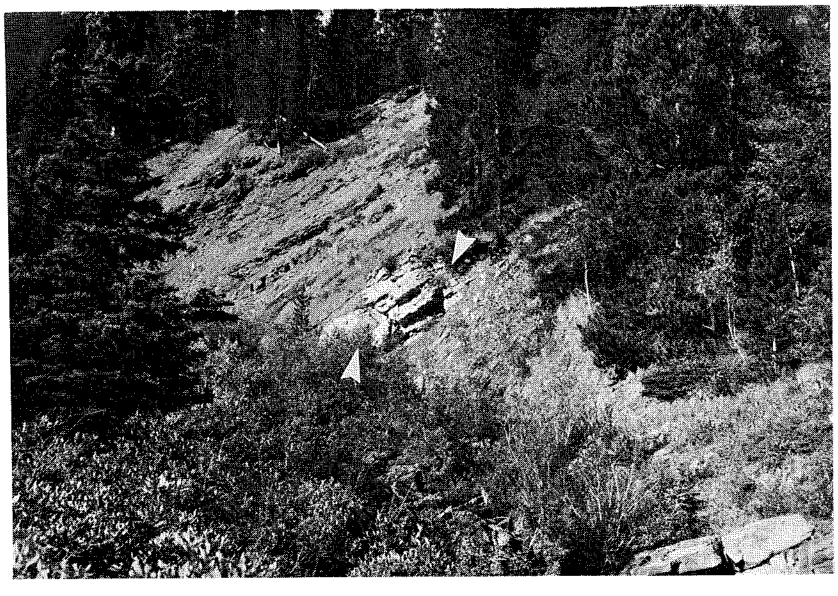

Fig. 53. Small creek tributary of McLeod River near rail trestle, illustrating light weathering strata of the Mackenzie Dolomite Lentil (arrows), and recessive siltstones and shales of the Vega Siltstone Member at Stop 6, Cadomin Rail/McLeod River.

transgression and the base of a probable parasequence boundary. A similar and possibly equivalent transgressive event was seen at Stop 3 on Fiddle River above the flat pebble conglomerate facies of Unit 3. However, the Mackenzie Dolomite does not occur at the Fiddle River locality. Excellent exposures of the Vega Siltstone Member occur above the dolomite up the creek (Fig. 53). Return to the rail line and proceed up river a short distance to the cliff-forming, resistant-recessive weathering exposure of the Vega Siltstone Member (Figs. 54, 55). Note the well developed hummocks and swales in some of the more resistant beds, particularly in the cliff-forming facies of Unit 13 (Fig. 55). The Vega Siltstone Member represents the progradational phase of a transgressive-regressive cycle and part of a coarsening and shallowing upward succession. The upper Vega Member represents deposition in a probable shoreface environment, with sediments deposited mainly between fair weather and storm wave base. The contact with the overlying shallower water Llama Member is placed between **Units 14 and 15** (Fig. 51), near the south end of the small alcove beside an old burned rail section cabin. The contact with the Starlight Evaporite Member and Whitehorse Formation occurs just south of the alcove and old burned cabin. The contact is abrupt, and may represent a disconformity. A similar abrupt contact was seen at Stop 4 on Fiddle River.

Proceed southward several hundred metres along the rail line and McLeod River to another wooden rail trestle. Here, we will briefly examine strata of the upper Starlight Evaporite and Winnifred members, and the contact and overlying exposures of the Jurassic Fernie Formation (Figs. 56, 57). From the trestle, "red bed" facies in the lower Starlight Evaporite Member can be seen on the south side of the river. Proceed across the trestle and along the east side of the river to the base of the cliff-forming dolostones of the Winnifred Member and contact with the Starlight Member (Fig. 56). Note the well developed solution or collapse breccia in **Unit 32** at the base of the cliff. These breccias are included in the Starlight Member. The angular dolostone clasts in part display fine, crenulated cryptalgal lamination. The clasts and associated strata are facies of a tidal flat or shallow lagoonal environment. The Winnifred Member at this and other localities in the area consists mainly of dolostones with varying concentrations of quartz silt and sand.

JURASSIC

An exposure of the overlying Jurassic **Nordegg Member** can be seen beside McLeod River just up stream from the rail trestle. However, a better exposure of the Nordegg Member will be examined on the east side of the river and rail line, southeast of the trestle.

The Nordegg Member is well developed at the McLeod River section (Figs. 57, 58), in a facies more rich in chert than is usual. The Nordegg Member is overlain by platy black limestones that probably represent the Red Deer Member. The Poker Chip Shale is not exposed. The Rock Creek Member and Passage beds of the Fernie Formation, and lower Nikanassin Formation are well exposed.

The lower beds of the Jurassic Fernie Formation are exposed in the ditch along the rail line immediately south of the trestle over McLeod River. The **base of the Jurassic** at McLeod River is marked by a grey granule layer about 10 cm thick, on top of the Triassic dolomite. There is a recessive and unexposed interval some 3 m thick above this, then about 6 m of platy and hummocky, dark grey, fetid, calcareous, fine grained sandstone at the base (Fig. 59) passing upward into sandy limestone with black chert nodules and layers, and to thin-bedded black chert. Small-scale hummocks(?) occur in this interval.

About 15 m of yellow-weathering, chert comprises most of the **Nordegg Member** at McLeod River. The chert is well exposed in bluffs east of the rail line. A short walk through the trees is necessary. The blocks below the bluffs afford the opportunity to examine in detail a number of sedimentary structures from throughout the Nordegg interval.

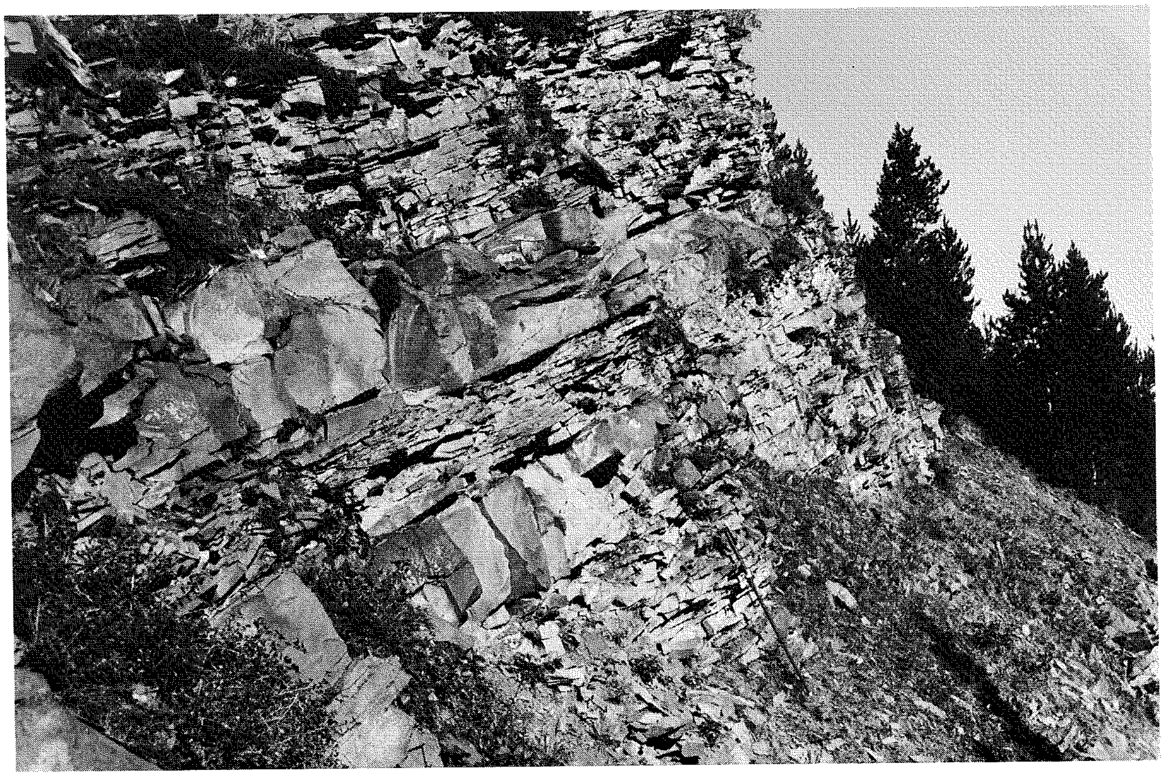

Fig. 54. Resistant-recessive weathering strata of the Vega Siltstone Member at Stop 6, Cadomin Rail/McLeod River.

Fig. 55. Hummocky cross stratification in siltstones of Vega Siltstone Member. Same locality as Figure 54.

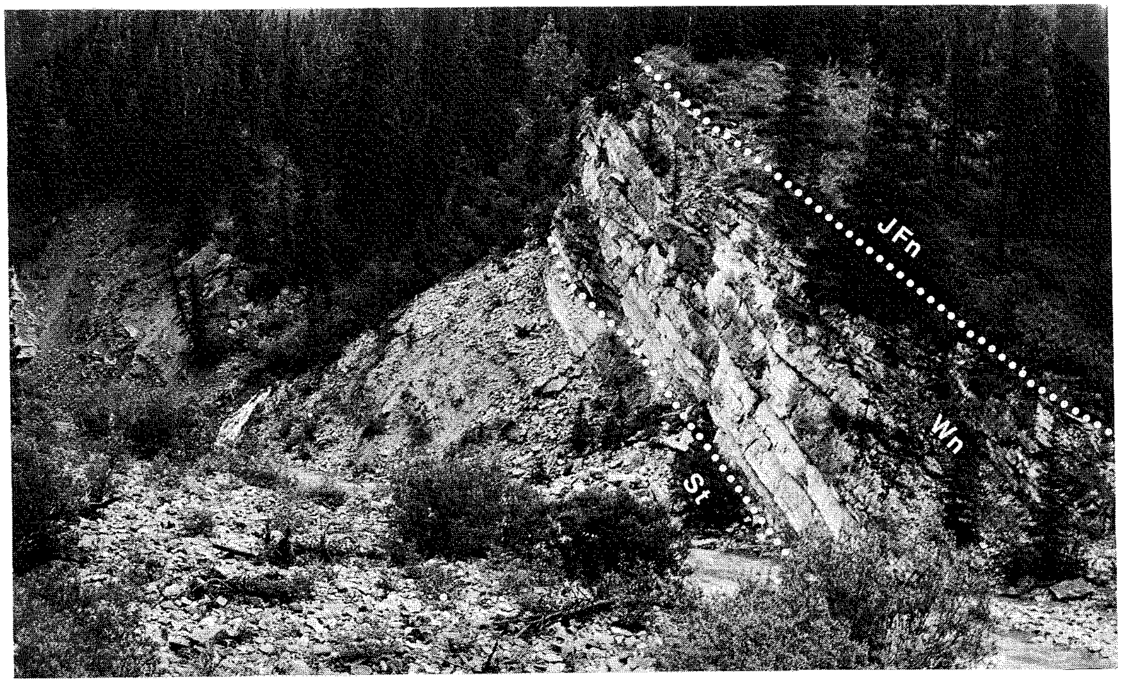

Fig. 56. Lithology and contact relationships between Starlight Evaporite and Winnifred members of Whitehorse Formation and Jurassic Fernie Formation at Stop 6, Cadomin Rail/McLeod River; St= Starlight Evaporite Member; Wn= Winnifred Member; JFn= Jurassic Fernie Formation.

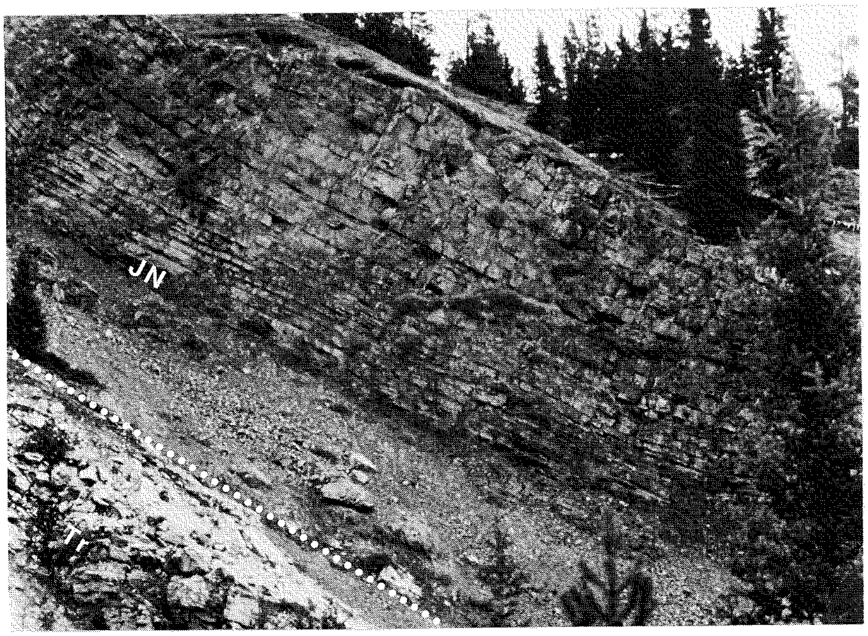

Fig. 57. Nordegg bedded cherts (above) overlying Triassic strata (below), Mcleod River; JN= Jurassic Nordegg Member; Tr= Triassic Winnifred Member

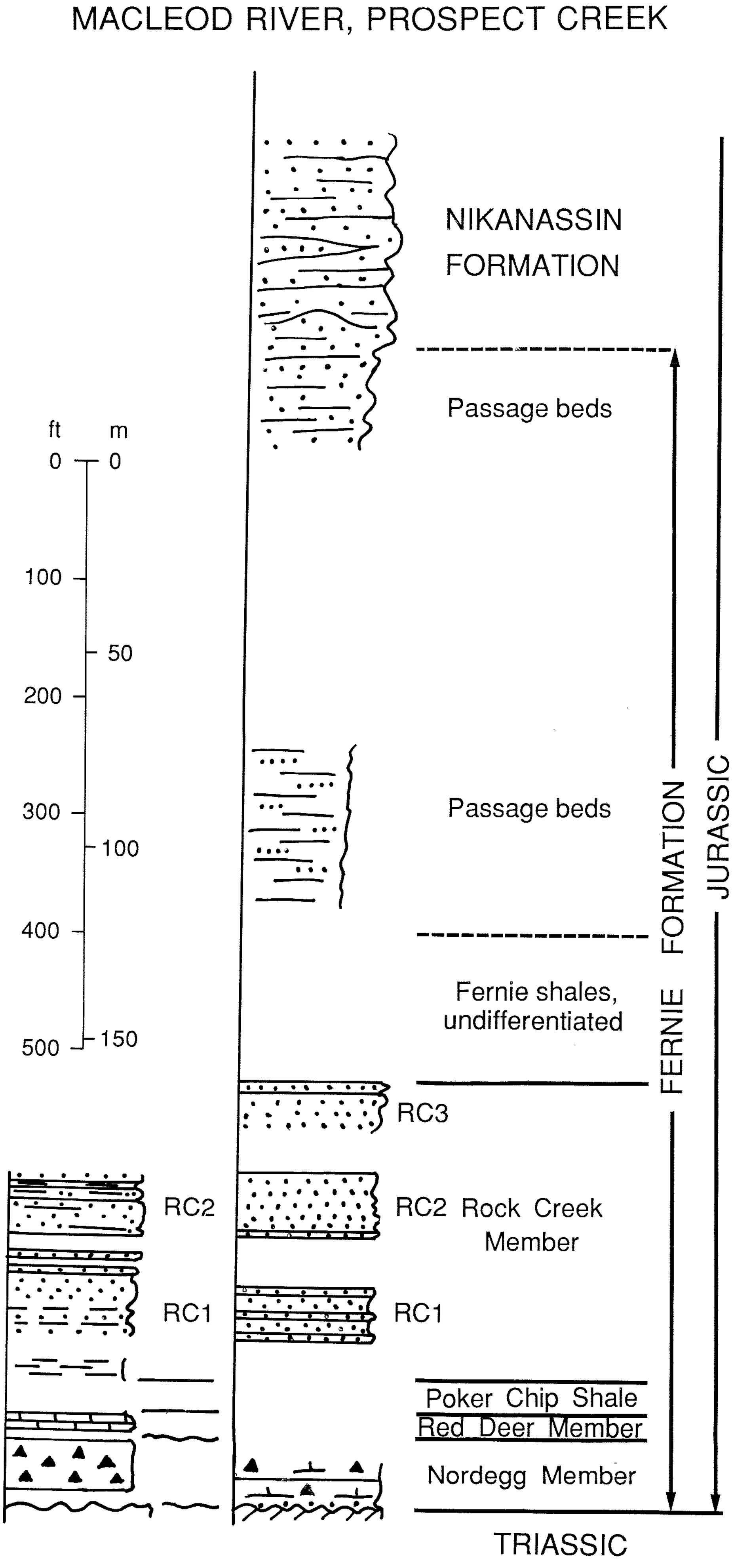

Fig. 58. The Jurassic section at McLeod River and Prospect Creek south of Nordegg, Alberta. The short section on the left is exposed along the river and in the trees, the longer section along the rail line, the road between Cadomin and Mountain Park, and along Prospect Creek.

The chert beds vary from 15 cm thick at the base of the resistant unit, to 1.2 m thick at the top. The chert is medium to dark grey, brittle and strongly fractured. Most is massive and structureless, but some is very finely laminated, and some of the laminae are disrupted (Fig. 60). There are thin, wavy and irregular layers of rusty, quartzose siltstone and fine grained sandstone interbedded within the chert. Some beds have minor irregularly distributed and irregularly shaped, thin limestone patches (Fig. 61). Rusty stylolites suggest that the thin limestone layers were more widespread originally, and have been removed by dissolution.

The cherts that comprise the Nordegg at this locality are shown in thin section in Figures 62, 63, and 64.

Platy, black, carbonaceous, slightly phosphatic limestone is poorly exposed beside the washed-out railway line opposite the Nordegg bluffs. The limestone occupies about a 4.5 m-thick interval that lies a small distance above the top of the Nordegg. It contains abundant small fish(?) fragments, cephalopod arm hooks and aptychi, belemnites, pectinacean bivalves and small *Ostrea,* as well as ammonites that suggest an earliest Toarcian age and are similar to those found in the Poker Chip Shale. However, the lithology suggests that the outcrop represents the **Red Deer Member**, so that it may be younger here than elsewhere, transitional to the Poker Chip Shale.

About 12 m of unexposed strata are assumed to underlie the bed of the McLeod River. This recessive interval represents a typical occurrence of the **Poker Chip Shale Member**.

Three major sandstone units, with associated siltstones and shales characterize the **Rock Creek Member** at McLeod River, although poor exposure of the softer units does not permit precise stratigraphic interpretations.

Soft and recessive grey shale and mudstone, 6 m-thick, and containing sideritic nodules, is exposed in the bank of McLeod River near the washed out rail line. It probably represents the lowest part of the heterogeneous Rock Creek succession. Siltstone laminae, sideritic layers, and eventually carbonaceous, fine grained sandstone beds, reaching 0.6 m in thickness, increase upwards within this unit. The strata are strongly bioturbated, especially in the upper parts of the sandstone beds, while retaining very fine lamination in the lower parts of many beds. Small-scale 'hummocks' may also be seen in the sandstones.

Another cycle, 5.2 m thick, begins with a 2.7 m-thick unit of soft mudstone and siltstone. This is overlain (abruptly) by a resistant, hard, fine grained, partly calcareous sandstone unit (**RC1**) that forms a resistant ridge on either side of the river (Fig. 65). The beds vary from 2.5 to 30 cm thick. They are wavy and irregular on a small scale, completely bioturbated, without internal lamination. The thicker beds, more prominent in the lower part of the bluff, are apparently structureless. The thinner beds, mainly in the upper part of the outcrop (Fig. 66), are rippled, and contain argillaceous partings and minor shale and mudstone rip-up clasts.

A heterogeneous package, about 50 m thick, of sandstones, shales, mudstones and siltstones occupies the overlying, generally recessive interval, as judged by small outcrops in the river bed. The sandstones are fine grained, partly calcareous, thinly and irregularly bedded, and clustered in units 1.5 to nearly 4 m thick, separated by unexposed recessive strata as thick as 3 m. The sandstones are strongly bioturbated, with traces resembling *Planolites* and *Paleophycus*, sporadic ripples, and contain small siltstone rip-up clasts. Low angle cross-bedding occurs uncommonly. The sandstones vary from clean and light grey, hard quartzose to dark grey, carbonaceous, soft and rubbly. The degree to which relict lamination is preserved is variable, as is the pyritic and sideritic content and the rusty coloration.

Fig. 59. Lowest exposed beds of Nordegg Member limestones and sandstones at McLeod River. Note small "hummock".

Fig. 60. Thin rhythmic layering, Nordegg chert at McLeod River.

Fig. 61. Wavy and thinly laminated chert with minor relict limestone, Nordegg Member, McLeod River.

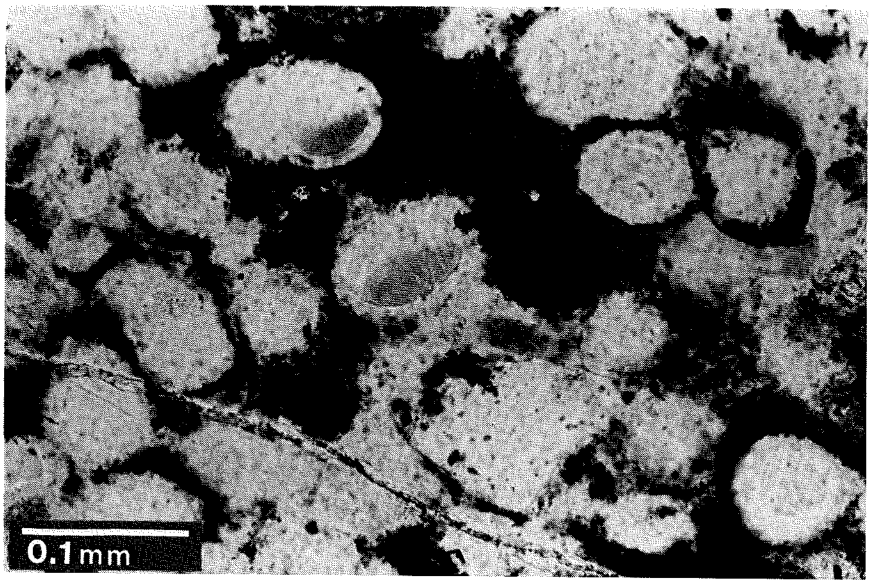

Fig. 62. Thin section, Nordegg chert at McLeod River, showing geopetal fill(?) marked by organic matter in voids within chalcedonic spherules.

Fig. 63. Thin section, Nordegg chert at McLeod River, showing wall structure and varied fill in voids within chalcedonic spherules.

Fig. 64. Thin section, Nordegg chert at McLeod River, showing chalcedonic infill banding in voids within spherules.

Fig. 65. Lowest Rock Creek sandstones (RC1) and underlying siltstones of the same coarsening-upward cycle, McLeod River.

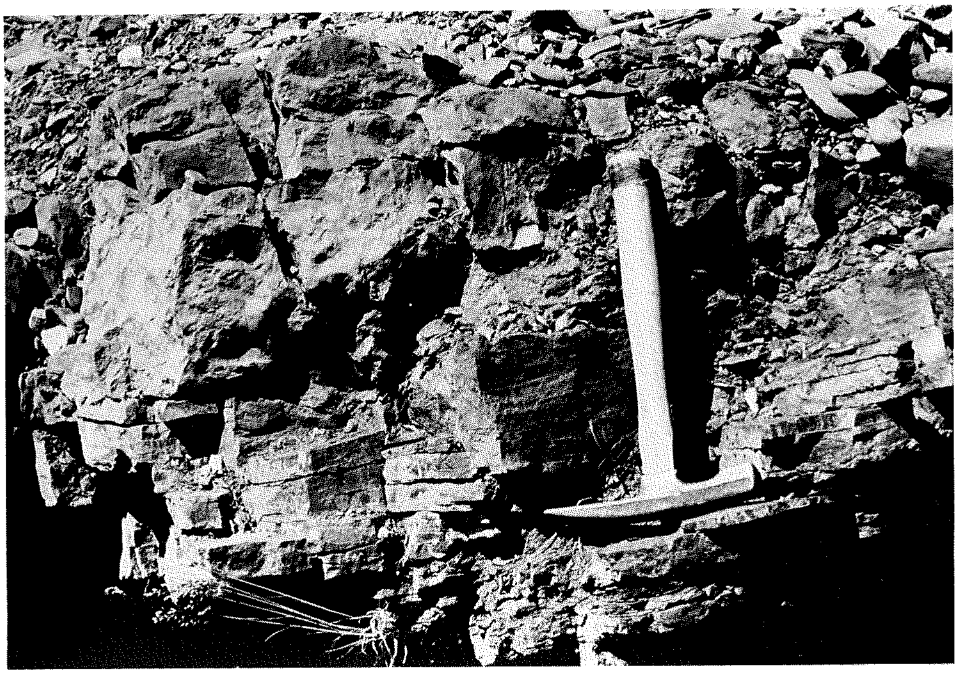

Fig. 66. Rusty weathering, burrowed and rippled sandstones with argillaceous partings and intraformational rip-up clasts at top of resistant lowest Rock Creek sandstone (RC1), McLeod River.

Small plant fragments lie on some bedding surfaces, and ironstone bands, some of which are brecciated, occur in the lower part of the recessive, poorly exposed interval in the creek bed. Also in the lower part of the recessive unit, some bedding surfaces are littered with small, broken-up oyster(?) shells and rhynchonellid brachiopods. This interval contains a variety of trace fossils, including *Ophiomorpha*(?) in the lower part, and *Rhizocorallium* and *Thalassinoides* in the upper part.

The facies in the lower part of the recessive unit, suggest lagoonal or other restricted-circulation environments, developed behind a barrier represented by the bluff-forming sandstone (RC1) below. They may be gradationally overlain by shoreface strata developed in front of a younger barrier facies (RC2), prograding in association with continued subsidence of the shelf.

A 6 m thick cliff-forming sandstone outcrops along the river near another small railway trestle (**RC2**; Fig. 67). The sandstone is fine grained, hard and blocky, light grey to light brown, calcareous, with varying amounts of limonite and pyrite (Fig. 68). The beds are without prominent internal structure, but contain some layers of limonitic siltstone and layers of pebbles reworked from the siltstone. Some of the beds pinch and swell slightly; one exhibits very large scale, very low angle lensing, perhaps deposited in shoreface or beach environments, or as low amplitude sand waves on a shallow shelf.

The interval above RC2 is estimated to contain from 12 to 15 m of unexposed recessive strata.

The third Rock Creek sandstone unit (**RC3**) forms a bluff along the old rail line with intermittent exposure of some 14 m of strata. Some of the more prominent beds comprise fine grained, quartzose, light grey to light brown, hard sandstone, with a variable limonite content. The bedding is mainly thin, but varies up to 0.5 m in thickness. It is irregular on a small scale, with fine internal lamination, small scale, low-angle crossbedding, minor ripples and siltstone rip-up clasts. Finely comminuted shells form minor beds of coquina. Carbonaceous, strongly bioturbated, very fine grained sandstones are a minor part of the unit. Prominently burrowed, rusty sandstones in the upper part of the unit contain locally abundant randomly oriented belemnites, *Gryphaea*, wood fragments and phosphatic nodules, the product of condensation and incipient hard ground formation (Fig. 69). The quartzose sandstone is shown in thin section in Figure 70.

The covered interval above the highest Rock Creek sandstone is about 60 m thick, and probably is occupied by equivalents of the **Middle Jurassic** Highwood Shale of southwestern Alberta and the lower part of the **Upper Fernie Shale** (Fig. 4).

Continue along the rail line toward the junction of McLeod River and Prospect Creek, to the road that leads south from Cadomin to Mountain Park. The Jurassic strata here, of which about 55 m are exposed, are typical of the **Passage beds** (Fig. 71), the highest member of the Fernie Formation. The lowest exposures are soft and recessive, dark grey shale and mudstone. They have yielded 14 species of calcareous and arenaceous Foraminifera and 1 ostracode species, which J.H. Wall (pers. com.) assigned to the Oxfordian and to moderate (mid-shelf) depositional depths.

Higher in the Passage beds unit, there are packages with abundant very thin (6 mm) laminae to 20 cm-thick beds of very light grey siltstone and very fine grained sandstone that weathers light brown. Whereas some are apparently entirely without internal structure, others are finely bioturbated. Rusty-orange sideritic concretionary layers occur. The bedding surfaces of many of the brown sandstones are smooth with an abundance of very fine carbonaceous material and very fine detrital mica (Fig. 72). The chert and mica content of the sandstones distinguish them from those of the quartzose Rock Creek Member. Very low angle, small scale cross-lamination occurs.

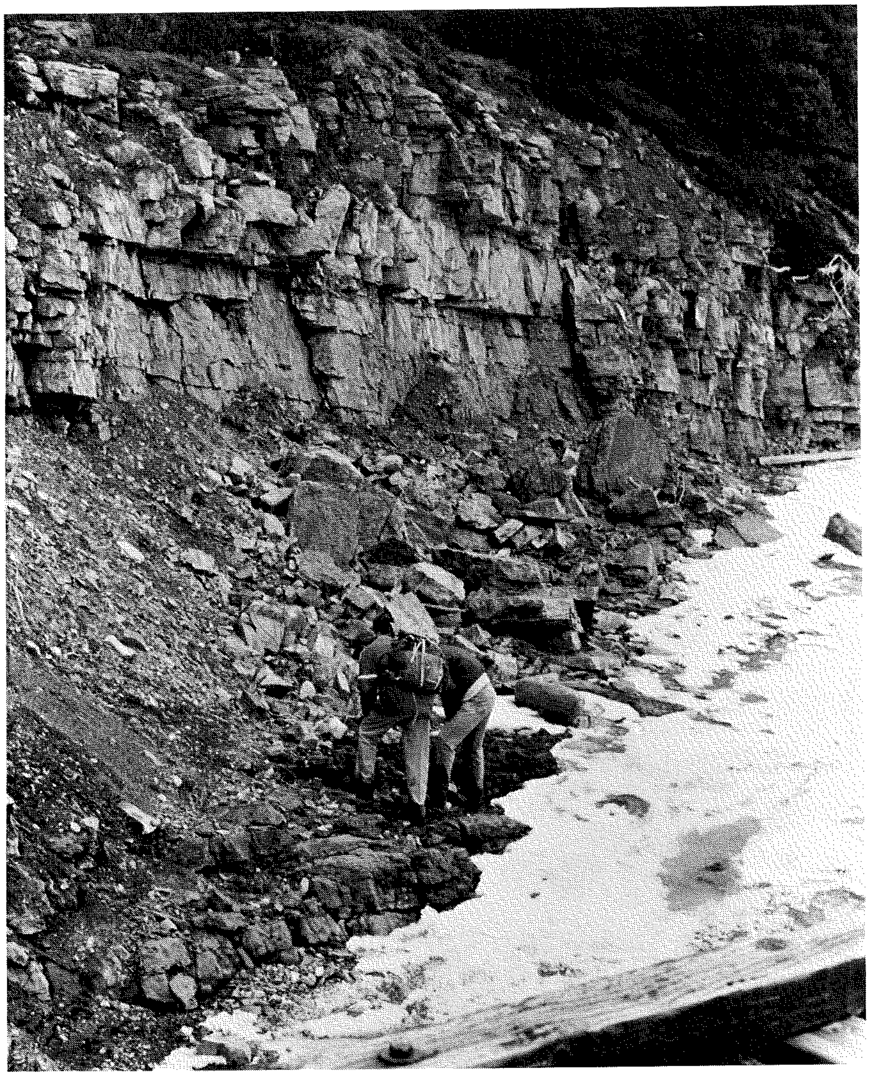

Fig. 67. Middle Rock Creek sandstone (RC2), McLeod River.

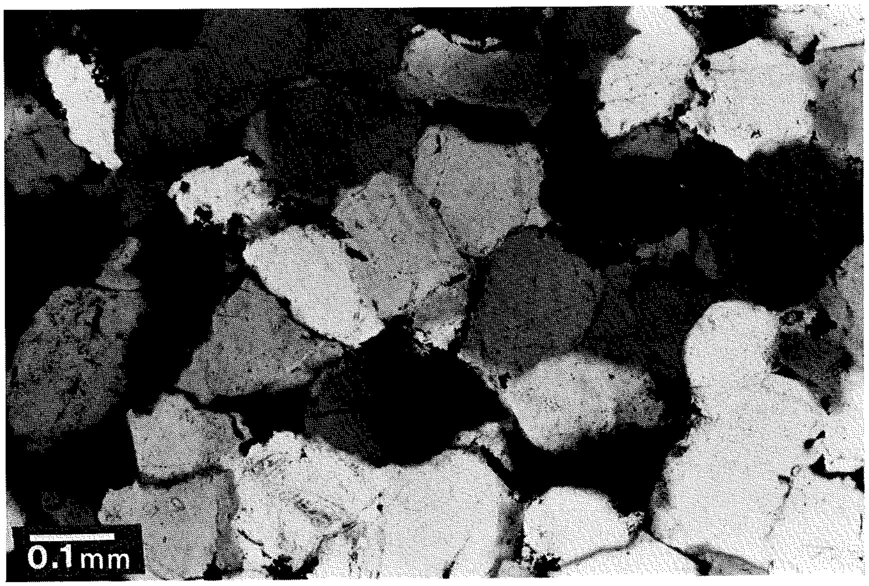

Fig. 68. Thin section of fine grained quartzose sandstone from the second Rock Creek sandstone (RC2) in the McLeod River section south of Cadomin.

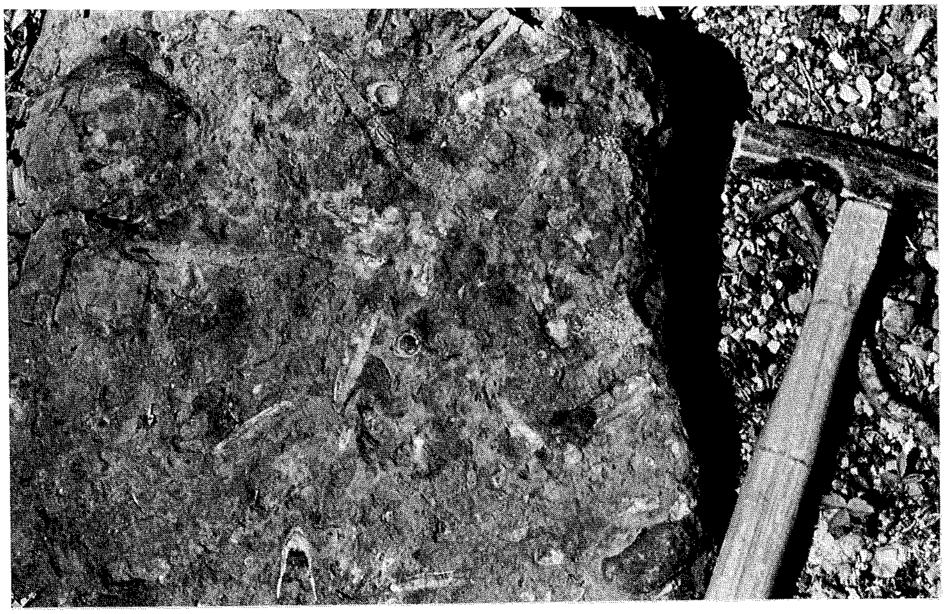

Fig. 69. Bedding surface with belemnites and phosphate pebbles, top of highest Rock Creek sandstone (RC3), McLeod River.

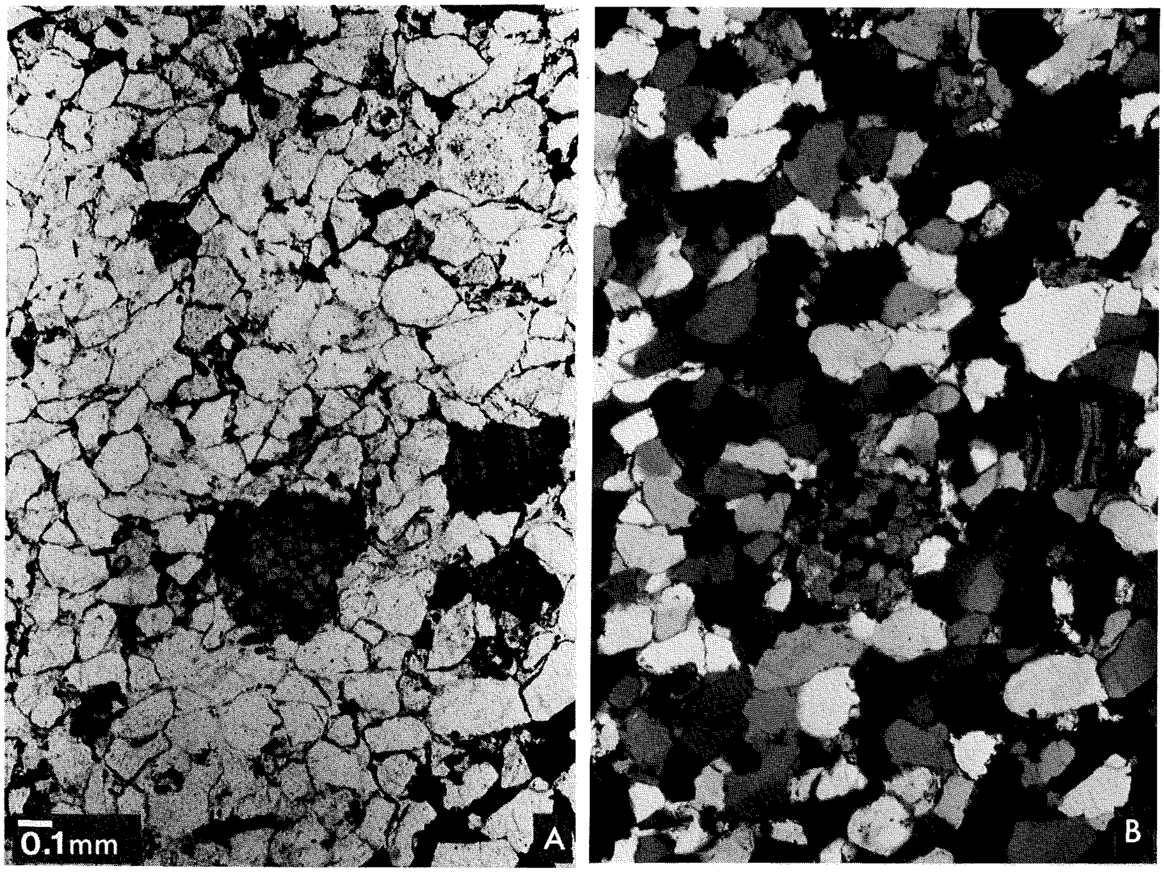

Fig. 70. Thin sections (A. plane light and B. x-nicols) of fine grained quartzose sandstone from the third Rock Creek sandstone (RC3) in the McLeod River section south of Cadomin, with *Inoceramus* or belemnite fragments.

Fig. 71. Siltstones and thin sandstones of the Passage beds, road outcrop at junction of Prospect Creek and McLeod River.

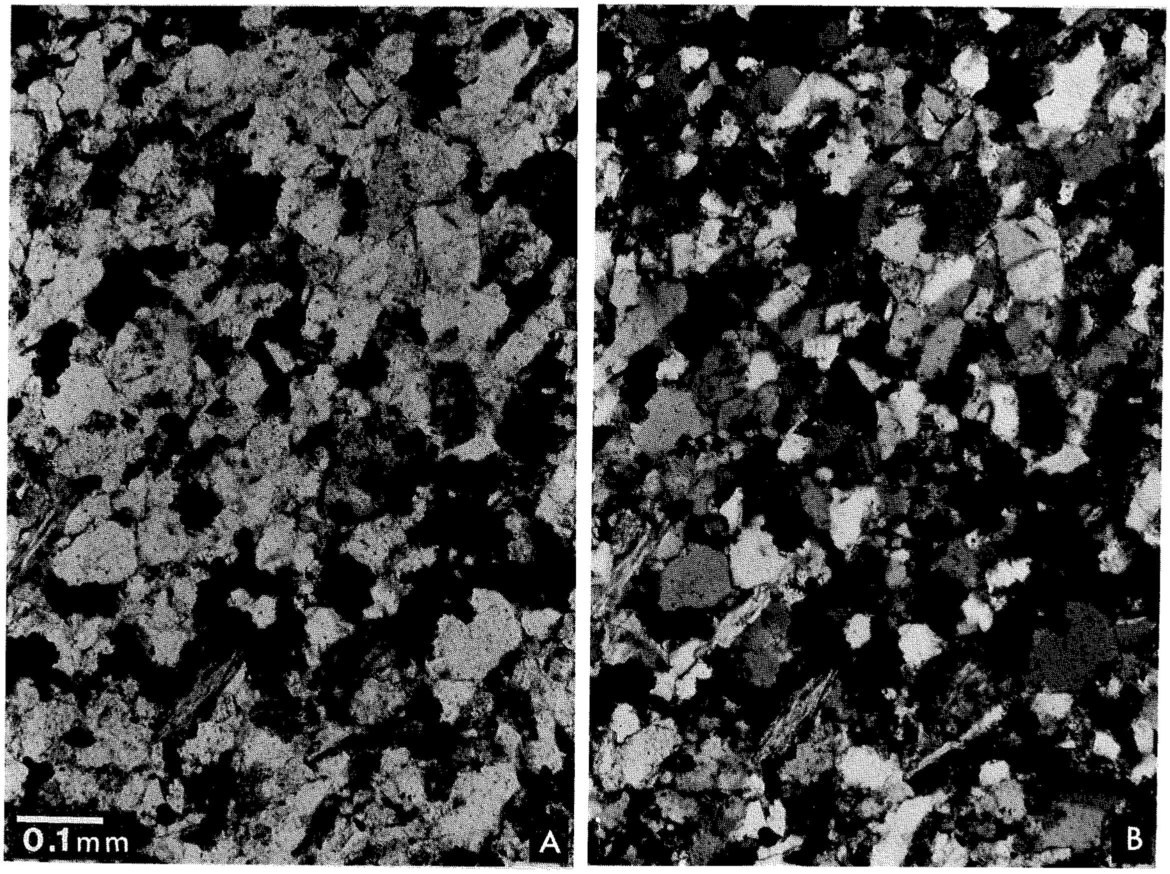

Fig. 72. Thin sections (A. plane light and B. x-nicols) of very fine grained sandstone from the Passage beds, junction of Prospect Creek and McLeod River. Note feldspar, mica, chert and opaque grains.

The highest strata in this outcrop are cut by a very fine grained **sandstone dyke**, crosscutting at a low angle, sheared and contorted. This is situated near the bridge at the confluence of Prospect Creek with McLeod River. The shales here have yielded 7 species of Foraminifera. J. H. Wall (pers. com.) notes that they are probably Oxfordian or possibly post-Oxfordian and that they are more restricted than the lower microfaunas, probably deposited in shallower environments. An additional 100 m or so of Passage beds underlies the covered interval along Prospect Creek upstream from the bridge.

An outcrop about 45 m thick farther up Prospect Creek contains the gradational contact of the Passage beds with the overlying **Nikanassin Formation** (Fig. 73). Sandstone beds within the upper Passage beds (lower 30 m) here reach 30 cm in thickness. The highest Passage beds have yielded the arenaceous Foraminifera *Haplophragmoides* and *Ammobaculites*, indicating inner shelf to littoral, possibly brackish conditions, according to J.H. Wall (pers. com.). The lowest Nikanassin strata (comprising the upper 15 m or so of the strata exposed) are dominated 85 to 90% by sandstone beds, some reaching 1 m in thickness in the upper 8 m. The base of the Nikanassin is placed where sandstones become dominant, and is approximately equivalent to the appearance of the lowest hummocky stratification. Many of the beds are strongly bioturbated throughout the sequence. More Nikanassin exposures a short distance up the creek display good hummocky cross-stratification (Figs. 74, 75).

Fig. 73. Contact of Nikanassin Formation sandstones (N, left) and Passage beds at top of Fernie Formation (F, right).

Fig. 74. Lower beds of Nikanassin Formation, with hummocky cross-stratification, Prospect Creek.

Fig. 75. Thin section of fine grained sandstone from the lower Nikanassin Formation in the Prospect Creek section south of Cadomin. Note the abundance of chert and the presence of feldspar (top centre).

FIELD STOP NUMBER 7

Shunda Creek, East of Nordegg

The section at Shunda Creek is located on Highway 11, a few kilometres east of the turnoff into Nordegg (Fig. 1). Here, we will briefly examine the Lower Jurassic Nordegg Member of the Fernie Formation in its type area, the Upper Jurassic and possibly Lower Cretaceous Nikanassin Formation, and the Lower Cretaceous Cadomin Formation. The original designation of the Nordegg Member (Spivak, 1949) referred to subsurface occurrences in the Nordegg area and no type section has been formally designated since, although Rosenthal (1989) considered the Shunda Creek section to be the type section. The Nordegg unconformably rests on carbonates of the Carboniferous Rundle Group. Triassic rocks were either not deposited in this area, which lay beyond the eastern edge of the Triassic depositional basin, or were removed by pre-Jurassic erosion.

The Jurassic section at Shunda Creek (Fig. 76) is situated palinspastically well east (cratonward) of the Fiddle River and McLeod River sections. The Nordegg is therefore in its typical carbonate-chert platform facies and the Jurassic section as a whole is thin. Middle Jurassic strata, if any are present in this area, are not exposed. The covered interval above the Nordegg is marginally thinner than its equivalents regionally, suggesting that some of the thin character is due to tectonic effects. It is unusual that no Rock Creek sandstone is exposed, suggesting the possibility of tectonic removal although the unit is thin in the Nordegg region. The Nikanassin is represented by a thin remnant near its eastern erosional limit below the Cadomin conglomerate.

The contact with the Lower Carboniferous Rundle Group limestones is sharp, with about 10-15 cm not exposed, and it is slightly offset by minor faults. The Carboniferous limestone is massive, rubbly, light grey, and cherty.

The Nordegg Member here (Fig. 77) comprises about 37 m of regularly bedded (beds reach 0.5 m thick), light to dark grey, structureless or finely laminated limestone (about 70%), and thin bedded black chert (about 30%, but more in lower and upper part). There are also thin layers of brown-weathering, finely laminated dolomitic siltstone. The chert is distributed generally along the bedding, forming discrete beds, with some structures indicating a nodular origin, at least in part. The cherts that comprise the Nordegg at this locality are shown in thin section in Figures 78 and 79, and in an SEM photomicrograph (Fig. 80).

The covered interval above the Nordegg exposure harbours about 50-60 m of **undifferentiated Fernie** recessive strata, presumably equivalent to the Poker Chip and younger shale units, but no Rock Creek sandstone outcrops.

Small outcrops in the ditch in the upper part of the recessive interval expose about 7 m of light-coloured limonitic sandstones, probably representing the **Nikanassin Formation.**

About 9 m of interbedded medium grained sandstone and siltstone with coaly carbonaceous partings outcrop a short distance eastward along the highway. Some of the sandstones are crossbedded. The exposure represents the **Nikanassin Formation** (Figs. 81, 82). The unconformable contact with the overlying **Cadomin Formation** is abrupt. The lowest 4 m of the Cadomin consists of chert pebble conglomerate and laminated, lenticular and cross-bedded medium grained sandstone. The overlying 7.5 metres are mainly cross bedded, laminated sandstone with conglomerate lenses. The Cadomin is the lowest unit at this latitude to contain extrabasinal clasts derived from extra-cratonic terranes to the west, including at this locality, green cherts pebbles thought to come from the Cache Creek Group. The Cadomin is gradationally overlain by 6 metres of thinly interbedded nonmarine sandstones and siltstones of the Gladstone Formation.

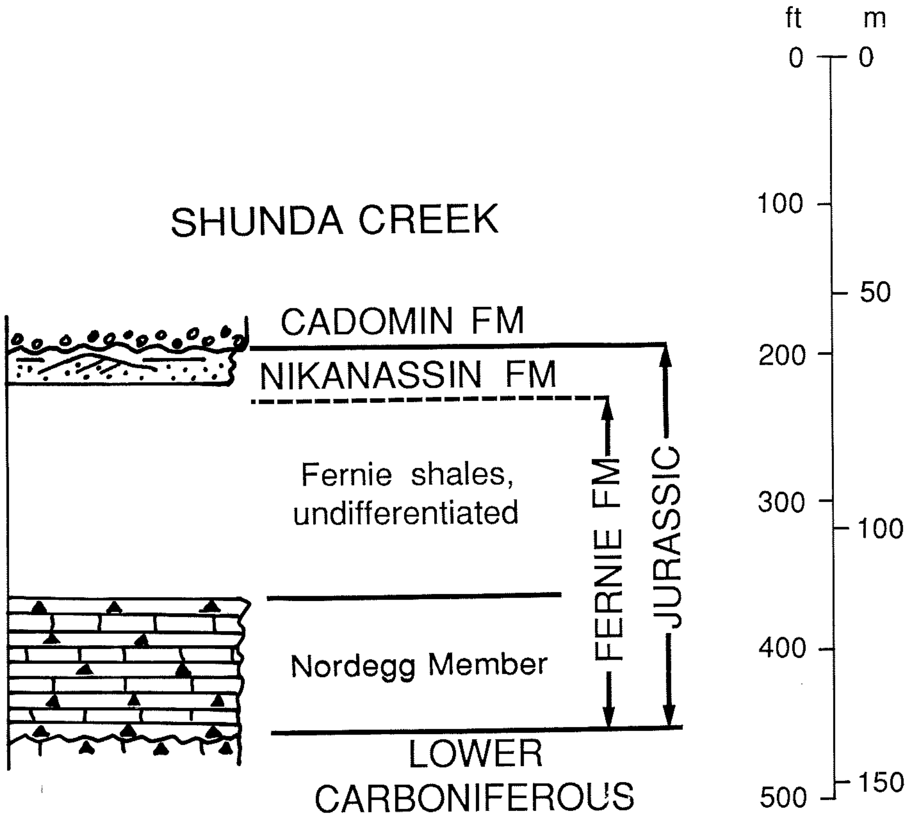

Fig. 76. Jurassic section exposed along Highway 11, east of Nordegg near Shunda Creek crossing.

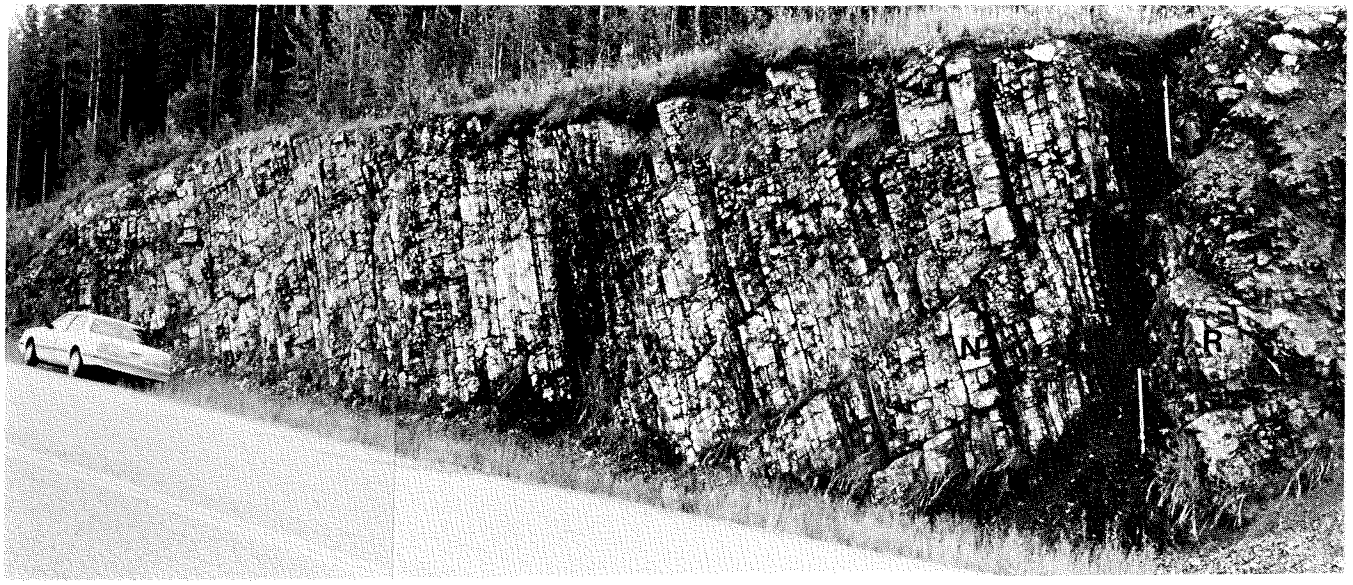

Fig. 77. Overturned and mildly faulted bedded cherts and limestones of the Nordegg Member (N), disconformably overlying Lower Carboniferous cherty limestones of the Rundle Group (R; right). Highway 11 at Shunda Creek east of Nordegg.

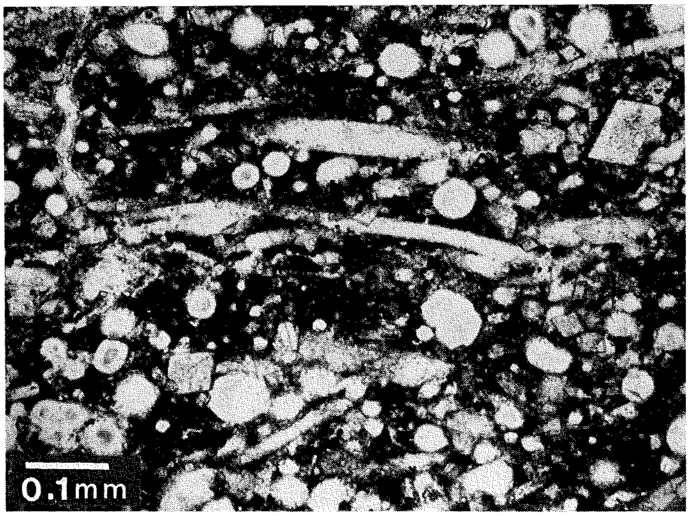

Fig. 78. Thin section, Nordegg chert near Nordegg, showing sponge spicules and carbonate rhombs.

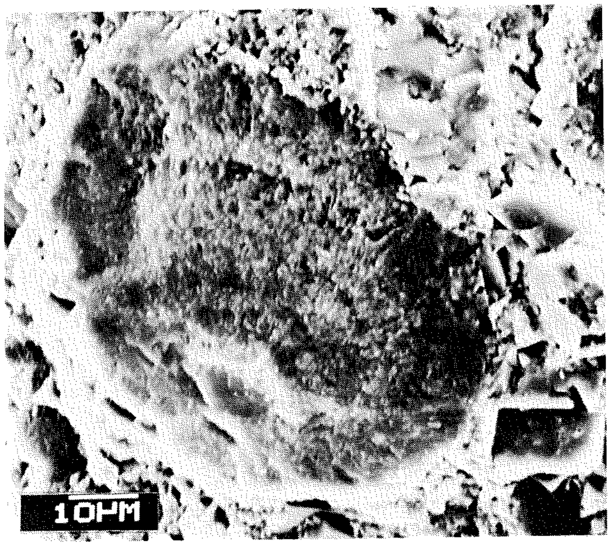

Fig. 80. SEM photomicrograph, Nordegg chert near Nordegg, showing chalcedonic infill of void in chert.

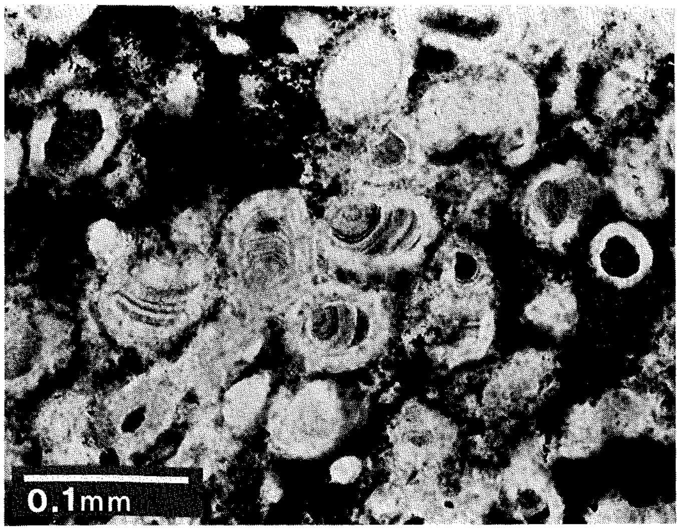

Fig. 79. Thin section, Nordegg chert near Nordegg, showing banded chalcedonic infill of solution(?) cavities in chert.

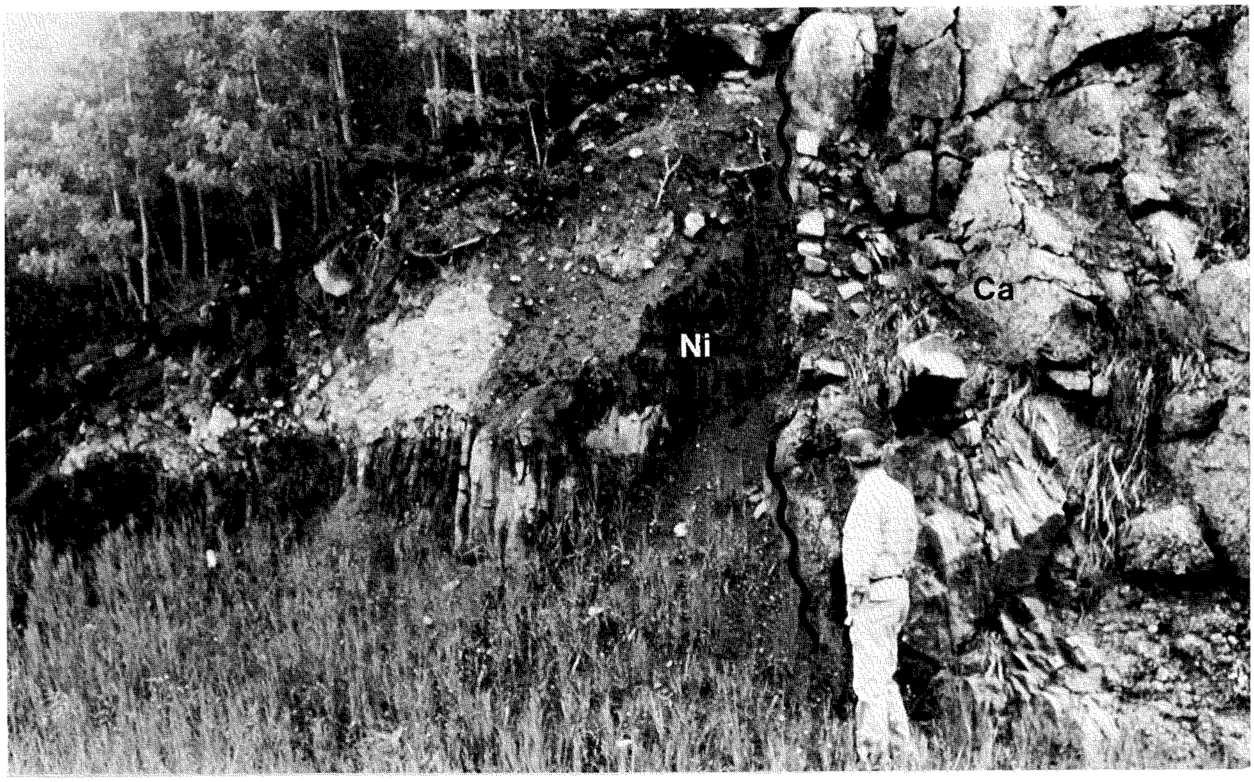

Fig. 81 Thin Nikanassin sandstones and siltstones (Ni; left), unconformably overlain by Cadomin conglomerates and sandstones (Ca; right). Highway 11 near Shunda Creek east of Nordegg.

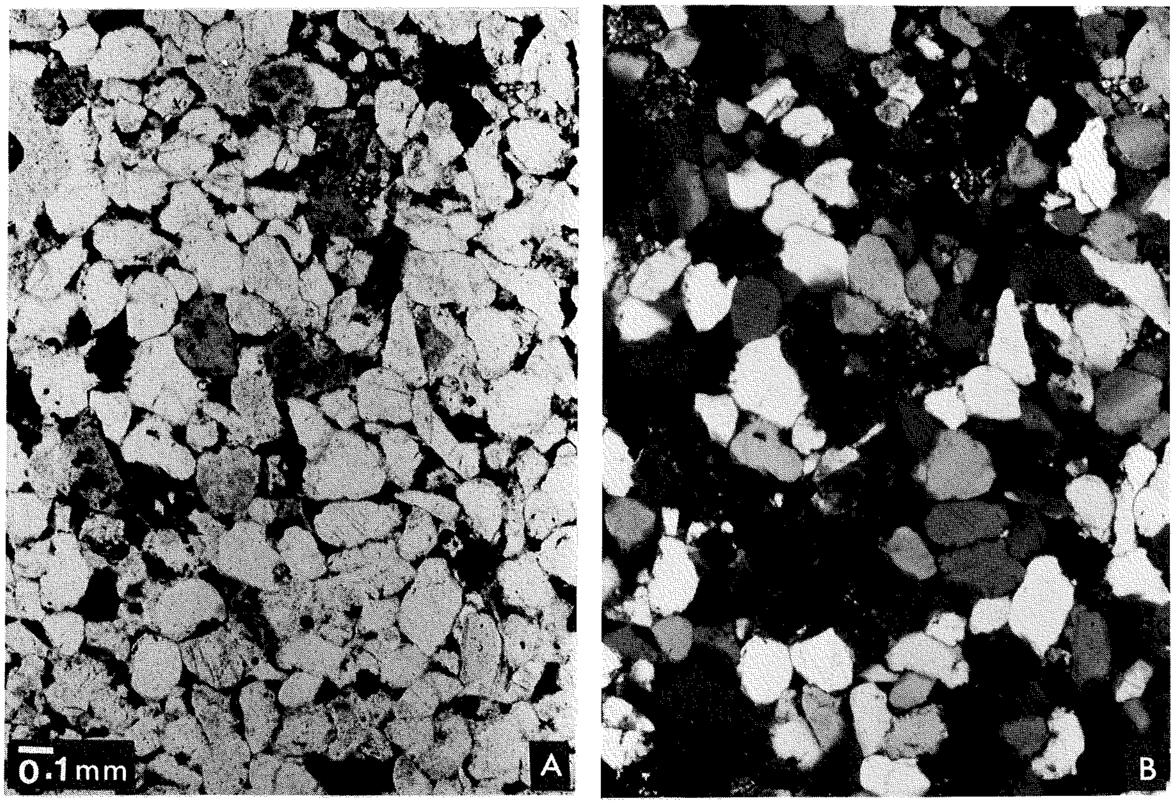

Fig. 82. Thin sections (A. plane light and B. x-nicols), fine grained sandstone from the Nikanassin Formation near Shunda Creek east of Nordegg. Note chert and other lithic grains.

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