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A REVIEW OF THE BONNET PLUME AREA, EAST-CENTRAL YUKON TERRITORY (Including Snake River, Solo Creek Noisy Creek and Royal Creel areas)

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INTRODUCTION

The first aim of this report is to summarize what is known about the Paleozoic stratigraphy of four areas: Snake River, Solo Creek, Noisy Creek and Royal Creek (Fig. 1). Interesting phenomena, including dramatic facies changes at various stratigraphic levels as well as some unusual tectonic events, characterize these areas. These phenomena have all been described, at least to some extent, in published literature; some are well known, others less so. However, no convenient synthesis of any of the four areas has yet been published. In each case important bits of information lie buried in various publications and considerable effort is required to track them down. In addition, a lot of useful information is contained in technical reports produced by the petroleum industry which, though unpublished, are available from the Department of Indian and Northern Affairs (Canada Oil and Gas Lands Administration or COGLA).

The second aim of this report is to integrate information on the above four areas with what is known of the larger, encompassing area, hereafter called the Bonnet Plume area. The Bonnet Plume area straddles the junction of three Mountain systems: the Mackenzies, Richardsons, and Werneckies (Fig. 2). The area also straddles what was, at times, a deep water connection between the Richardson Trough and the Misty Creek Embayment, or, at other times, a land connection between the Ogilvie, Peel and Mackenzie Arches. There must also be a connection, in the casual sense, between such diverse features as the Richardson Fault Array, the long-lived Paleozoic facies belts, and the Bonnet Plume Basin.

This report is one of a series of Open File reports on the geology of the Mackenzie Corridor, the area between the 60th parallel and the Arctic coast and between the Canadian Shield on the east and the Mackenzie or Richardson Mountains on the west. Because it is part of a series, this report is not designed to stand alone. To make use of this report readers will require access to three Geological Survey of Canada geological maps: Map 1528A, Wind River map area, Map 1529A, Snake River map area (D.K. Norris, 1982a, b) and Map 1282A, Nash Creek map area (Green, 1972).

SNAKE RIVER AREA

Figure 3 shows control points and lines of sections. Readers should also refer to the Snake River map (GSC Map 1529A, D.K. Norris, 1982b).

In this area the mountains trend east-west, approximately at right angles to what was facies strike throughout much of Early Paleozoic time. The belt of Devonian facies change is evident on the Snake River map from the distribution of the shale unit mapped as Dsh. The belt of Ordovician facies change, which is not evident on the Snake River map, occupies the same geographic belt.

Franklin Mountain and Mount Kindle formations and equivalents

Within the Snake River map area strata of Ordovician age change from entirely shallow-water carbonates in the east to mostly shaly basinal carbonates in the west. Although not mapped as such, the basinal strata represent a tongue of the Road River Formation that extends some 50 km eastward from the Richardson Trough. The first published information on this basinal facies was provided by Ziegler (1967); his Snake River section shows a thick (over 600 m) Mount Kindle Formation that includes a tongue of Road River strata in the basal part. Later, a series of lithofacies maps by Lenz (1972) provided more detail on the distribution, through time, of the Road River facies.

Figure 4 presents the generalized stratigraphy and the geometry of the Road River tongue. Section L-2 (Williams, 1969) is in the general vicinity of the Snake River section of Ziegler (1967) and Section 19 of Lenz (1972). Section 63-39, 2 is the same location as Section 18 of Lenz (1972). Sections 63-39, 2 of Norford (1964) and M-388, 41 of Aitken et al. (1982) provide the only published paleontological collections (listed in Appendix 4, Norford and Macqueen, 1975). There are several unpublished industry reports that provide measured and described sections with age designations, but no paleontological data: Bullock and Associates (1960), Sproule and Associates (1960), Geophoto Services Ltd. (1962) and Williams (1969). The following observations are based in part on my own work (Bullock and Associates, 1960; Williams, 1969).

Arctic Red River area (east end of Fig. 4)

The stratigraphy here is well known and is discussed in Aitken, Cook and Yorath (1982). The entire section consists of dolomite, mostly micro to fine crystalline, but with occasional medium to coarse crystalline layers. There is a discontinuous basal quartzose sandstone. Silt and floating quartz sand grains are common near the base, and occur sporadically throughout the Franklin Mountain Formation. The informal 'cherty' and 'rhythmic' units are of dubious value in this area (*ibid.*, p. 16), and are not identifiable farther west. Silica, as fossil replacement, vague tracery, cindery layers, nodules, or stringers to fairly thick beds of solid chert, occurs throughout the entire section, including the Mount Kindle Formation.

The unconformity below the Mount Kindle Formation is not usually obvious, however, in a section near M-388, 41 (H-W-42, Bullock and Associates, 1960) basal Mount Kindle beds contain floating coarse quartz grains, lenses of dolomite breccia that weather red or purple, and a lenticular bed, up to 1 m thick of a granular chert or quartzite. In none of the unpublished sections west of M-388, 41 is there any convincing evidence for an unconformity, in fact, the Mount Kindle/Franklin Mountain contact is arbitrary, being usually placed below the lowest abundance of colonial corals. The Mount Kindle Formation contains several thin (metres thick) biostromes, usually medium crystalline, often highly silicified.

Discussion of units, Snake River area

For the purpose of discussion, strata in the Snake River area are divided into five informal units (Fig. 4). Units A and E are composed of shallow-water dolomites which resemble their homotaxial equivalents of the east. Unit D represents a deeper water facies. Units B and C represent a transitional lithology with considerable lateral variability.

Unit E, basal dolomite

Unit E, 100 to 160 m thick, consists of light coloured dolomite, generally very fine crystalline but with occasional coarser layers up to coarse crystalline. Silica is not abundant, it occurs as siliceous tracery, very thin layers, or as chert nodules. The basal few metres are sandy and, in most sections, there is a basal quartzose sandstone up to 30 m thick. In most sections the upper contact is abrupt, but in some the upper beds are dark, argillaceous and thin bedded, gradational into the overlying shaly strata. Silicified brachiopods, crinoid debris and trilobites occur in unit E.

Unit D, shaly limestone

This unit is between 155 and 290 m thick, the variability appearing to be a result of facies change at the top. The predominant rock type is dark grey to black, dense, argillaceous, pyritic, thin-bedded to platy limestone. This unit is recessive and usually poorly exposed. Dark grey shale occurs as partings to thin beds; the proportion of shale increases from east to west. Black chert nodules, thin bioclastic layers, thin layers of limestone pebbles, and soft-sediment slump structures occur sporadically. Graptolites, trilobites and brachiopods are fairly abundant.

Unit C, bedded chert and carbonate

This unit varies between 100 and 210 m thick, the variability being due mainly to facies change to Unit D at the base. The unit consists of thin bedded, rhythmically interbedded dark grey, argillaceous carbonates and black chert (approximately 40% limestone, 30% dolomite and 30% chert). In the upper few tens of metres, bioclastic material, including fragments of colonial organisms, is abundant. The upper contact appears to be a transition.

Unit B, limestone and dolomite

Unit B is 120 m to 160 m thick. In some sections it is nearly all limestone, in others (including those plotted on Fig. 4) it is all dolomite. The dolomite is mostly micro to very fine crystalline. In the basal portion of unit B, in two sections, are layers of dolomite breccia or dolomite pebble conglomerate; the matrix consists of light grey, medium to coarse crystalline dolomite. Veins of dolomite or calcite are common through such layers. Where composed of limestone this unit differs from Unit D in being more resistant, less argillaceous, thicker bedded, and crystalline rather than dense. Whether dolomite or limestone, unit B grades, from base to top, from fairly dark to fairly light coloured. There are rare thin bioclastic layers, traces of brachiopods and crinoids, and rare black chert nodules.

Unit A, biostromal dolomite

This unit is usually about 250 m thick but ranges from 180 m to 320 m. It is nearly all dolomite, limestone beds are rare. Most of the dolomite is medium grey, very fine to fine crystalline but there are several layers of lighter coloured medium to coarse crystalline dolomite; these layers, 1 m to 30 m thick may, in some sections, constitute up to 50% of the unit. These coarse dolomite layers are probably biostromes, however, textures usually have been obliterated; in some there are poorly preserved colonial corals (including *Favosites*-type and chain corals), stromatoporoids, brachiopods, cup corals, gastropods and straight cephalopods. Such layers are usually silicified to some degree, sometimes resembling a cindery mass of quartz and chert. Beds of solid, light coloured chert occur, as well as nodules of dark chert. On rare occasions thin regular beds of black chert interbedded with dolomite occur, a lithology like that of Unit C.

In section 63-39, 2 Norford (1964) observed an erosion surface with a relief of 40 cm at the base of Unit A. In none of the other measured sections was this unconformity observed. However, local erosional surfaces may be fairly common within unit A. This is suggested by the occurrence at several horizons of thin layers with a conglomeratic texture. In one exposure, near section M-1, fragments of black chert up to 20 cm in diameter that appear to be clasts, not nodules, occur in a rudite layer (Williams, 1969, Appendix item 40).

Age and correlation

In the type area (Franklin Mountains) the Franklin Mountain Formation ranges from Late Cambrian into Early Ordovician and the Mount Kindle Formation from Late Ordovician into Early Silurian (Norford and Macqueen, 1975). The sub-Mount Kindle hiatus spans the entire Middle Ordovician. Presumably the same situation exists at M-388, 41, at the east end of Figure 4.

In the west, Unit E has yielded a Late Cambrian age (F4) near the middle of the unit, and Unit D, in the lower half, an Early Ordovician age (F3). Although no other paleontological determinations have been published, certain deductions can be drawn from the maps of Lenz (1972). First, it is necessary to assume that strata designated 'Road River' by Lenz are Units C and D. His Lower and Middle Ordovician maps (*ibid.*, Figs. 5, 6) show the Road River facies extending east beyond his section 18 (63-39, 2; Fig. 4); hence Unit D would include Lower and Middle Ordovician strata. His Upper Ordovician map (*ibid.*, Fig. 7) shows a carbonate to Road River facies front east of, but near, his section 19 (L-2, Fig. 4); hence Unit C and, presumably Unit B, would include Upper Ordovician strata. His Lower Silurian map (*ibid.*, Fig. 8) indicates that the carbonate facies extends across the line of section, westward beyond his section 19; hence Unit A would include Lower Silurian strata. Norford (1964) although listing no fossils, labelled Unit A of section 63-39, 2 as Silurian and Upper Ordovician. In summary, Unit A plus at least parts of Units B and C correlate with the type Mount Kindle Formation. Unit E plus part of Unit D correlate with the type Franklin Mountain Formation. The upper part of Unit D plus, probably, parts of units C and B are Middle Ordovician strata which have no eastern equivalent, a time represented by the sub-Mount Kindle hiatus.

In the southwestern corner of the Upper Ramparts River map (adjacent and east of the Snake River map) Aitken et al. (1982) mapped a Transitional unit, equivalent to the Franklin Mountain Formation. They describe (*ibid.*, p. 17) ". . . a significant increase in limestone beds at the expense of dolomite . . . and the appearance of intercalated beds of dark-coloured shale . . . coarse debris-flow breccia indicates that at least part of the unit consists of slope deposits." Section B-335, 2 of Cecile (1982, p. 44) is located in this area (Fig. 3); this section is very similar, at least in thickness and gross aspect, to section 63-39, 2, Fig. 4, however in the Cecile section the Unit D equivalent consists of argillaceous dolomite rather than limestone.

Some observations and deductions

The sub-Mount Kindle unconformity of the east cannot be identified in the west. If present, beneath Unit A or perhaps within or below Unit B, the hiatus must be of shorter duration than in the east where no Middle Ordovician strata are present.

It is interesting that the thick Franklin Mountain dolomite of the east is composed entirely of a shallow-water facies whereas the thinner time-equivalent western strata are in large part a deeper water, more open-marine facies. Obviously the facies belts were not directly determined or controlled by local rates of subsidence. Through part of Late Cambrian-Ordovician time the rate of subsidence in the east was about double that in the west. Or, put another way, the Snake River area behaved as a mildly positive arch through that span of time. Regional isopach maps (Williams, in prep.) indicate that this Snake River positive area was actually part of the much larger feature known as the Mackenzie Arch or Redstone Arch.

On the map, Figure 13, a partial shale-out line is shown trending southeastward from the Snake River area to the eastern margin of the Misty Creek Embayment. This line is based on the assumption that units C and D, Figure 4, are (or were before post-Laramide erosion) continuous with the Franklin Mountain Transitional unit of Aitken et al. (1982). The existence of this facies belt is one of the main reasons for challenging Cecile (1982, p. 29) who maintains that it is unlikely that there was any 'shale' connection between the Richardson Trough and the Selwyn Basin via the Misty Creek Embayment in early Paleozoic time.

Delorme, Landry/Arnica and Hume formations and equivalents

Figure 5A is a diagrammatic illustration of facies relationships within the Hume to Delorme package. The sediments of the eastern part are well known; lithology and facies relationships are described by Aitken et al. (1982). Points to emphasize are:

1) The Hume Formation consists of an upper part that is mainly limestone and a lower part that is argillaceous limestone and shale;
2) The terms 'Bear Rock', 'Arnica' and 'Landry' are facies terms for rocks dominated by anhydrite, dolomite or limestone respectively, that form a single depositional package;
3) The Landry/Arnica package grades from restricted-marine to open-marine both vertically and from east to west.

Of main concern in this report are sediments of the western part of Figure 5A, the Snake River area. Concepts implicit in this diagram were first articulated by geologists of Shell Oil Company as illustrated by Ziegler (1967, p. 49) and Bassett and Stout (1968, Fig. 5). There are no other published reports dealing specifically with facies relationships in this area; however there are several important stratigraphic sections measured and described by A.W. Norris (1967, 1968); these are plotted on Figure 5B which also indicates the nomenclature used in these reports. Several significant fossil collections are plotted on Figure 5C. A partial history of nomenclature is shown on Figure 5D.

The following discussion is based in part on my own unpublished field observations (Williams, 1969).

Discussion of units

Delorme Formation

This unit consists of dolomite with subordinate limestone, generally light in colour and micrograined to aphanitic, with textures indicative of a shallow-water, somewhat restricted marine origin. Erosional unconformities at the base and top of this unit are evident from occasional exposures of carbonate rubble in a matrix of pale green pyritic shale. Fine, disseminated pyrite and an abundance of silt occur in the carbonates through zones some tens of metres thick above both unconformities; the weathered pyrite gives rise to the two prominent markers: the upper and lower orange zones of Ziegler (1967).

Whether the west-to-east thinning and truncation of the Delorme Formation is primarily a result of erosion, of differential subsidence, or both, is not yet known. Westward, beyond the confines of the cross-section, the Delorme Formation becomes more open-marine, more Arnica-like, in that there are layers of dark, fine to medium crystalline, somewhat fetid dolomite (see Section MQ-10, Macqueen, 1974).

Fossil collection F6, Figure 5C, requires some discussion because its stratigraphic position is by no means clear from reading the cited reports. Broad and Lenz (1972) mention that the fossiliferous beds are associated with orange-weathering strata referred to by A.W. Norris (1968) as the Gossage Formation. As is obvious from Figure 5B, the questions arise: "Which Gossage?", "Which orange zone?" Broad and Lenz (1972, p. 415) further state that the collections come from strata that disconformably overlie ". . . dark, massive Ronning dolomites." The term 'Ronning', as used by some geologists, includes the Delorme Formation, however, in the Snake River area only the Mount Kindle dolomites fit the above description. There can be little doubt that the F6 collections are from basal Delorme strata. Similar reasoning applies in the case of a fish collection (Dineley, 1965).

'Arnica' dolomite (Snake River area)

This unit is entirely dolomite, generally medium grey, becoming darker up-section, micrograined to aphanitic, in part argillaceous and with thin dark shale breaks, and occasional chert nodules. The orange weathering pyritic zone (upper orange zone) above the basal unconformity has been mentioned.

Cranswick limestone (Snake River area)

At the type section (A.W. Norris, 1968) there are two members: an upper recessive member and a lower cliff-forming member. The lower limestone is a medium grey, variably bioclastic lime-mudstone: corals, stromatoporoids, brachiopods and crinoids (including two-holers). Individual massive beds tend to pinch and swell within a framework of thin bedded limestone. A possibility (not thoroughly investigated in the field) is that this lower member consists of a series of soft-sediment flows.

The limestones of the upper member are dark grey to black, more argillaceous, less bioclastic, and contain a higher content of interbedded shale. The upper contact with the Road River shaly strata is gradational; in fact it is a matter of opinion whether this upper recessive member should be regarded as part of the Cranswick or part of the Road River Formation (see discussion in Pedder and Klapper, 1977, p. 227).

The succession from the unconformity below the upper orange zone through to the basal Road River shales represents a transgressive, deepening-upward sequence. The onset of this transgression can only be dated as Late Emsian or earlier. A drowning event, or change from subtidal yet relatively shallow-water deposition to deep water deposition is recorded at the contact between lower and upper Cranswick members; this drowning event can be tied down to within the *inversus* conodont Zone (Collection F2, Fig. 5C). Conodonts of the *inversus* zone occur in both members (Pedder and Klapper, 1977).

Road River Formation (Snake River area)

The Road River Formation consists of shale, mostly calcareous, with limestone interbeds; limestone beds are most abundant near the base and near the top. In the lower part of the section the rocks are dark grey to black; limestones are argillaceous mudstones, the shales often show a sooty, carbonaceous appearance. Some lime-rich layers show soft-sediment slump structures, scoured surfaces, or large scale crossbedding. In the upper part of the section the shales are lighter in colour, often with a greenish hue. Limestone lenses at the top of the section are less argillaceous and, often highly fossiliferous, with corals, brachiopods, crinoids and gastropods. It is a matter of interpretation (and accident of exposure) whether or not one identifies a Hume limestone interval. The contact with Canol shale is not exposed in this area.

Landry/Road River transition

Along the frontal ranges of the northern Mackenzie Mountains, strata dip steeply to the north. Where Hume and older formations are predominantly carbonates the structure is simple; where tongues of shale appear in the sequence small folds and north-dipping thrust faults are common. Hence, the lateral transition zones of both Hume and Landry limestones into shales are not usually well exposed. The relationships shown on Figure 5A are not adequately documented, however the following observations lend support:

- Clinoforms in basal Hume strata dip to the west or south.
- The seaward tongues of Landry limestone consist of variably bioclastic mudstone, mostly crinoid debris, but also fragments of stromatoporoids and corals (two-hole crinoids extend to the uppermost Landry strata).
- Coarse rudite texture (lime mudstone fragments, broken stromatoporoids) is visible in some Cranswick limestones.
- Pebbles of limestone lie scattered within the shale at some limestone/shale contacts.

Section C, Figure 5 is not located along the line of section (approximately along 65°30'N) but lies some 40 km farther south (Fig. 3). However this Section probably does lie in an analogous position, near the carbonate/shale front (Fig. 16). To the west, within a few kilometres of Section C, the resistant Landry carbonate ribs lose all topographic expression and the interval is mostly covered.

Nomenclature

It is evident from Figure 5D that nomenclatural usage in this area is confusing and still in a state of flux. Names used on Figure 5A for the Snake River Section are temporary expedients.

The term 'Delorme', as used by Ziegler (1967) and Bassett and Stout (1968) has generally been avoided, except in industry reports. One reason may be that, failure to recognize that there were two orange weathering markers, led to lack of recognition of the existence of the Delorme Formation. This would explain the varied usuage of the term Gossage, as in Figure 5B. When Tassonyi (1969) introduced term the "Gossage Formation" he was unaware of the existence of the Delorme Formation, either in the subsurface or in the northern Mackenzie Mountains (conversation with the late E.J. Tassonyi, 1971).

The term 'Road River' evokes the image of black rocks, whether shale, limestone, or chert. The upper member of the Cranswick Formation and the overlying dark shales fit that connotation. It is questionable, however, whether the overlying grey shales should be included. A.W. Norris (1985) has introduced the term 'Mount Baird' Formation for this light-coloured upper section. In essence this new name applies to:

a) The lower shaly part of the Hume Formation where both the upper Hume and upper Landry limestones are present.

b) The shale equivalent to all of the Hume Formation plus, probably, some shale equivalent of the Landry Formation.

Thus, the Mount Baird is analogous to and the same age (early Eifelain) as the Headless and Funeral formations of the southern Mackenzie Mountains.

SOLO CREEK DOME

Solo Creek, a north-flowing tributary of the Peel River, lies in the northeast corner of the Wind River map (G.S.C. map 1528A, D.K. Norris, 1982a). Its main branch breaches the core of a dome exposing Paleozoic carbonates. The dome is flanked by recessive Devonian shaly strata except on the east, where the carbonates of the core are up-faulted against Cretaceous clastics. In several early industry reports this structure was called Margery Dome.

Little stratigraphic information has been published. A partial section of the core carbonates is described in Norford (1964, Section 3). This is plotted as section 8a on the Wind River map (for plotted Section 8b, 3 km to the north, nothing has been published). Another partial section of Devonian shaly strata is described by Fåhraeus (1971, Section V) and (the same section) by Ludvigsen (1972, Section V). Section 22 of Lenz (1972) is located on Solo Creek, but provides no details. Many industry reports contain measured sections, the net result of which is a variety of conflicting interpretations. My own investigation of this area was limited to an air-photo interpretation plus a half-day ground and helicopter reconnaissance (Williams, 1969). Figure 6 is an interpretative summary. It must be stressed that this interpretation is not based on adequate mapping and all thicknesses are estimates.

Description of units

Unit 1, dark carbonates and chert

The upper part of this unit is described in Norford (1964, Section 3, units 1-12). It is described as dark grey, fine crystalline, mostly thin-bedded dolomite, with abundant black chert as nodules, lenses and thin bands. Silurian corals were collected from this interval (*ibid.*, p. 124). Lower in the core of the dome Williams (1969) noted thin bedded, platy, argillaceous limestone; this unit weathers to ragged hoodoo-like cliffs, stained light buff.

Unit 2, shelf dolomite

This unit forms the resistant core of the dome. It plus the underlying Unit 1 are mapped as unit ЄDb on the Wind River map 1528A. Unit 2 consists of light to medium grey, fine, medium, rarely coarse crystalline dolomite. It forms massive, light-medium grey weathering cliffs. The lower contact appears to be gradational. The upper contact is discussed below.

Over most of the dome this dolomite is estimated to be in the order of 350 m thick. On the north end of the dome it is much thinner; Units 13 to 19 of Section 3 of Norford (1964), measured 130 m of unit 2 dolomite and the top of the exposure was estimated to lie only a few tens of metres below Devonian shale outcrops (*ibid.*, p. 26).

On the southern part of the dome, where the unit is thick, the uppermost beds of Unit 2 show some coarse bioclastic texture, including crinoids, some excellent vuggy and intercrystalline porosity, and traces of pyrobitumen.

Unit 3, debris-laden shale

This unit, estimated to be about 200 m thick, occurs only around the northwestern end of the dome. It was mapped as the Road River Formation by D.K. Norris (1982a) on the Wind River sheet. Most of Unit 3 is represented in Section V of Ludvigsen (1972) whose description is quoted in full (ibid., p. 302) " . . . a drab sequence of unfossiliferous, black, calcareous shales with interspersed lenses and beds of breccia composed of limestone, dolomite, or completely replaced by silica. The lenses are up to 1.5 m in thickness and in places thin laterally to zero thickness within a distance of 7 m along a bedding plane. The breccias are interpreted as having been deposited by turbidity currents that swept still-unconsolidated calcareous material off adjacent carbonate banks and into a deep basin where *in situ* faunas were restricted by near-anaerobic conditions. Upon acid digestion, the breccias yielded a diverse, but fragmental, fauna of brachiopods, ostracodes, crinoidal debris, conodonts, corals, bryozoans, dacryoconarid and tentaculitid tentaculites, and trilobites.".

Unit 4, debris-sheet

Unit 4 forms a resistant layer, about 30 m thick, that forms the highest topographic expression of the dome. It is mapped as the Ogilvie Formation on the Wind River map. Unit 4 is featured by Cook and Mullins (1983) as an example of debris-sheets in basinal strata (see their Figs. 53-55). The clasts, up to 7 m across (! not a missprint), consist of shoal-water pellet grainstone. Unit 4 is a composite of several debris flows separated by finer grained turbidites (*ibid.* p. 564).

Unit 5, shale and covered

This unit forms a recessive, low-lying belt flanking the dome (unit mapped as Dsh, Wind River map). Immediately north of the dome, in east flowing tributaries of Solo Creek, are several small exposures of shale with debris beds, similar to Unit 3; it is unclear whether these outcrops belong in Unit 5, or if they are structural repeats of Units 3 and 4, as they have been mapped on the Wind River map.

Unit 6, Canol-like shale

This unit seldom outcrops but it forms rounded hills covered by silvery weathering talus of black siliceous shale. This unit has been mapped as the Canol Formation on the Wind River sheet. No measurement is possible but it must be thick, possibly several hundred metres.

Section 22 of Lenz (1972)

For Section 22, located at Solo Creek dome, the following stratigraphic section is given (*ibid.*, chart, p. 325):

Upper Givetian-Lower Frasnian	Canol or Canol-like shale
Upper Eifelian-Lower Givetian	Hume?
Gidennian-Lower Eifelian	Gossage
Upper Silurian	missing
Upper Ordovician-Lower Silurian	Mt. Kindle
Lower and Middle Ordovician	Road River

Of the above units, it is obvious that as applied to units of Figure 6, the Canol-like shale = Unit 6, Mt. Kindle = Unit 2 and Road River? = Unit 1. How the Hume and Gossage were recognized in Units 3, 4, and 5 is not evident.

Age and correlation

The only published paleontological control for pre-Devonian strata is a Silurian coral (*Cystihalysites* or *Halysites* sp.) high in Unit 1 reported by Norford (1964, p. 124). The lithology of this unit is similar, though less cherty, to that of Unit A of the Snake River area (Fig. 4) and to that of Unit 1 of the Noisy Creek area (Fig. 7). The hoodoo weathering character was also noted in the Snake River Unit A strata. In both the Snake River and Noisy Creek areas this cherty unit was deduced (no direct evidence) to be Ordovician.

The age of Unit 3 is Early Devonian (Siegennian-Early Emsian), documented by Fåhraeus (1971, Section V) and Ludvigsen (1972). Thus, this section is older than the Cranswick limestone at Snake River (Late Emsian, Pedder and Klapper, 1977). The lowermost strata of Unit 3 are not exposed; the lowest collection contains *Monograptus yukonensis* (Ludvigsen, 1972, Fig. 5, collection V-1).

There are no published data on the age of the Unit 4 debris-sheet or the younger Devonian units of Solo Creek dome. In the lower canyon of the Peel River, some 30 km west of the dome, a bed similar to Unit 4, described as "a limestone breccia containing abraded stromatoporoids, corals, and cobbles of two-hole crinoid encrinite" was assigned, on the basis of conodonts, to the Late Emsian by Perry, Klapper and Lenz (1974, p. 1058). These authors noted that a similar breccia occurs on Solo Creek (presumably unit 4).

Some observations and deductions

The state of affairs depicted in Figure 6, it bears repeating, is not adequately documented, but it will serve as a basis for discussion.

In the opinion of Lenz (1972, section 22) Unit 1 contains Lower and Middle Ordovician strata but the only published fossil identification (Norford, 1964) indicates a

Silurian age. Possibly both authors are correct and Ordovician through Lower Silurian strata are present in Unit 1, i.e. a Road River or transitional Road River facies equivalent to the Mount Kindle and Franklin Mountain formations.

The Unit 2 dolomite must be either Silurian or earliest Devonian (no published fauna); it could be a bank facies of either the Mount Kindle or Delorme Formations. Whatever its age, it must lie at or very near to its western carbonate/shale front because only the Road River facies is exposed in the lower Peel Canyon, 30 km to the west (Lenz, 1972, Section 23).

In Figure 6 it is implied that the carbonate debris in Units 3 and 4 was derived from the upper part of the Unit 2 carbonate bank. A similar interpretation had been deduced by Geophoto Services Ltd. (1962). This relationship is also implicit in the mapping on the Wind River sheet (D.K. Norris, 1982a). If this interpretation is correct, then the upper part (at least) of Unit 2 must be Lower Devonian. In other words, the Unit 2 dolomite probably represents the seaward edge of the Delorme carbonate bank. Note that we do not know the precise age of uppermost Delorme strata in this area, merely that it is older than Late Emsian (Fig. 5C).

If, however, Unit 2 is the Mount Kindle Formation (Upper Ordovician-Lower Silurian) as deduced from Section 22 of Lenz (1972), then the contact between Units 2 and 3 must be an erosional unconformity.

Whatever the age of Unit 2, by Early Devonian time the area over which Units 3 and 4 were deposited lay in fairly deep water, as attested to by the turbiditic deposits. No thorough study of current directions has yet been published. Cook and Mullins (1983, Fig. 54) deduced a south to north transport for Unit 4.

NOISY CREEK AREA

Noisy Creek, a tributary of the Bonnet Plume River, flows in a northerly direction through the northeastern quadrant of the Wind River map area. East of its headwaters, near latitude 65°25'N, is the western termination of the front ranges of the Mackenzie Mountains. On this terminal mountain the upper part of the Mount Kindle Formation and a nearly complete section of the Delorme Formation are well exposed, both composed of shallow-water carbonates as typically developed in the Mackenzie Mountains farther east. Along Noisy Creek and its tributaries, deeper water, shaly Road River strata are exposed.

Road River strata of the headwaters area of Noisy Creek occupy a north-plunging syncline. Precambrian rocks of the Knorr Range underlie the western limb, with dips up to 85°E. On the eastern limb, dips in the exposed shale are less, up to 35°NW. A covered belt, about 4 km wide, separates the Road River exposures from the Mount Kindle and Delorme carbonates to the east; this is not evident from the Wind River map, which shows a fault, down on the west, between the two facies belts.

Excellent exposures of basal Road River strata occur in creeks and ridges along the western limb and north-plunging south end of the syncline. Upper Road River strata are best exposed on the eastern limb. To obtain a complete Road River section several segments, scattered over an area of about 100 km^2, must be pieced together. This fact, plus the occurrence in this area of several small normal faults, accounts for some of the discrepancies among the measured sections to be discussed.

On Wind River map (D.K. Norris, 1982a) a section location is plotted at 65°23'N, 134°11'W (No. 14). This section was studied by A.W. Norris and the description first published in Norford (1964, Section 4). The same section, with more detail, was given in A.W. Norris (1967, Section 7) and later in A.W. Norris, 1985. This location is near Section No. 20 of Lenz (1972). A.W. Norris' section is incomplete, and Lenz gave no lithologic details; therefore Section M-2 (Williams, 1969), though lacking any paleontologic control, serves as the basis for the following discussion.

Section M-2, generalized on Figure 7, is a composite section. The basal part (Units 1 to 5) has the same location as the section plotted on the Wind River map (No. 14). Unit 6 was studied in an east flowing stream valley some 6 km to the northwest; Units 7, 8 and the Canol Formation were studied on the eastern limb of the syncline along the main branch of Noisy Creek. The various segments of Section M-2 add up to about 2 km, however, because of many hazards to accuracy, the total error could be ± 500 m.

Description of units

Unit 1, bedded chert and carbonates

The limestone and dolomite beds are medium to dark grey, micrograined, argillaceous, laminated, thin bedded. About 50% of the rock consists of black chert in regular bands usually less than 10 cm, but occasionally up to 25 cm thick.

The upper contact with a carbonate conglomerate is well exposed but is highly fractured and veined with calcite. There has been some tectonic disturbance but the relationship is, almost certainly, an erosional unconformity.

The lower contact lies within a 30 m covered zone. Strata below are structurally concordant and consist of dense dolomite and shale typical of Precambrian sediments elsewhere on Knorr Range. On a ridge adjacent to the studied section a layer of quartzite 15 m thick lies between the Precambrian dolomite and Unit 1. Whether this is a basal Paleozoic sandstone or a Precambrian sandstone is not known.

As a mappable unit on air photos, Unit 1 thins from east to west and disappears within about 3 km.

Unit 2, coarse debris-sheets in shale

The outcrops are often massive, resembling a normally deposited carbonate. However, the conglomeratic texture is evident on close inspection. Pebbles and boulders are composed of limestone, dolomite and, rarely, of black chert; they appear to have been derived from the underlying unit. The matrix consists of finer grained detrital carbonate with fragments of brachiopods, crinoid stems, corals and stromatoporoids. Covered intervals, judging from talus, consist of dark shale.

The conglomerate lenses thin from east to west and lose all topographic expression within a distance of 2 km.

Unit 3, bioclastic limestone and shale

The basal 60 m of this unit consist of dark calcareous shale. Above this shale the lower part of Unit 3 consists of fine to medium-grained bioclastic limestone; graded bedding occurs in some layers. There are scattered, well rounded limestone pebbles. Dark shale partings, and layers of dense argillaceous limestone occur throughout the section. Brachiopods, crinoid stems and corals are abundant.

The upper half of Unit 3 consists mainly of dark calcareous shale with layers several metres thick of dense argillaceous limestone. Lenses and pods of bioclastic material occur throughout. Brachiopods, corals and monograptids are abundant.

Unit 4, mainly covered

There are a few small outcrops of dark calcareous shale and argillaceous limestone.

Unit 5, shale, shaly limestone with debris flows

This unit consists of dark grey calcareous shale gradational to shaly limestone; shale predominates in the lower part. There are many thin layers and one thick (30 m) layer of bioclastic limestone or limestone-pebble conglomerate. Both pebbles and matrix consist of bioclastic (mostly crinoidal) lime-mudstone.

North from the measured section Unit 5 is mostly covered, Units 4 and 5 form a prominent strike valley that extends a distance of 15 km. Within this distance there are 40 or more discrete carbonate masses. These range in size from a few tens of metres in width and thickness to nearly 1 km in length (along strike) by 40 m thick. The predominant lithology is a sparsely bioclastic light-coloured lime-mudstone (see Macqueen, 1974, p-325 (Emsian carbonate masses)). Their resistance to erosion in comparison to the enclosing shaly strata, plus a steep dip, results in their pinnacle-like profile. The carbonate knobs are apparently not limited to any one stratigraphic horizon, but occur throughout the interval of Unit 5.

Characteristically neither bedding or texture are evident in these knobs. Under favourable weathering conditions, however, a conglomeratic texture is obvious, with fragments up to a metre in size. Boulders and matrix are of the same composition. These carbonate masses have been interpreted as reefs by many geologists, however they are, almost certainly, channel deposits, as interpreted by Cook and Mullins (1983; see their Figs. 56, 57, p. 574).

Unit 6, ridge-forming limestone

The dominant lithology is medium to dark grey, shaly lime-mudstone with rare layers of bioclastic limestone and interbeds of calcareous shale. There are a few layers, only a centimetre or so thick, of chert-pebble conglomerate. Corals, brachiopods and crinoid stems (including two-holers) are abundant.

Unit 7, calcareous shale, shaly limestone

Unit 7 is not exposed in contact with Unit 6, it was examined on the other side of the syncline, some 5 km to the east, where the base is not exposed.

It consists of medium to dark grey calcareous, blocky, thin bedded to rubbly shale, grading in the upper 100 m to dark grey, shaly to silty lime-mudstone. The uppermost beds contain soft-sediment slump structures, interbeds of black fissile shale, and large pyrite nodules.

Unit 8, Canol-like shale

The dominant lithology is dark grey to black, hard, siliceous, platy shale. The streak ranges from brown to grey. Thin concretionary limestone beds occur near the top.

Giant oblate carbonate concretions (or concretion-like masses) occur sporadically. These are composed of micrograined limestone or dolomite with thin, even bedding. Several small orthocones were seen in shale talus.

This unit is fairly resistant, forming steep cliffs that show patches of red or yellow weathering. On the plateau areas the talus weathers a distinctive silvery colour. The main distinction from the Canol Formation is in the presence of the giant concretions.

Canol Formation

This shale is black, hard, platy, noncalcareous, with a brown streak (bituminous). Cliffs weather to a yellowish colour. The lower contact, apparently conformable, was placed at the top of the highest occurrence of concretionary limestone.

Relation to units of D.K. Norris (1982a) Wind River map

The Lower Cambrian Illtyd limestone is mapped along the east flank of the northern end of Knorr Range. This unit pinches out, or is truncated, from north to south; it is not present in Section M-2. Strata labelled Road River Formation on the Wind River map include Units 1 to 5 of Section M-2 plus, probably, shaly strata that are older than Unit 1. D.K. Norris' Ogilvie Formation Formation is Unit 6, the ridge forming limestone; his Lower and Middle Devonian shale unit (Dsh) includes Unit 7, 8, and the Canol Formation of Section M-2.

D.K. Norris mapped a fault, down on the west, separating the shaly strata of Noisy Creek from carbonate strata on the mountain east of Noisy Creek. The map gives the impression that the two contrasting facies are in contact across the fault; actually a covered belt at least 4 km wide along Noisy Creek separates the two facies. This fault may exist as mapped, however a 20°W dip, at the level of the Precambrian surface, would accommodate the stratigraphic displacement.

The stratigraphic section of A.W. Norris (1967, 1985 and in Norford, 1964)

This section was first published as Section 4 in Norford (1964); more lithologic and paleontological detail was published later (A.W. Norris, 1967, Section 7); a graphic summary appears on Figure 5 of Norris (1985). A.W. Norris' Road River Formation corresponds well with Units 3, 4, 5 and probably the basal part of Unit 6 of Section M-2, if allowance is made for minor differences in measurements. This correlation is confirmed by Norris' reference to the distinctive carbonate masses in the upper third of his Section (Norris, 1985, p. 12).

Underlying Norris' Road River Formation is a unit labelled Ordovician(?); this is described in Norford (1964, p. 33) as fine to medium crystalline limestone with silicified corals, none identified (*ibid.*, p. 124). Only 158 feet (48 m) were seen. How this particular unit fits with Section M-2 is unresolved. It cannot be the bedded chert and carbonate, Unit 1. Is it part of Unit 3? boulders from Unit 2? part of the dolomite mapped as Little Dal Formation? a remnant of Mount Kindle dolomite not present in the M-2 exposure? Interestingly, dolomite rubble with a Mount Kindle aspect was seen near Section M-2 but was not found in place (Williams, 1969).

Sections 20 and 21 of Lenz (1972)

The coordinates given for Section 20 plot about 4 km west of where the basal units of Section M-2 were studied. Unit 1 and the conglomerate lenses of Unit 2 of Section M-2 thin to the west-northwest; this is apparent on air-photographs and was confirmed on the ground (Williams, 1969). It is probable that both Units 1 and 2 are missing where Lenz studied the section and found Gidennian rocks lying directly on the Precambrian. It was on the basis of this relationship that Lenz (1972, p. 327) introduced the term 'Bonnet Plume High'.

Lenz (*ibid.*, p. 344) mention ". . . small Lower Emsian reefs . . ." near his Section 20; this is obviously a reference to the debris flows of unit 5, Section M-2.

Section 21 of Lenz is located some 22 km farther north. Here, according to his chart (*ibid.*, p. 325) the Road River section includes Lower, Middle and Upper Ordovician a well as Lower and Upper Silurian. In other words, in the Noisy Creek area north of the Bonnet Plume High, the Ordovician-Silurian part of the Road River Formation is considered to be without significant gaps.

Age and correlation

Unit 1, the bedded chert and carbonates is lithologically identical to Unit C of the Snake River Section L-2, (Fig. 4) which, as deduced from Lenz (1972) is probably Upper Ordovician. This unit is also similar to Unit 1 in the core of Solo Creek dome (Fig. 6) which, according to Norford (1964), is Silurian. Lenz (1972) apparently did not encounter Unit 1 in his Section 20, however, in his discussion on Lower Ordovician paleogeography (*ibid.*, p. 335) he states that a tongue of "deeper-water graptolitic shale and limestone paralleled the east side of the Bonnet Plume High . . ." In a later paragraph (*ibid.*) "Near the junction of the Knorr Range . . . and the Mackenzie Mountains to the east, a coarsely crystalline dolomite, reef-like mound lies stratigraphically beneath Lower Ordovician graptolite-bearing shales". Leaving aside, for the moment, the reference to the reef-like mound, it is apparent that Lenz observed fossiliferous Lower Ordovician shales in an outcrop east of, but not far from, the unit 1 outcrops of Section M-2.

A fossil localty is recorded within D.K. Norris' Road River Formation at a point 10 or 11 km north of Section M-2 (location 89892, Wind River map). This collection is probably late Middle Ordovician according to B.S. Norford (pers. comm., 1987).

In summary, Unit 1 is probably of Ordovician age.

The remainder of the section, up to the base of the Canol Formation, must range from Gidennian to (at least) Early Eifelain (Section 20 of Lenz, 1972, p. 325). The debris flows of Unit 5 are Early Emsian with faunal elements in common with the Michelle Formation (*ibid.*, p. 344; Macqueen, 1974, p. 326). These lie on *Monograptus yukonensis* bearing shale (Perry, Klapper and Lenz, 1974, p. 1057). Units 2 to 5 of the Noisy Creek area (Gidennian to Early Emsian) correlate with the dated basal section of the Road River Formation at Solo Creek (Sieginean to Early Emsian; Fåhraeus, 1971).

On the basis of its stratigraphic position, the abundance of two-holed crinoids, and a vague lithologic similarity, the ridge-forming limestone, Unit 6, may correlate with the Cranswick limestone at Snake River. The Cranswick is Late Emsian (Pedder and Klapper, 1977). By elimination, then, the shale of Units 7 and 8 must be Eifelian and, possibly, younger Devonian.

The Mystery dolomite

As was mentioned previously in the discussion of the relationships of the M-2 Section to Wind River map units, D.K. Norris (1982a) mapped a fault between the Noisy Creek syncline and the western end of the Mackenzie Mountains. The most persuasive evidence for a fault in this area is the apparent juxtaposition of Devonian shaly strata and the dolomite mapped as the Precambrian Little Dal Formation (approximately 65°23'N, 134°08'W). Only a narrow gravel-filled creek separates the two rock types. I am convinced that this is a Paleozoic dolomite, based on vague organic textures. I found it impossible to determine its structural attitude. The dolomite shows no obvious signs of major faulting. The dolomite may indeed be in faulted contact with the Devonian strata, a consequence of compression in the core of the syncline, but it may be a bank-edge carbonate more or less in its original stratigraphic position. This is the relationship depicted on Figure 7.

As mentioned previously, Lenz (1972, p. 335) reported a reef-like mound stratigraphically below Lower Ordovician shale, which, he postulated, was a Lower Ordovician reef. This reference, almost certainly, is to the Mystery dolomite.

There are, then, three interpretations, all tenable on the basis of present knowledge, on the identity of the Mystery dolomite: A Precambrian fault slice, a Lower Ordovician reef, or the western edge of the Delorme carbonate bank. It is the latter that is depicted on Figure 17, Times 6 and 7.

Some observations and deductions

The area of good exposures is small, confined mainly to a narrow north-south trending belt, with only a short segment with east-west trending exposures. Therefore, it is impossible to draw any definite conclusions regarding facies trends or tectonic history. However, a few observations are pertinent.

1) No Cambrian rocks are present in the headwaters, however, Lower Cambrian carbonates occur farther north on Noisy Creek. Whether these rocks are missing because of non-deposition, inferring a Cambrian high, or post-Cambrian erosion cannot yet be determined.

2) Ordovician deep water strata occur within a few kilometres west, north and east of Lenz' Section 20 where Lower Devonian deep water strata lie directly on the Precambrian. Given the present state of our knowledge, this phenomenon can be interpreted in at least three ways:

   a) A paleohigh that remained emergent, i.e. above sea level, through Ordovician to Early Devonian time, as per Lenz (1972, p. 327, the Bonnet Plume High).

   b) A submerged paleohigh which, because of its sea bottom relief, received no sediments until Early Devonian time.

   c) A small(?) fault block that was uplifted and subjected to subaerial erosion as deep as the Precambrian, at some post-Ordovician–pre-Early Devonian time, and then down-faulted into deep water.

   If explanation a or b is correct, the same explanation could apply to the missing Cambrian strata (item 1); if explanation c is correct, the unconformity cannot explain the missing Cambrian.

3) Throughout Early, Middle and much of Late Devonian time the Noisy Creek area remained a site of deep water sedimentation.

4) We have too few data to determine the direction of transport of the Devonian debris sheets. The fact that the conglomerates of Unit 2 thin and pinch-out from east to west suggests a westward flow in Early Devonian time. The fact that the Emsian carbonate channel deposits occur with a fairly even distribution along a north-south trending strike valley suggests that the carbonate bank from which they slumped lay either to the east or to the west. Carbonate banks of the appropriate age existed to the east (Snake River area). Similar banks are also known to the west (e.g. Royal Creek area) but were much more remote.

THE ROYAL CREEK AREA

Royal Creek is a north-flowing tributary of the Wind River. The area of interest, centred about 65°N, 135°W, lies near the southwestern edge of the Bonnet Plume Cretaceous basin. Geological maps covering the area are the Wind River sheet, GSC map 1528A (D.K. Norris, 1982a), and the Nash Creek sheet, GSC map 1282A (Green, 1972).

The Royal Creek area is renowned for its excellent exposures of Silurian to Lower Devonian strata of contrasting facies: shallow-water carbonate bank facies and deep water shaly facies. The two facies belts are juxtaposed with little tectonic disruption of their original geometry. The Royal Creek area was a highlight of Field Excursion A14 of the 1972 International Geological Congress (Lenz and Pedder, 1972).

Most publications dealing with the Royal Creek area are concerned with the paleontology, particularly of the Silurian-Lower Devonian shaly strata. The simplified, interpretive diagram, Figure 8, was constructed mainly from reports by Fritz (1974) and Macqueen (1975) augmented by other material listed in Table 1.

Discussion of units

Illtyd Formation (Lower Cambrian, *Bonnia-Olenellus* Zone)

This unit consists of shallow-water platformal carbonates with minor fine clastics. Large bioherms, up to 180 m thick, occur in the easternmost exposures (Fritz, 1974, p. 311). Fritz speculates that the lithology indicates a rapid transgression over an eroded Precambrian surface of low relief (*ibid.*, p. 309). This unconformity is noticeably angular at Section 74-1A, 8 (southeastern end of Fig. 8).

Slats Creek Formation (Middle Cambrian, *Albertella* and *Glossopleura* Zones)

In the Wind River sheet this unit consists of siltstone and sandstone with local lenses of conglomerate. The large clasts are identifiable as locally derived from Proterozoic rocks. The thickness varies rapidly over short distances.

In the Nash Creek sheet, to the south, the Slats Creek equivalent consists of up to 1070 m of red sandstone, conglomerate and shale with several volcanic flows (Unit 5 of Green, 1972). This unit overlies the Precambrian with an angular unconformity.

Taiga Formation (Upper Cambrian)

D.K. Norris (1983) describes this unit as about 300 m of fine crystalline limestone and dolomite. It is not clear how this unit fits with the measured sections of Fritz (1974).

A profound unconformity at the base of the Taiga Formation can be seen on the Wind River map in an area about 65°02'N, 134°40'W (just southeast from MQ-13, Fig. 8). Here the unconformity cuts down-section from northwest to southeast truncating the ± 1500 m of the Middle and Lower Cambrian strata within a distance of 6 km, an angularity in the order of 10° to 15°.

Unnamed Upper Cambrian-Lower Devonian carbonate (ЄDb)

Where fully developed this unit ranges in age from Late Cambrian to Early Devonian or even, according to Lenz (1972), into Middle Devonian (*ibid.*, Sections 39, 41).

The unit is in the order of 2 km thick. The dominant lithology (Macqueen, 1975, p. 292) is fine to coarse grainstone; pellet grains are most abundant, other grains are ooids and bioclasts. A fenestral fabric is characteristic but other indicators of intra or supratidal conditions are lacking (*ibid.*, p. 293). Norford (1964, section 5) mentions the occurrence of limestone conglomerates; Fritz (1974, p. 32) mentions the occurrence of several layers of pseudo-breccia. Within this thick carbonate unit there are no recognizable unconformities or mappable sub-units, at least at the reconnaissance scale of mapping (Macqueen, 1975, p. 292).

As shown on Figure 8, the upper half (approximately) of this shallow-water carbonate bank is missing from the Royal Creek embayment. The age of the carbonates that directly underlie the shale-fill of the embayment is Ordovician, probably early Late Ordovician (collection C-26720, Macqueen, 1975).

Road River Formation

The most detailed lithological description of this unit is provided by Norford (1964, Section 6). Most paleontological detail occurs in various publications dealing with the headwaters of Royal Creek, an area some 35 km to the south; a summary is given by A.W. Norris (1985, p. 13). For present purposes it will suffice to state that the Road River Formation here consists of variably calcareous, dark-coloured, deep water shale (which may be up to 80% silica, Macqueen, 1975, p. 297) containing numerous allodapic limestones derived from the carbonate bank on the east. The uppermost strata consist of dark grey to black, noncalcareous shales and black chert; these are, probably, the Canol-like shales of Lenz (1972) and are part of Unit 13 of Green (1972).

The oldest Road River fauna obtained within the Royal Creek channel, according to published sources, is ?Ludlovian (Lenz, 1982), but Pedder (pers. comm., 1987) reports a probable Llandoverian age (Early Silurian) from the lowest exposed debris flow. The youngest fossiliferous strata in this area are of Emsian age (Lower Devonian, *inversus* conodont Zone, A.W. Norris, 1985, Fig. 3). Higher beds (Canol-like shales) are as yet undated. On Fig. 46.2 of Macqueen (1975), collections C-24748 to C-26753 (Early Devonian), as plotted, give the impression that they came from a position high in the Road River Formation. Actually, as is made clear in the text (*ibid.*, p. 298) these collections came from redeposited limestones that occur in the lower part of the Road River Formation.

In Section MQ-15 no Silurian fossils were found; if any Upper Ordovician or Silurian Road River strata are present here they must lie within the basal 150 m of the section, most of which is covered (Macqueen, 1975, p. 297). A similar situation occurs in the headwaters area to the south: a thin Silurian part of the Road River Formation (under 300 m), and a thick Lower Devonian part, over 500 m (Lenz, 1982, Fig. 2).

Geometry of the Royal Creek shale trough

From the reconnaissance-scale maps presently available little that is definite can be said. A short segment of a west-facing carbonate front is exposed at Royal Mountain. Assuming no significant lateral fault displacements, a mirror-image front, lying some 15 to 25 km to the north-northwest is demanded by the evidence (Fig. 8). This second front has not yet been recognized in outcrop. It is reasonable to conclude that this Royal Creek embayment was connected with the main Richardson Trough to the north, although this is by no means established.

Some 35 km due south of Royal Mountain Green (1972) mapped a 16 km long, north-south trending fault that separates carbonate strata on the east from Road River strata on the west. According to Pedder (pers. comm., 1987) this feature is actually a well exposed facies front, as seen at Royal Mountain. Clasts the size of houses can be seen in debris beds near the carbonate bank.

If one assumes that the two exposed segments were parts of one major front, then the shale trough extended for at least 50 km along a north-south direction. Such a geometry was favoured by Lenz (1972, e.g. his Fig. 9). There are other options. Rather than a cul-de-sac configuration there may have been a strait (one of several?) linking the Richardson and Selwyn paleodeeps. Or there may have been two isolated, more or less 'landlocked', semi-starved shale basins, of unknown shape or orientation, within the extensive carbonate bank. Or (a third option) it may be more correct to regard the Silurian to Devonian carbonate masses, such as that at Royal Mountain (Fig. 8) as large but isolated carbonate 'islands' that developed within the Road River seaway, the platform being the Upper Cambrian to Upper Ordovician carbonate blanket.

Some observations and deductions

Over those areas (fault blocks?) where Upper Cambrian through Lower Devonian carbonate banks developed there must have been remarkable tectonic stability. Through this time, approximately 130 m.y., subsidence amounted to about 2 km, an average rate of 15 m/m.y. Within this bank (or banks), so far as is known, there are no major unconformities and no interspersed shale tongues.

In some areas, including the Royal Creek shale trough, something happened in Late Ordovician time to cause carbonate production to cease. With continued subsidence such drowned areas remained almost starved of sediment until Early Devonian time (Fig. 8), at which time they must have lain under several hundred metres of water. How does one explain the paucity of Upper Ordovician-Silurian detritus in spite of the proximity of the carbonate bank? Are we seeing the effect of strong eroding or corroding currents?

A drowning event, or events, probably beginning in Middle Devonian time, put an end to carbonate production over the entire area. Slow clastic accumulation in deep water produced the Canol-like and Canol shales.

THE BONNET PLUME AREA - A SYNTHESIS

The four areas discussed above are all situated near or adjacent to the southern end of the Richardson Trough. This trough, as described by Lenz (1972, p. 329) persisted from at least Late Cambrian to Early Devonian time as a locus of deep-water sedimentation; contemporaneous sediments on the east and west flanks are shallow-water carbonates. Most of this paleotrough is now the site of the southern Richardson Mountains - a broad anticlinorium that formed at some uncertain time during Late Paleozoic and/or Early Mesozoic. The Richardson Anticlinorium coincides in area with, and is no doubt related genetically to, the Richardson Fault Array (D.K. Norris and Hopkins, 1977), a set of deep-seated, high-angle, dextral strike-slip faults of ancient lineage. The "complex kinematic history of the several blocks contained within the Richardson Fault Array . . . led ultimately to the development of the Bonnet Plume Basin . . ." (*ibid.*, p. 15), a Late Cretaceous successor basin which lies on the foundered southern end of the Richardson Antinclinorium (D.K. Norris, 1973, p. 27). Given this tectonic setting, it is not surprising that the Bonnet Plume area, including the Snake River, Noisy Creek, Solo Creek and Royal Creek areas, present some interesting and complex stratigraphy.

Paleogeographic reconstructions of Paleozoic strata that include all or part of the Bonnet Plume area have been presented by Norford (1964), Gabrielse (1967), Ziegler (1967), Douglas et al. (1970), Lenz (1972), Cecile (1982), Cecile and Norford (1985) and A.W. Norris (1985). That there are significant differences in interpretation is not surprising, given the tectonic, structural and stratigraphic complexity, and the reconnaissance nature of present geological maps.

The following attempt at an historical synthesis is focused on the Bonnet Plume area, which is but a small fraction of the above-cited reconstructions. The history is depicted by a series of maps and one set of time-slice cross-sections, Figures 9 to 19. The eastern belt covered by these figures is the western edge of the Mackenzie

Platform. Over this area (which includes the Snake River area) the geology is simple and reasonably well documented. The western belt is the realm of the Richardson Fault Array, where the reverse is true, and there are few constraints on the imagination.

Late Precambrian rifting

The Late Precambrian Windermere Supergroup (800-570 MA) extends the length of the Canadian Cordillera to at least as far north as Knorr Range (Fig. 9); from that point the Precambrian plunges north below Paleozoic cover, so the precise northern limit is unknown. Although the northeastern and southwestern limits shown on Figure 9 are erosional, the area of preservation may be a clue to the shape and orientation of the original basin. Eisbacher (1981), from an analysis of thickness, facies and depositional fabric has demonstrated that synsedimentary, rift-related tectonics controlled Windermere sedimentation. The basin axis (*ibid.*, p. 20) was aligned parallel with the Snake River-Knorr Faults. That the Snake River Fault was a major, probably transcurrent, fault zone was deduced from the fact that it separates distinctly different pre-Windermere Proterozoic assemblages (*ibid.*, p. 9). Post-Windermere right-lateral movement, in the order of 40 km, across the Knorr Fault has been deduced by D.K. Norris and Hopkins (1977, p. 15). They base this interpretation on the dramatic contrast in facies between the Rapitan diamictites west of Margaret Lake (point X, Fig. 9) and the mudstone units of the Knorr Range (point Y) which, they assume, are time equivalents. The time (or times) of movement across the Knorr Fault is unresolved.

As far as this present study is concerned, the main significance to be derived from Figure 9 is that the tectonic regime that will be postulated for various Paleozoic units had been established by Late Proterozoic time.

Cambrian basins and arches

Although in the deeper parts of the Selwyn Basin the Precambrian/Cambrian contact may be transitional (Fritz, 1982; Gordey, 1980) over most of western Canada, including the Bonnet Plume area, there was uplift, at least mild structural tilting, and bevelling by erosion.

Lower and Middle Cambrian sediments are present in the Richardson Trough and the Selwyn Basin but are missing in the area between (Fig. 10). The question is, what was the original extent of these sediments? Or, put another way, when did the intervening arch rise?

Concerning Lower Cambrian strata there is no compelling evidence as to whether or not an arch separated the northern and southern seas. Both the Illtyd Formation of the north and the Sekwi Formation of the south consist primarily of shallow-water carbonates with subordinate clastics (Fritz, 1974, 1976, 1978). It is possible that both formations are products of a single seaway resembling the Late Precambrian precursor (Fig. 9). At Time 1, Figure 17, the Lower Cambrian Illtyd carbonate is shown as overlain by and partly equivalent to a shale unit. Although such a shale is not known in the Bonnet Plume area, it's probable existence has been postulated by Fritz (1974, p. 311). An eastern sandstone facies analogous to the Backbone Ranges sandstone of the Selwyn Basin is entirely geophantasy.

Through Middle Cambrian time the arch must have been rising. In the Royal Creek area of the northern basin, Slats Creek strata consist of sandstone and conglomerate. Fritz (1974, p. 312) postulated ". . . small, fast-filling basins separated by areas of uplift . . .". This, plus the presence of Middle Cambrian volcanics in the Nash Creek map area (Green, 1972), suggests an extensional tectonic regime. Figure 17, Time 2, depicts synsedimentary movements within the Richardson Fault Array. South of the arch in the Misty Creek Embayment the Middle Cambrian Hess River Formation contains a thick flysch which was derived from the northwest (Cecile, 1982, p. 10).

Figure 11 depicts conditions at a time near the Middle/Late Cambrian boundary. At this time the three Cambrian seas were at least partially isolated from each other by three major arches: the Redstone (Mackenzie) Arch, its northern continuation, the Peel Arch, and the Ogilvie Arch (see Map 3, Williams, 1987). The Bonnet Plume area, as here interpreted, formed a land bridge connecting the three major arches. The presence of such a feature is deduced from: a) evidence for highlands from Middle Cambrian sediments, cited above, b) the angular sub-Upper Cambrian unconformity that cuts down section from north to south in the Royal Creek area (Wind River map, approximately 65°N, 134°35'W) and c) the fact that no Upper Cambrian strata have been found in the Noisy Creek area. This latter item could be as well attributed to other factors, including post-Cambrian erosion.

Following conditions depicted by Figure 11, a Late Cambrian transgression eventually linked the three seaways, completely covering the Redstone and Peel Arches, leaving a blanket of shallow-water carbonates (basal Franklin Mountain Formation or, in the Snake River area, unit E dolomite (Fig. 4)). Over these former land areas the basal contact of this Upper Cambrian unit is paraconformable, indicating that there had been little earlier Cambrian tectonic activity other than epeirogenic uplift (or eustatic fall). To the west, across the presumed Bonnet Plume Arch, a similar shallow-water Upper Cambrian carbonate (Taiga Formation) onlapped a terrain that had suffered considerable tectonic disruption. Figure 12 summarizes what is known of the nature and distribution of Upper Cambrian strata. In Figure 17, Time 3, it has been assumed that parts of the Bonnet Plume and Knorr fault blocks remained above sea level through Late Cambrian time.

Ordovician to Devonian seaways - the Bonnet Plume connection

As no Paleozoic strata are preserved over a large area between the Richardson Trough and the Misty Creek Embayment (Fig. 2) we can never know the paleogeography with certainty. Figures 13 to 16 show a deep water connection lasting through

Ordovician into Devonian time. This follows the reconstructions of most geologists (e.g. Lenz, 1972) but is in conflict with Cecile (1982) who believes that there probably was not a deep water connection, at least through Late Cambrian to Silurian time. Reasons for believing that a connection did exist include: a) "Strata assigned to the Road River Group in both basins are not only similar as a whole, but are similar at the formation level as well" (Fritz, 1985, p. 209). b) A transition belt within Lower and Middle Ordovician strata (carbonate to shale) is mappable east of, but flanking, the main Richardson and Misty Creek deeps (Fig. 13). A similar late Emsian front adds support (Fig. 16). c) The analogy provided by the Windermere rift-basin (Fig. 9, after Eisbacher, 1981).

Maps, Figures 13 to 16 and time-slice diagrams, Figure 17, Times 4 to 7, should be self-explanatory. The following items stress the main underlying assumptions:

1) The Late Cambrian Bonnet Plume Arch disappeared with the foundering of blocks of the Richardson Fault Array. This foundering was accompanied by westward tilting of the Mackenzie Platform (Fig. 17, Time 4).

2) To explain the occurrence of deep water strata lying unconformably on rocks as old as Proterozoic in the Noisy Creek area (Bonnet Plume High of Lenz, 1972) it is postulated that the Knorr block was particularly prone to yo-yo tectonics: uplifted some time in the Silurian, then plunged again to the depths (Fig. 17, Times 4, 5 and 6). The sub-Delorme unconformity (lower orange zone, Fig. 5A), coincided with the time of maximum uplift of the Knorr block (Time 5).

3) It has been assumed that the Mystery dolomite (Noisy Creek area) is a fragment of what was the seaward edge of the Delorme bank (Figs. 15, 17, Time 6). During Delorme time (Late Silurian-Earliest Devonian) the western edge of the Mackenzie Platform tilted westward (isopachs, Fig. 15). This tilting continued to a lesser degree through later Devonian time (Fig. 17, Time 7).

4) The Illtyd block, it has been assumed, underwent slow but continuous subsidence, and received a thick blanket of shallow-water carbonates uninterrupted by significant erosion (Fig. 17, Times 3 to 6) then was drowned in early Middle Devonian time (Time 7). Drowning occurred earlier over adjacent blocks (for ease in drafting, carbonate/shale fronts are shown coincident with faults).

5) The line of section of Figure 17 does not transect the Royal Creek channel (Fig. 8). However, conditions similar to those within the channel apparently also prevailed over a large part of the Yukon Stable Block. The stratigraphic section depicted on the west end of Figure 17 is based on sections 10 and 11 of A.W. Norris (1985) where 600 to 700 m of Road River strata (mostly Devonian) overlie an unmeasured carbonate whose age, at its top, is Late Ordovician.

6) The pre-Canol unconformity is a result of sediment-starvation in deep water. This condition prevailed for differing spans of time in different areas; the age of Canol-like shales, over distance, varies from Emsian to Fransian (Lenz, 1972, p. 349). Most geologists postulate pre-Canol uplift and subaerial erosion at the pre-Canol unconformity (e.g. A.W. Norris, 1985, p. 31 and his Fig. 14; Lenz, 1972, p. 347 and his Figs. 11, 12).

A return to life as an arch

A late Paleozoic uplift

Through Late Devonian and at least part of Mississippian time the Richardson Trough, including the Bonnet Plume area, formed a part of a much-enlarged depocentre into which a large volume of terrigenous clastics were transported, mainly from the north and northwest (Bassett and Stout, 1968, Figs. 10, 11; A.W. Norris, 1985, Figs. 15, 16). In most areas the Devonian/Mississippian contact is gradational, and not a lithologic break; for example the Tuttle Formation, as defined by Pugh (1983) straddles the boundary or, in terms of older nomenclature, the Imperial Formation ranges into the Mississippian. In the Bonnet Plume area, however, there is evidence for erosion at the Devonian/Mississippian contact.

The evidence is summed up on Figure 18. There is too little information to construct a sub-Mississippian map. Point B is in the Noisy Creek area, i.e. on the Knorr block of Figure 17. In this area the recognition and distribution of many formations is rather tentative (see the liberal use of question marks in the Noisy Creek area, Wind River map 1528A). However, taking the mapping at face value, nonmarine Mississippian clastics overlie Devonian Road River shale (mapped as Dsh, Wind River map). To the east and west (points A and C, Fig. 18) this contact is conformable and occurs within marine strata. From what we know of the Canol and Imperial Formations there is no reason to doubt that they were deposited in this area. Hence the Knorr block, once again exhibiting yo-yo tendencies, must have popped up at some time near the Devonian/Mississippian boundary.

Whether or not other blocks of the Richardson Fault Array were involved in this disturbance is impossible to say. Nor is it known how far north this uplift may have extended. It is possible that this uplift of the Knorr block was the initial pulse of forces that eventually created the Richardson Anticlinorium.

The Richardson Anticlinorium

Figure 19 is a greatly simplified picture of the geology below the sub-Cretaceous erosion surface. This map was derived by plotting all unfaulted Cretaceous/Paleozoic contacts as mapped on the Wind River map. No attempt was made to consider the, no doubt complex, histories of individual blocks within the Richardson Fault Array. Nevertheless, the overall impression: a pre-Cretaceous north-plunging anticline at the southern end of the Richardson Anticlinorium, is probably correct.

The anticlinorium, of which only a small segment appears on Figure 19, extends for 150 km northward beyond the Peel River. Over most of this distance Middle Cambrian Slats Creek clastics form the core, flanked by Road River, Upper Devonian and Mississippian clastics. It is possible to date the development of the uplift only within broad limits. The uplift of the Knorr block (Fig. 18) may mark its inception; the pre-Permian erosion (point A, Fig. 18) may be a later manifestation. The maps of Dixon (1986, Figs. 10, 13, 16) suggest that most of the warping and erosion had been accomplished by Albian (Late Early Cretaceous) time.

The Cretaceous - Early Tertiary, Bonnet Plume Basin

The sediments and tectonic setting of this intermontane depression (Fig. 2) were discussed by D.K. Norris and Hopkins (1977). Since then, there has been some additional exploration, including drilling, to investigate coal reserves. For this more recent information I am indebted to A.R. Sweet (1987, pers. comm.).

The Bonnet Plume Formation consists of conglomerate, sandstone, siltstone, mudstone and coal or lignite. The total thickness is unknown but is at least 1500 m. In those areas that have been drilled there appear to be three sequences, each consisting of a lower part dominated by conglomerate and an upper part dominated by siltstones, mudstones and coal measures. The sediments are mostly, if not entirely non-marine; the conglomerates may be channel deposits, the finer sediments and coal measures formed in lacustrine and swamp environments. The age of the Bonnet Plume Formation ranges from Albian(?) to Eocene with no significant time gaps. The coal rank grades from high volatile bituminous in the lower part to lignite in the upper part of the formation.

An east-west gravity profile across the basin (Sobczak and Long, 1980) indicates that the axis of maximum thickness lies near the eastern edge of the basin, adjacent to the Knorr Fault. Apparent dips at the sub-Cretaceous unconformity are low on the west

(0 to 1°E) and high on the east flank of the basin (10-15°W) (*ibid.*, p. 50). This geometry suggests a half-graben. There has been some post-depositional tilting and faulting, however, in general, the Cretaceous-Tertiary rocks have suffered little deformation.

Scattered outliers of Cretaceous strata indicate that the original extent of the basin was somewhat greater than the present (D.K. Norris and Hopkins, 1977, Fig. 6). Surrounded as it is by Paleozoic mountains (Fig. 2) there can be no doubt that the Bonnet Plume Basin is, in part, a basin of preservation. Although there are no published detailed sedimentological studies, it is probable that the area was also a depocentre. However, perhaps 'basin' is not the best word to describe the tectonic setting. It is probable that the Bonnet Plume Formation represents a surviving segment of an aggrading stream: the ancestral Bonnet Plume River. This river delivered detritus from the rising Laramide orogen northward into the marine seas of the Eagle Plains.

SUMMARY

The name 'Bonnet Plume' signifies an area of east-central Yukon Territory. The Bonnet Plume is one of three northwesterly flowing rivers, the Snake, Bonnet Plume and Wind Rivers that together drain the area. The name has already been used for two tectonic features within the area: the Late Cretaceous Bonnet Plume Basin and the Early Paleozoic Bonnet Plume High.

The Bonnet Plume area contains the junction of three mountain systems: the Mackenzies, Werneckies and Richardsons. Within this area a system of north-south trending strike-slip faults, the Richardson Fault Array, meld with the easterly-trending folds and thrusts of the Mackenzie Mountains. Tectonic movements within this tectonic zone have exerted a profound influence on thickness, facies and subsequent preservation or erosion of strata ranging in age from Late Precambrian to Tertiary. The Bonnet Plume area was, in turn:

- part of a Late Precambrian rift-basin,
- Part of a mid or Late Cambrian arch,

- a deep water connection between the Richardson and Selwyn Basins, from Ordovician through Devonian time,
- part of the Late or post-Paleozoic Richardson Anticlinorium,
- part of a Cretaceous river system.

Some of the consequences of this complex history are revealed by the stratigraphy of four sites within the Bonnet Plume area: the Snake River, Solo Creek, Noisy Creek and Royal Creek areas. In the Snake River area there are carbonate/shale fronts, or transition belts at three levels: Ordovician (part of Franklin Mountain Formation), Lower Devonian (Landry Formation), and Middle Devonian (Hume Formation). In the Noisy Creek area and Solo Creek dome there are thick sections of Lower Devonian (pre-Landry) deep water, shaly strata that contain abundant carbonate detritus including conglomerates, turbidites, debris-sheets and channel fill. The Delorme Formation, was probably the carbonate bank that provided this debris, although the original geometry (bank to deep) as well as the precise correlation, remains obscure. In the Royal Creek area, in contrast, Silurian-Lower Devonian bank and deep water strata are exposed in what is, more or less, their original geometry.

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TABLE 1

Measured sections, Royal Creek area

	Central Illtyd Range	South Illtyd Range	Wind River East	Wind River West	Royal Creek	Royal Mtn.	Royal Creek East	Royal Creek headwaters	Prongs Creek
Maqueen, 1975	MQ-11	MQ-12	MQ-13	MQ-14	MQ-15	MQ-16			
Fritz, 1974	74-1A, 6		74-1A, 8	74-1A, 7					
Norford, 1964		63-39, 5			63-39, 6				
Norris, 1968					63-53, 8				
Norris, 1985		M-410, 9			M-410, 8		M-410, 36	M-410, 37, 38	M-410, 11
Lenz, 1972		39			40		41	42	38
Lenz and Pedder, 1972								I and II	

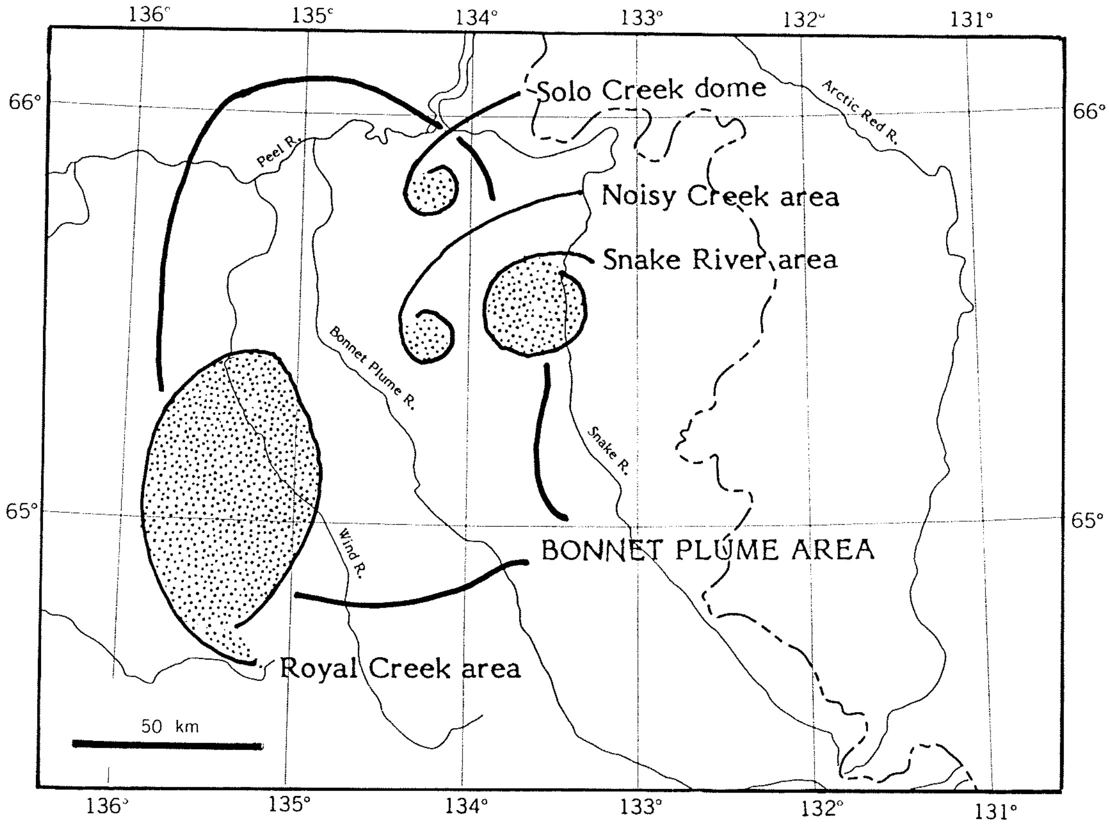


Fig. 1, Index Map

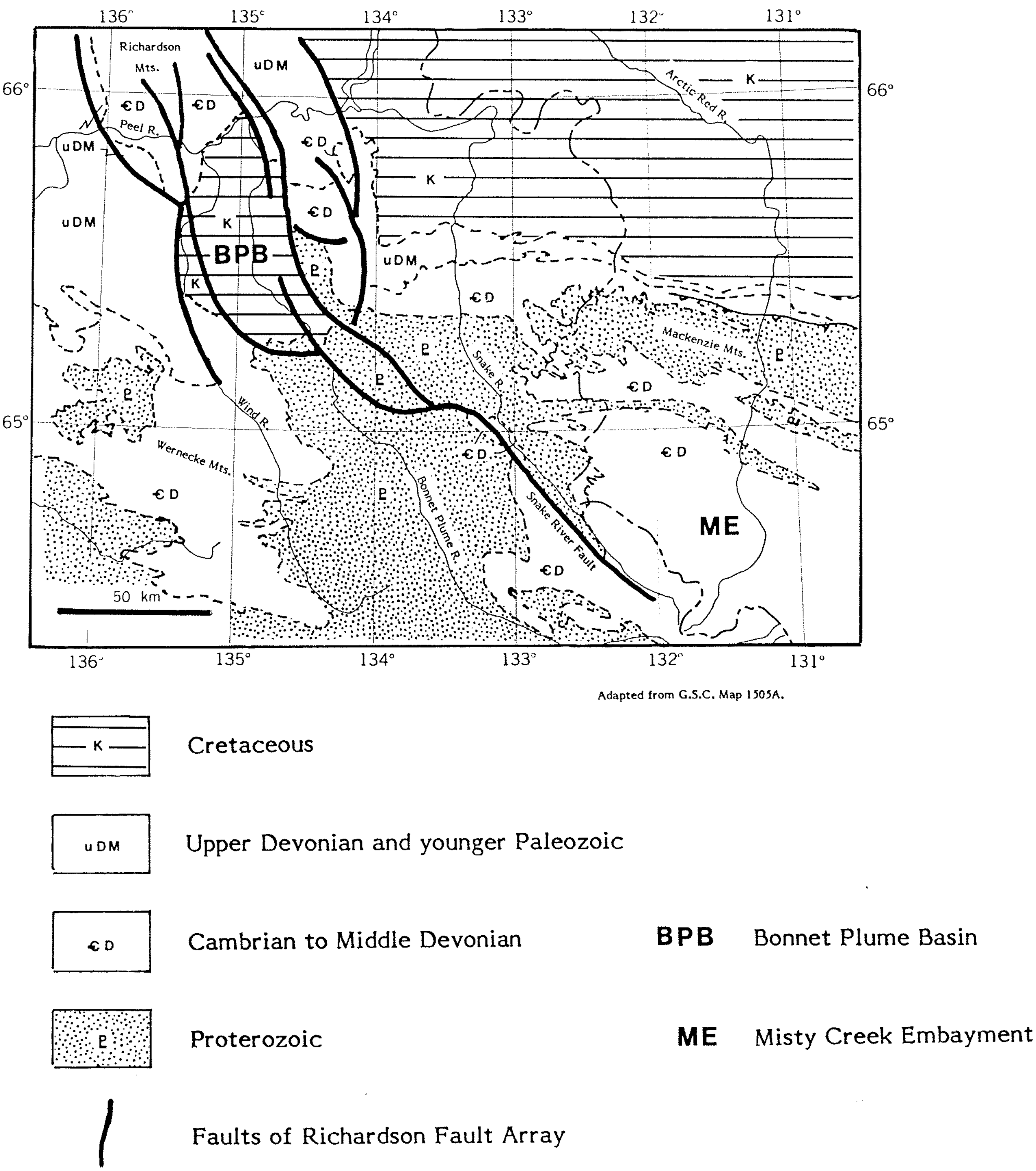
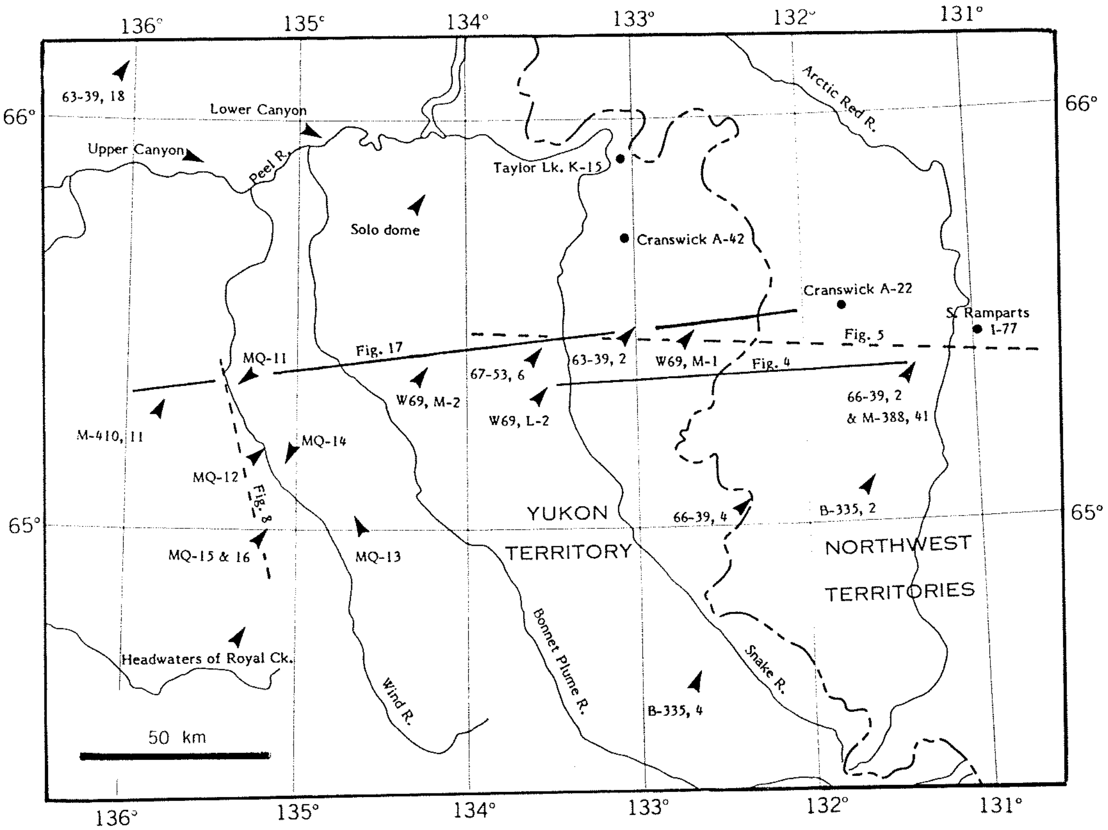


Fig. 2, Tectonic assemblage map.



• Wells

➤ Surface section

abbreviations:

M388	Aitken et al., 1982	G.S.C. Memoir 388
B335	Cecile, 1982	G.S.C. Bulletin 335
MQ	Macqueen, 1975	G.S.C. Paper 75-1C
63-39	Norford, 1964	G.S.C. Paper 63-39
66-39	A.W. Norris, 1967	G.S.C. Paper 66-39
67-53	A.W. Norris, 1968	G.S.C. Paper 67-53
M-410	A.W. Norris, 1985	G.S.C. Memoir 410
W69	Williams, 1969	Unpublished

Fig. 3, Selected control points.

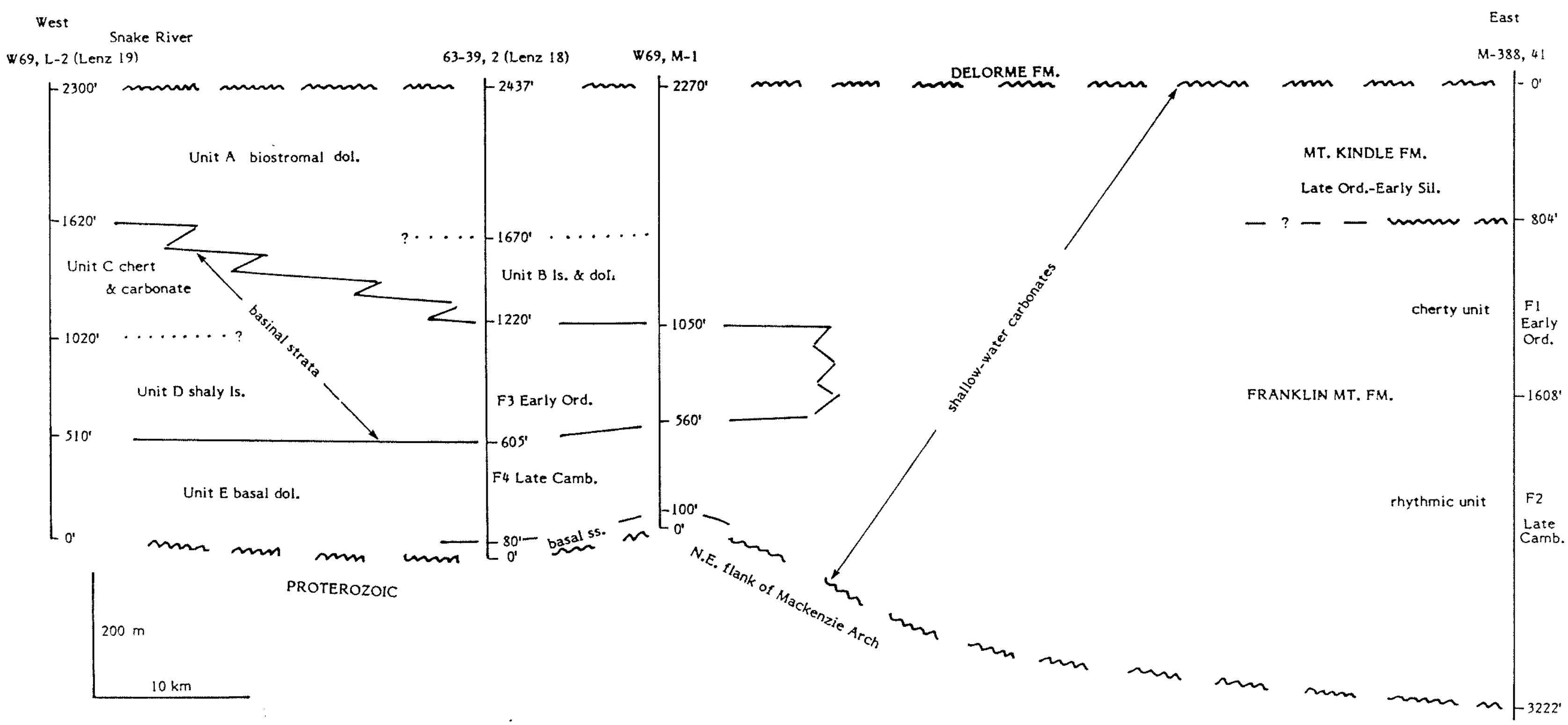


Fig. 4, Cross-section, Lower Paleozoic, Snake River area.

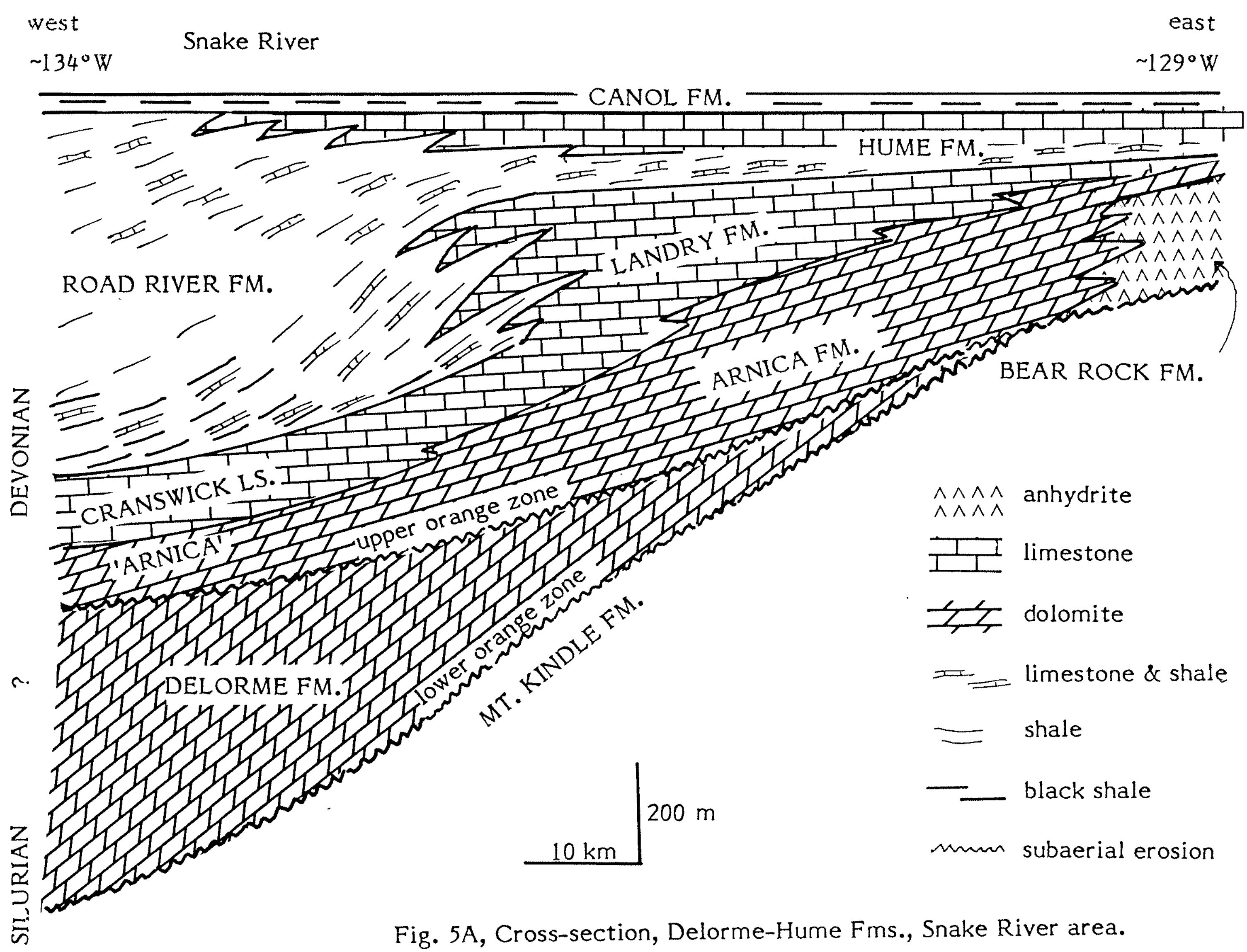
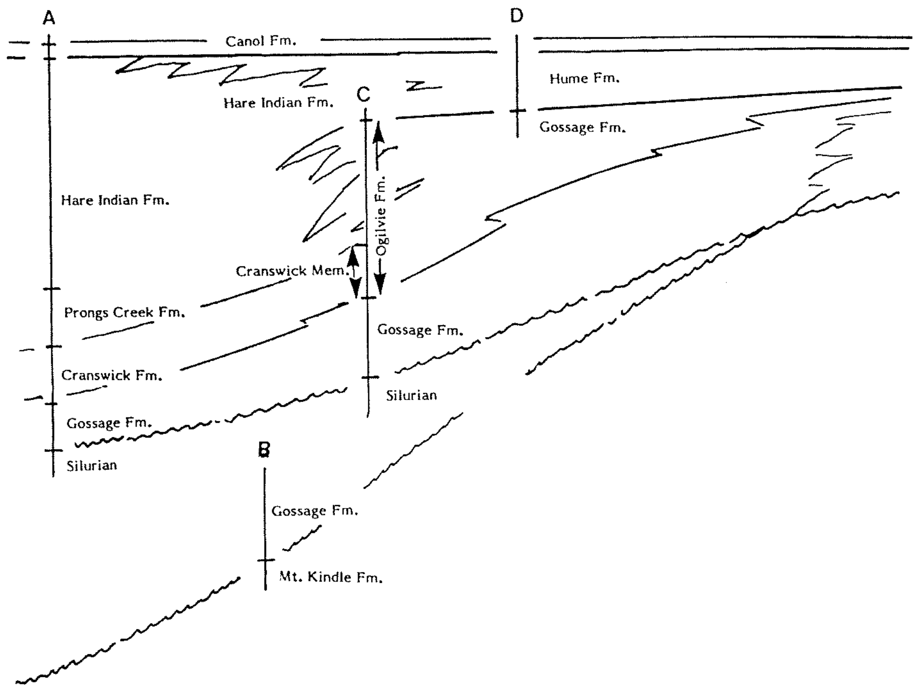


Fig. 5A, Cross-section, Delorme-Hume Fms., Snake River area.
Lithology



A. A.W. Norris, 1968, G.S.C. Paper 67-53, Section 6

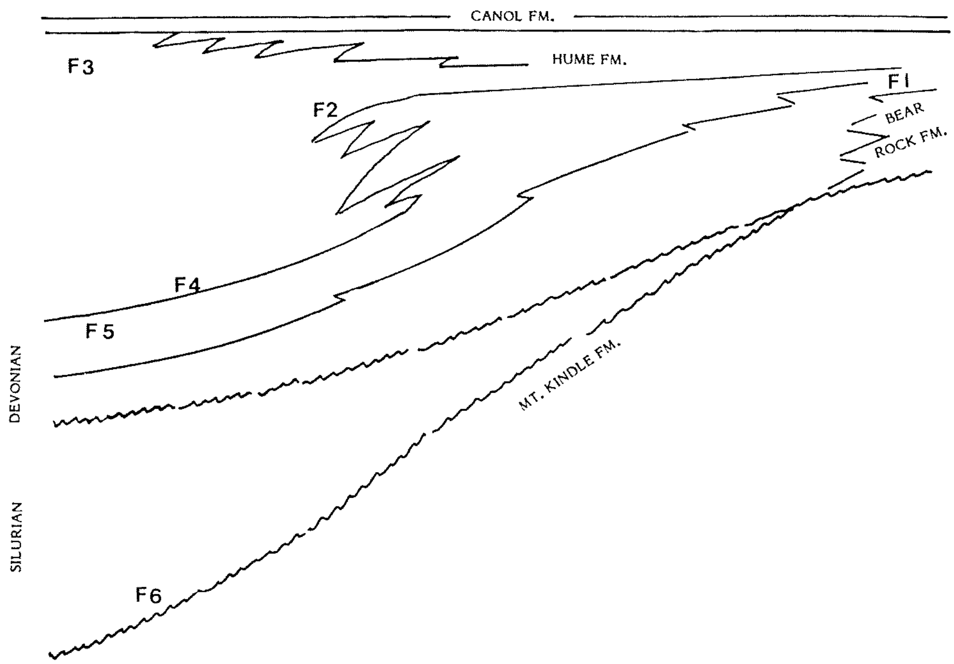
B. A.W. Norris, 1967, G.S.C. Paper 66-39, Section 5

C. *ibid.*, Section 4

D. *ibid.*, Section 2

Nomenclature as in cited reports

Fig. 5B, Important measured sections



F1 Late Emsian-Early Eifelain, Uyeno and Mason, 1975.

F2 Eifelian, c. *costatus* Zone, Raasch, 1982.

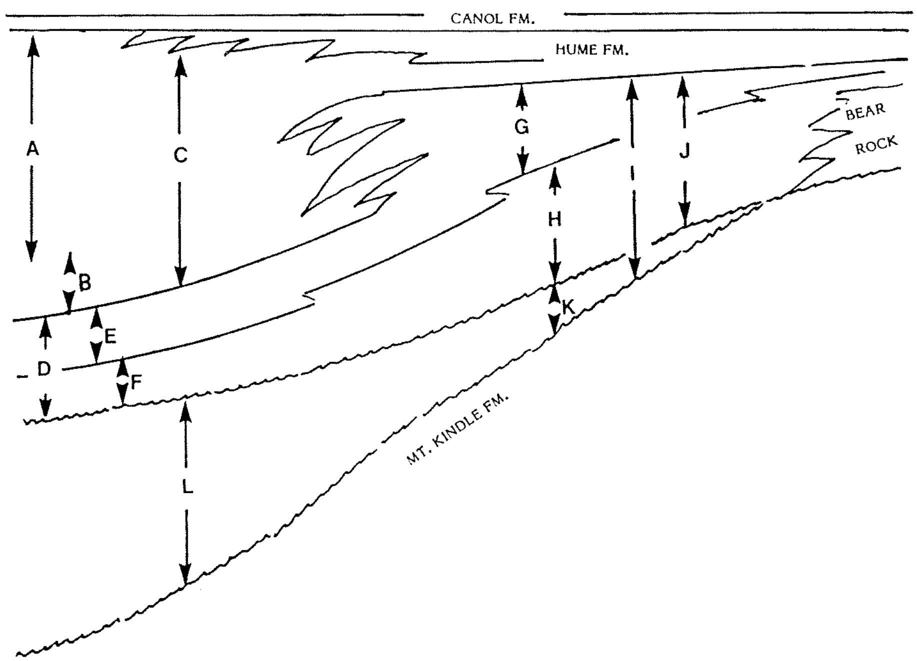
F3 Late Eifelian to Early Givetian, *ensensis* Zone, G.S.C. Loc. No. C-63124, T.T. Uyeno, pers. comm., 1984.

F4 Early Eifelian, c. *partitus* Zone, Raasch, 1982.

F5 Emsian, *inversus* and *serotinus* Zones, Pedder and Klapper, 1977.

F6 Late Silurian, Broad and Lenz, 1972. Ludlovian, G.S.C. Loc. No. 53133, T.T. Uyeno, pers. comm., 1984.

Fig. 5C, Significant fossil collections.



A, Hare Indian; A.W. Norris, 1968.
Mount Baird; A.W. Norris, 1985.

B, Prongs Creek tongue; A.W. Norris, 1968.
Road River tongue; A.W. Norris, 1985.

C, Battleship; Ziegler, 1967.
Dsh; D.K. Norris, 1982b.

D, Bear Rock; Ziegler, 1967.
Arnica; D.K. Norris, 1982b.

E, Cranswick; A.W. Norris, 1968.

F, Gossage; A.W. Norris, 1968.
Tatsieta; Pugh, 1983.
Unnamed carb.; A.W. Norris, 1985.

G, Landry; Aitken et al., 1982.

H, Arnica; *ibid.*

I, Gossage; Tassonyi, 1969.

J, Gosage; Aitken et al., 1982.

K, SD; *ibid.*

L, Delorme; Ziegler, 1967.
Gossage; A.W. Norris, 1967.
SD; D.K. Norris, 1982b.

Fig. 5D, History of nomenclature

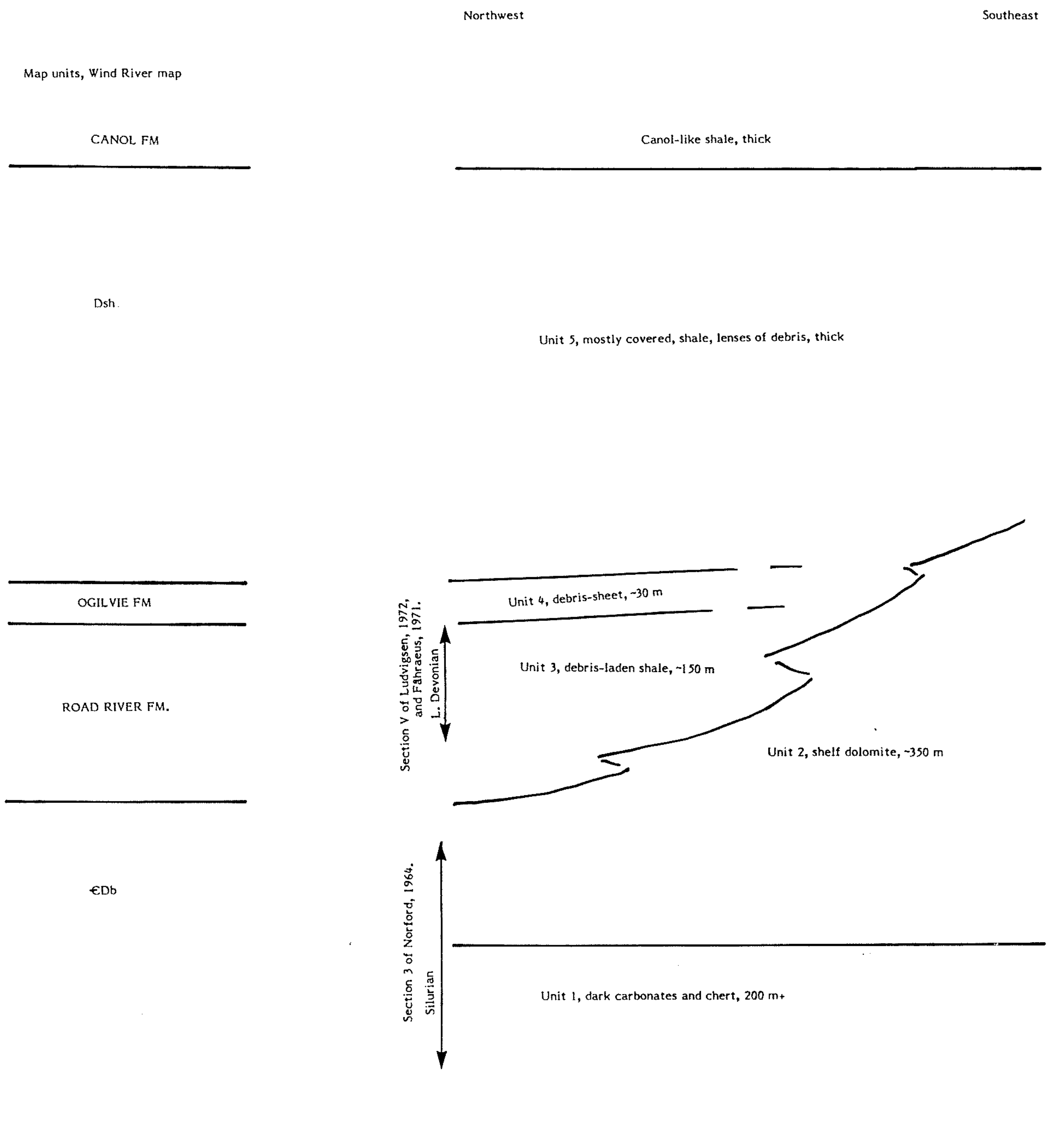


Fig. 6, Stratigraphic section, Solo Creek dome.

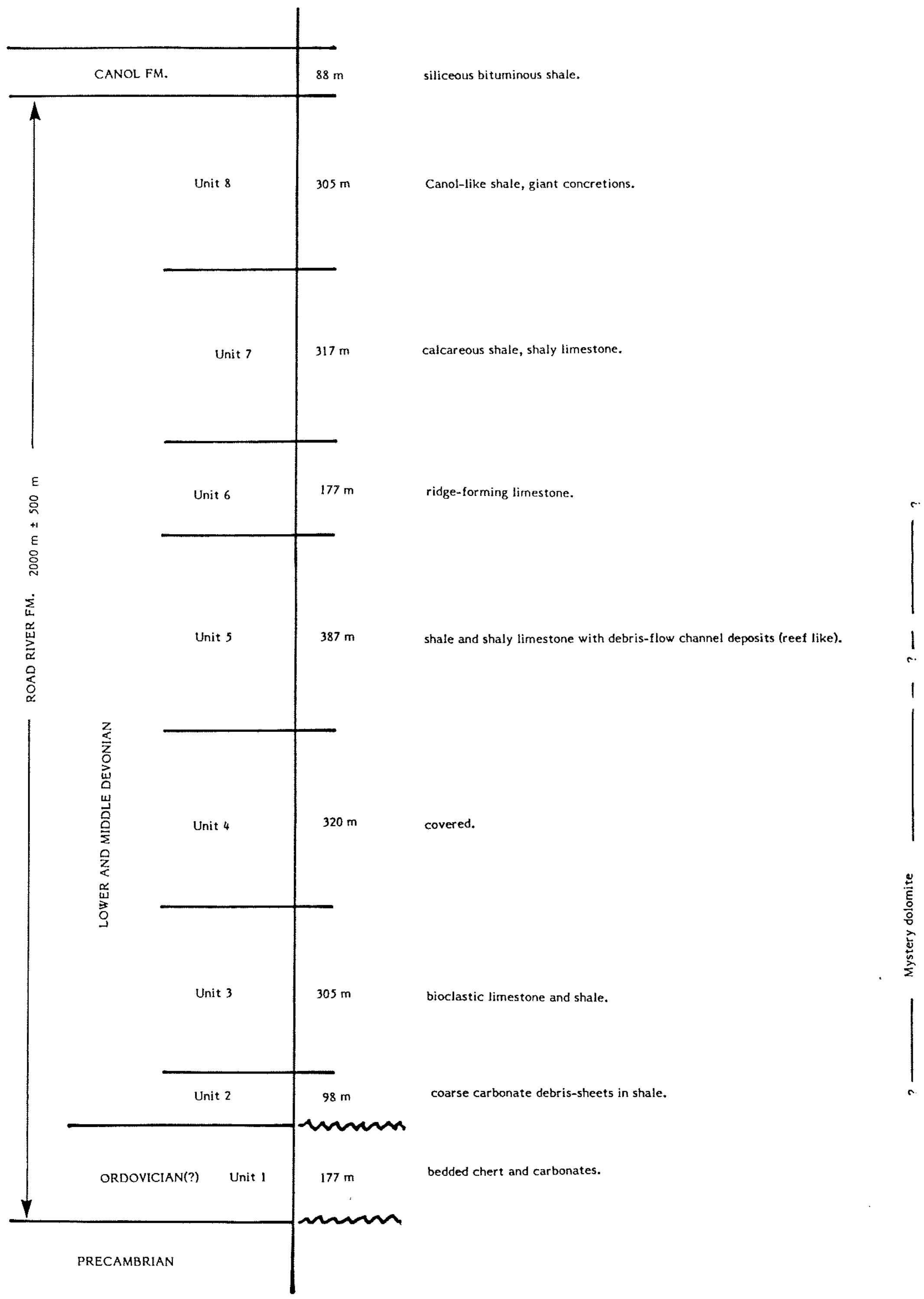


Fig. 7, Stratigraphic section W69, M-2, headwaters of Noisy Creek. ~65°23'N, 134°11'W.

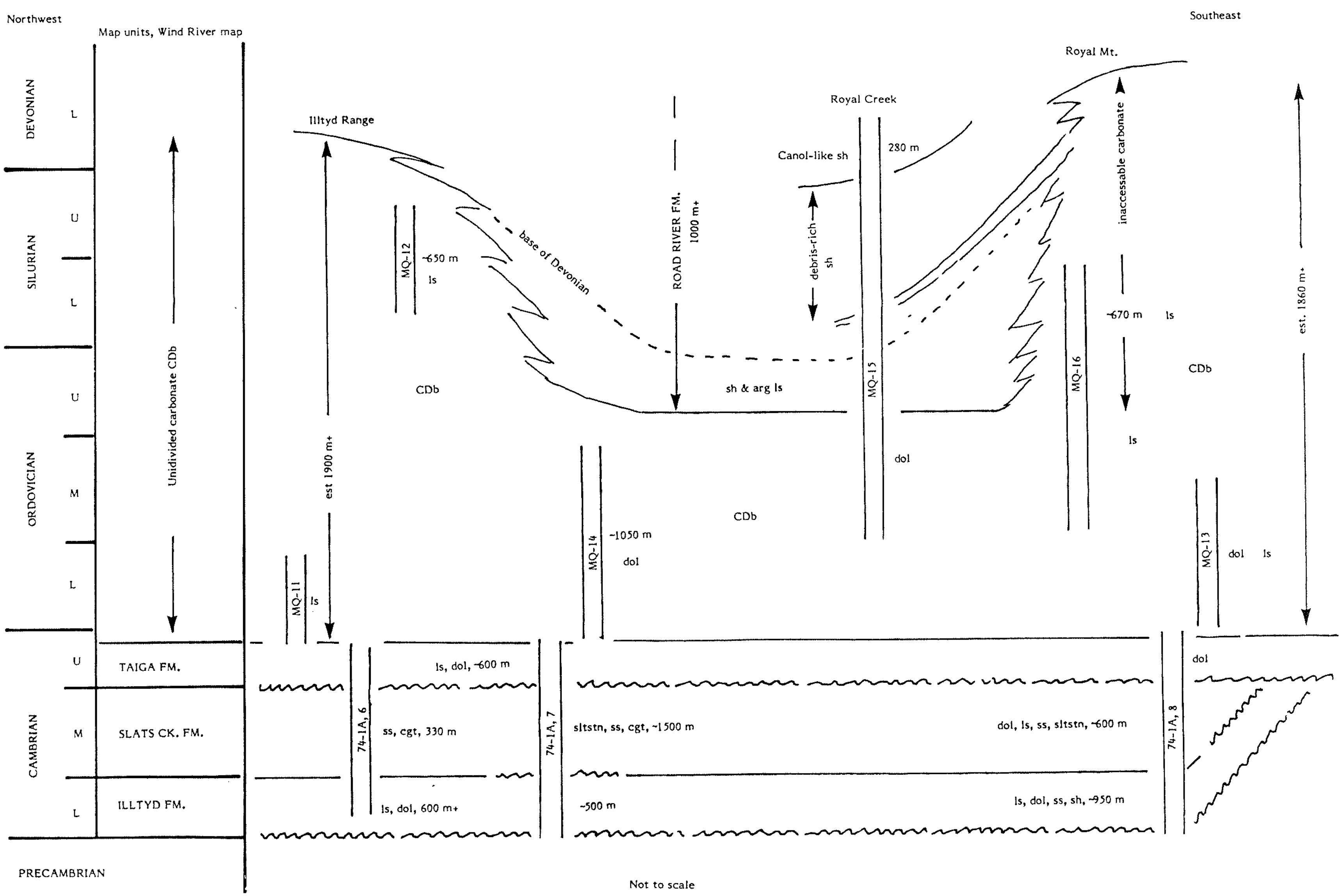
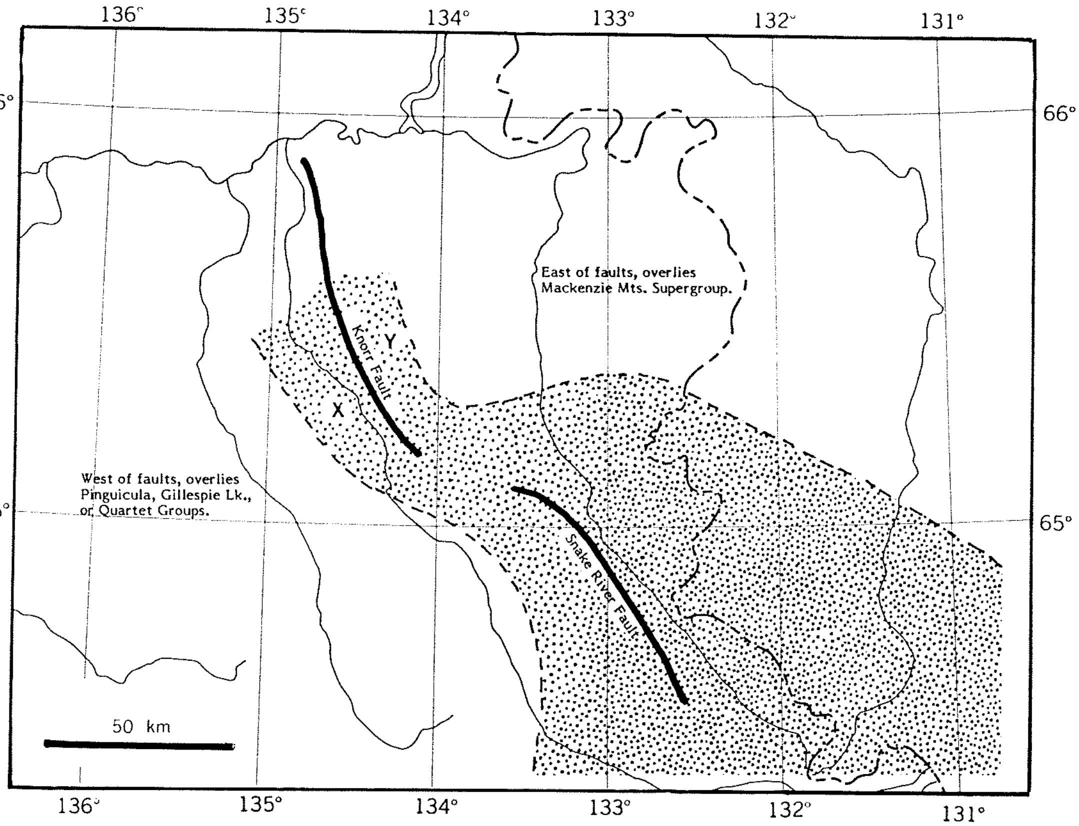


Fig. 8, Cross-section, Royal Creek area.



Modified from Fig. 13 of Eisbacher, 1981.

Windermere Supergroup

X Margaret Lake exposures

Y Knorr Range exposures

Fig. 9, Distribution of Windermere (Late Precambrian) rocks.

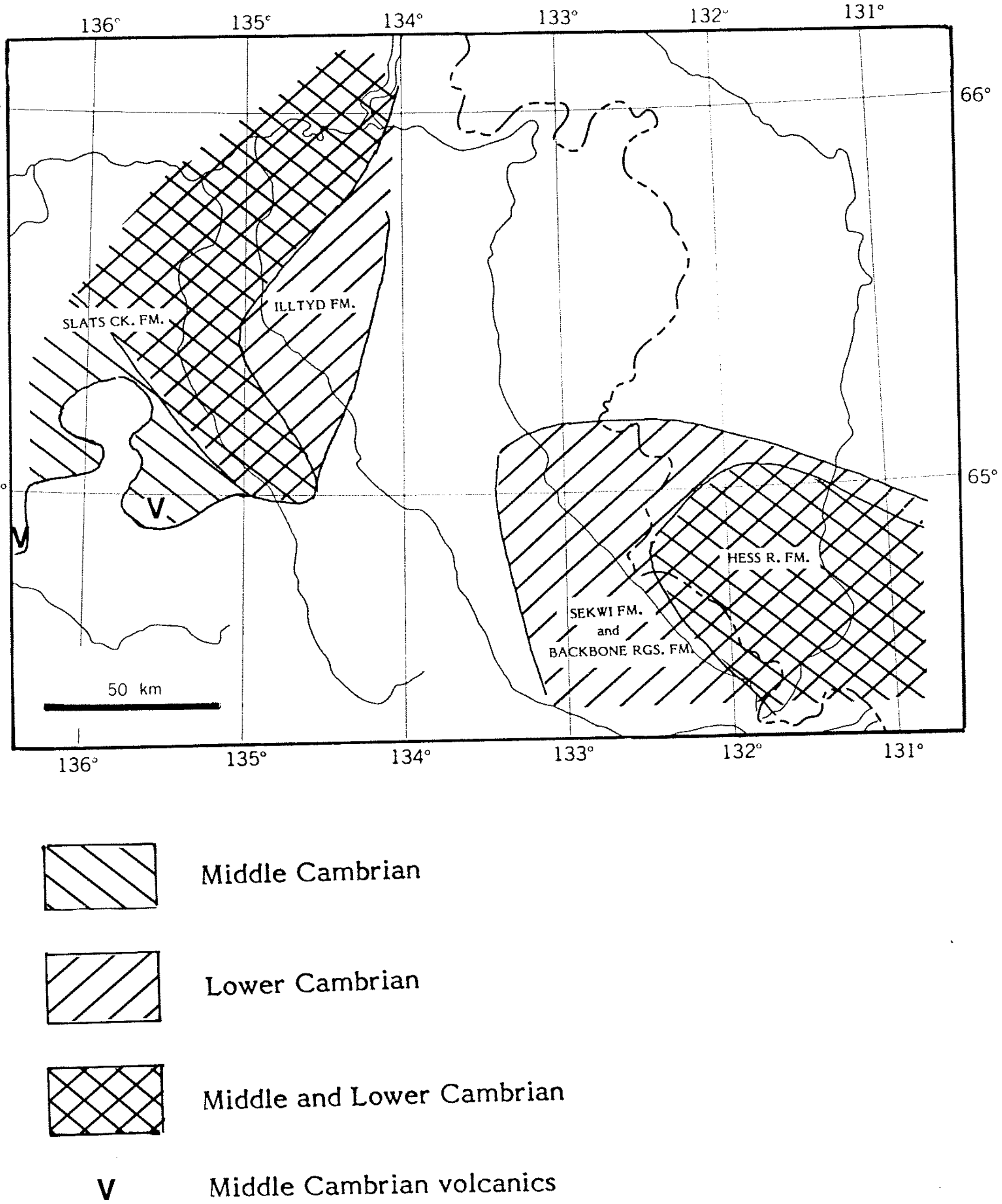
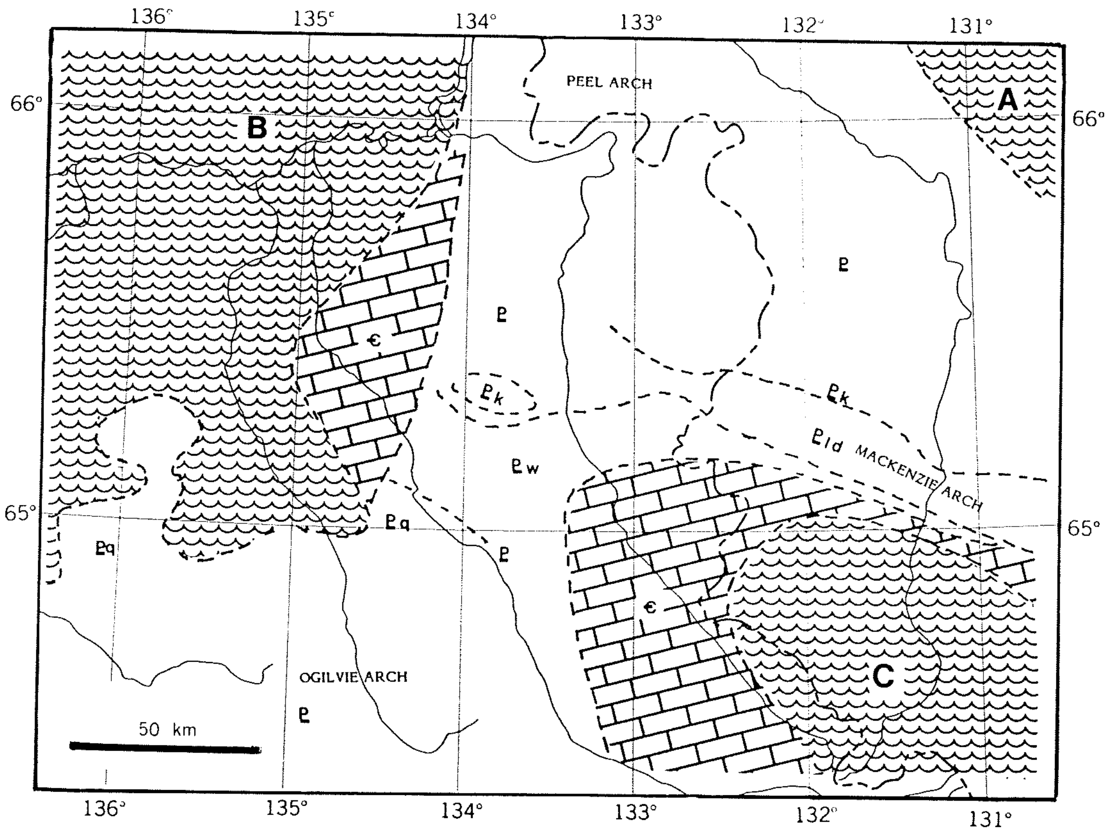


Fig. 10, Distribution of Lower and Middle Cambrian rocks.



Seaways, transitional contact:

- A Saline River Fm. to Franklin Mt. Fm., (Saline Sea)
- B Slats Creek Fm. to Road River Fm., (Richardson Sea)
- C Hess River Fm. to Rabbitkettle Fm., (Misty Creek Embayment)

Geology of exposed areas:

- Lower Cambrian
- Proterozoic
- Windermere Supergroup
- Little Dal Group
- Katherine Group
- Quartet Group

Little Dal Group and Katherine Group: Mackenzie Mts. Supergroup

Fig. 11, Geology and geography at a time near the Middle to Late Cambrian transition.

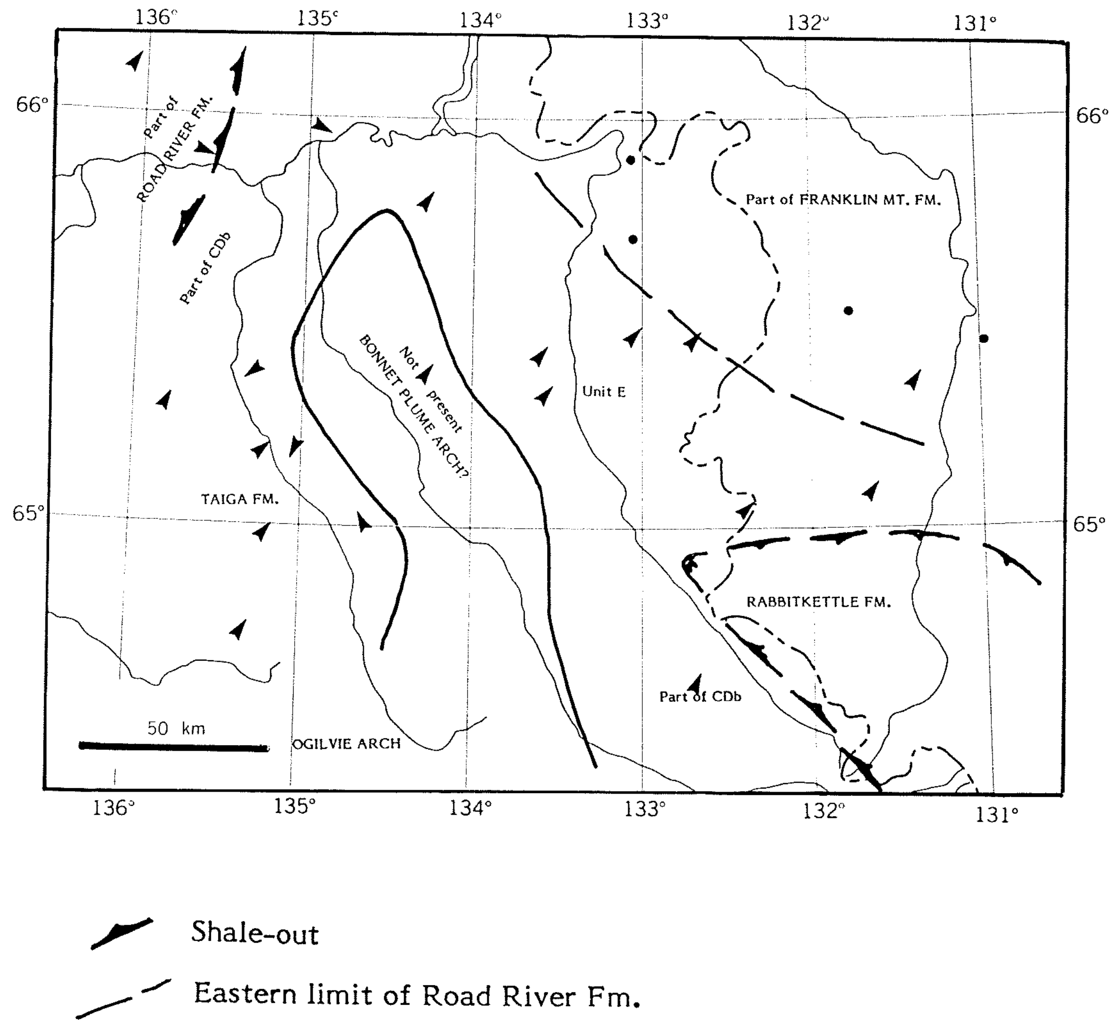
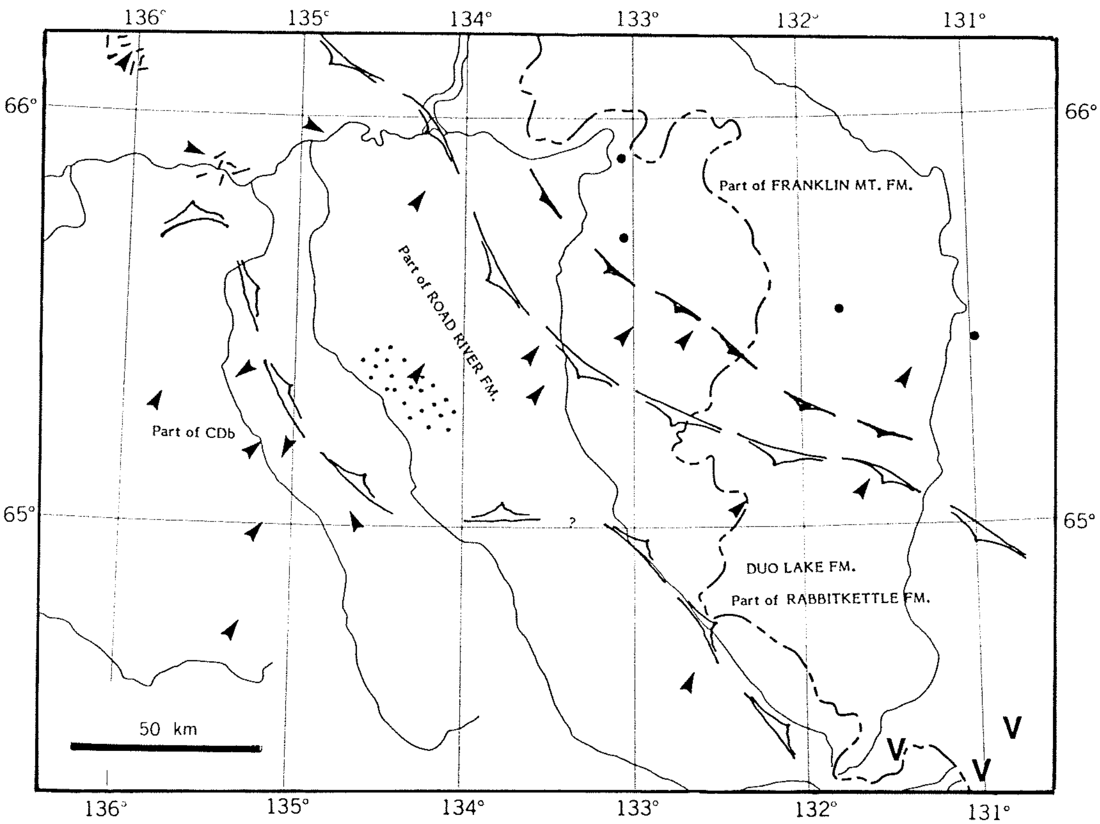


Fig. 12, Distribution of Upper Cambrian rocks.



Shale-out total.

Shale-out, partial.

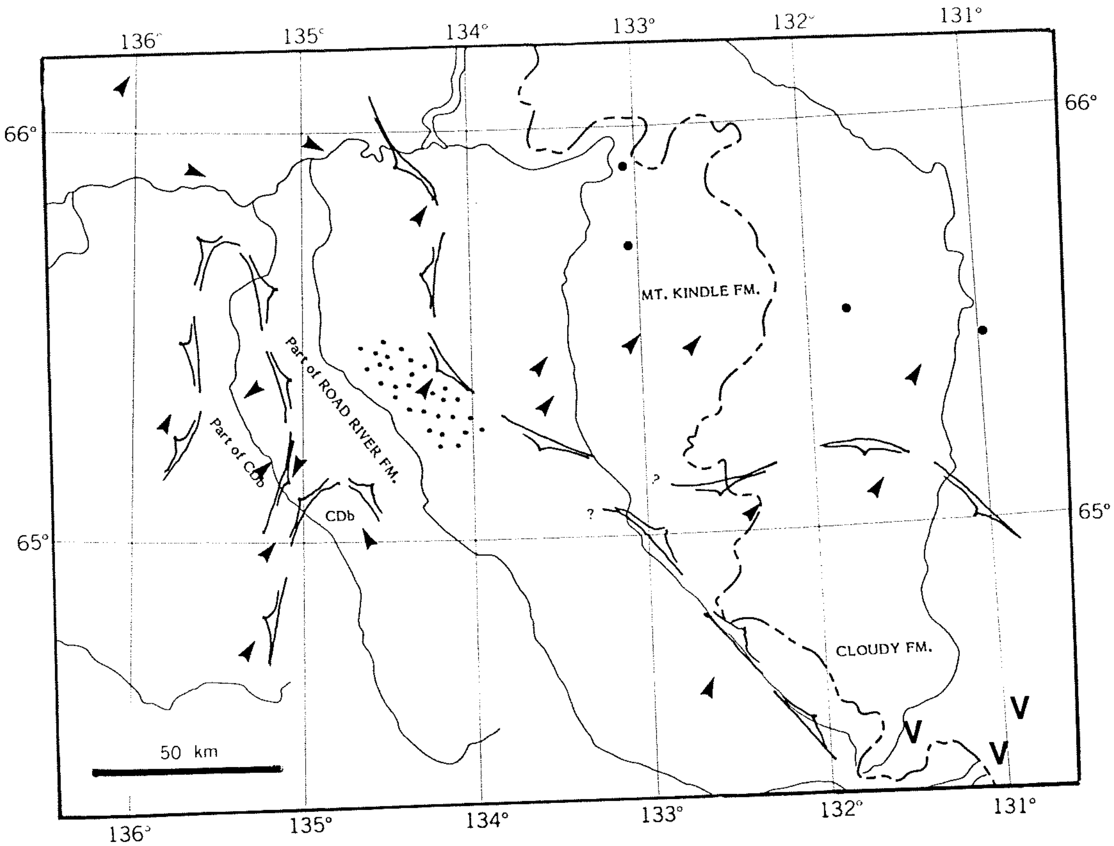
Lower and Middle Ordovician debris beds.

Section cut out by post Ord.-pre-Devonian erosion.

V Volcanics

CDb Undivided Cambrian-Devonian carbonate

Fig. 13, Distribution of Lower and Middle Ordovician rocks.



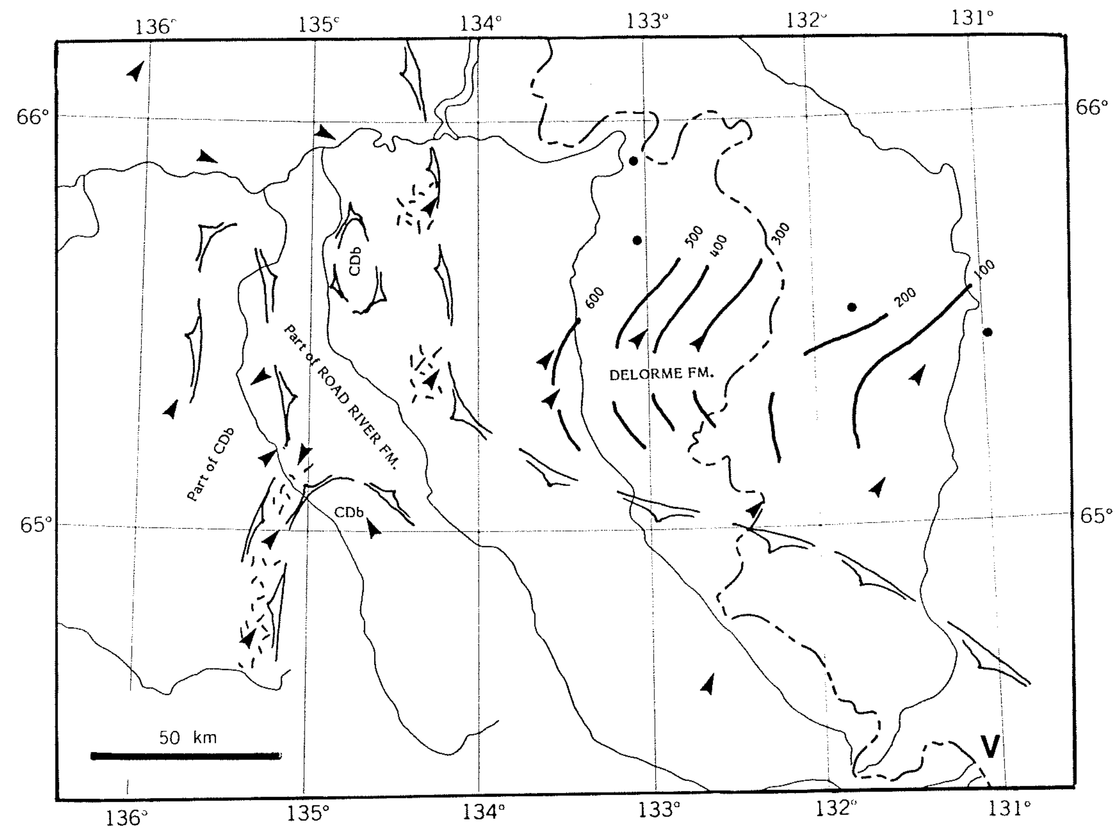
Shale-out

Section cut out by pre-Delorme erosion.

V Volcanics.

CDb Undivided Cambrian-Devonian carbonate.

Fig. 14, Distribution of Mt. Kindle Fm. and equivalents.



Isopach, metres.

Shale-out.

Early Devonian (pre-Emsian) debris-beds.

V Volcanics.

CDb Undivided Cambrian-Devonian carbonate.

Figure 15, Distribution of Delorme Fm. and equivalents.

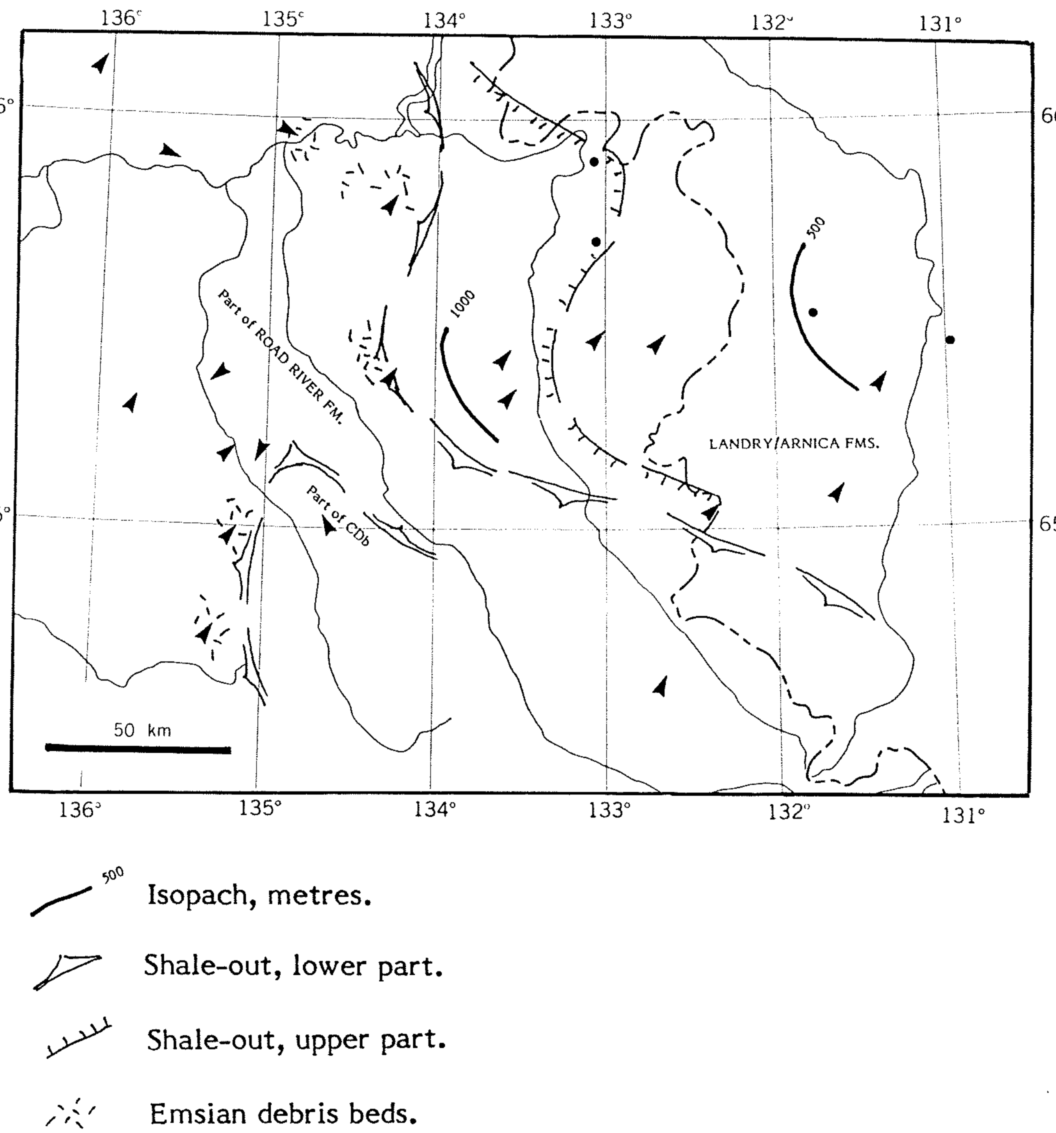


Fig. 16, Distribution of Landry/Arnica Fms. and equivalents.

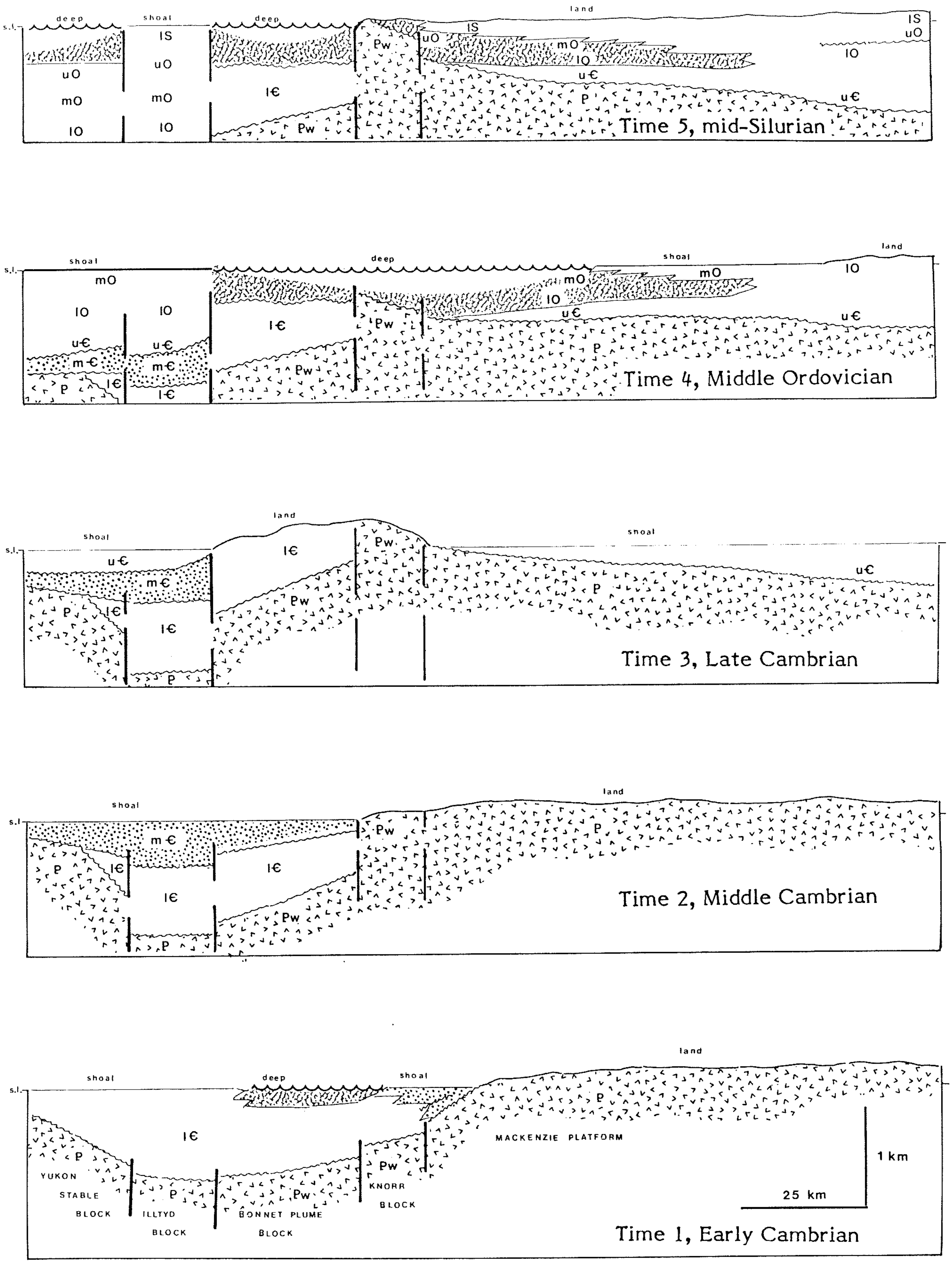
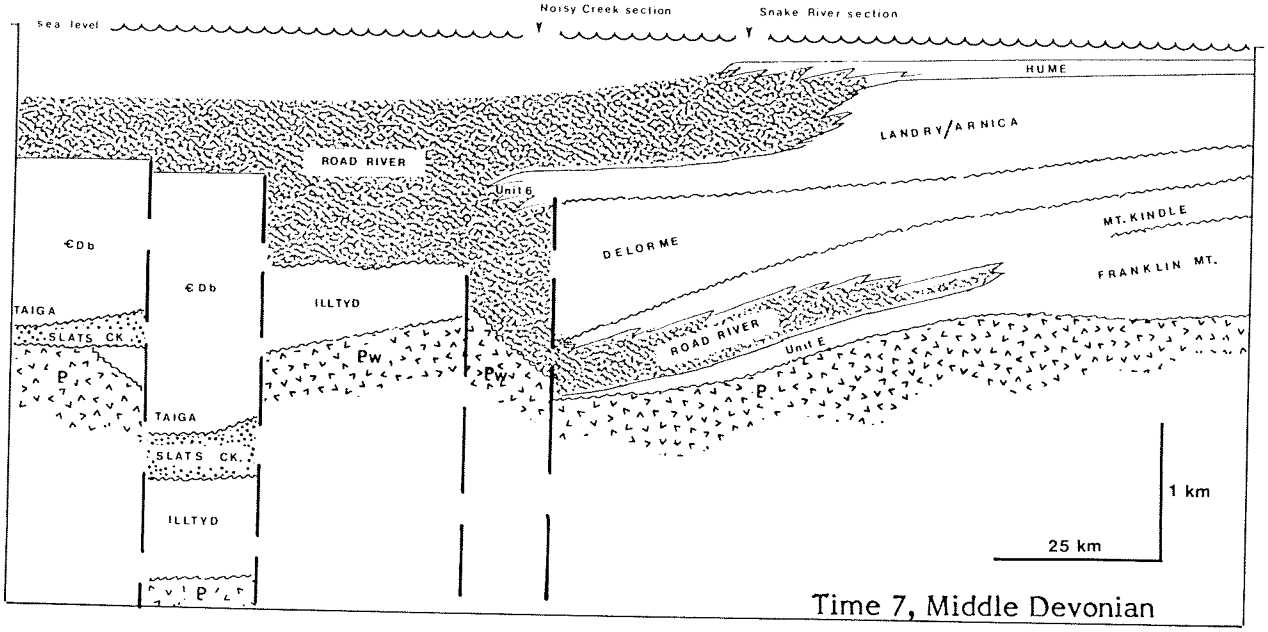
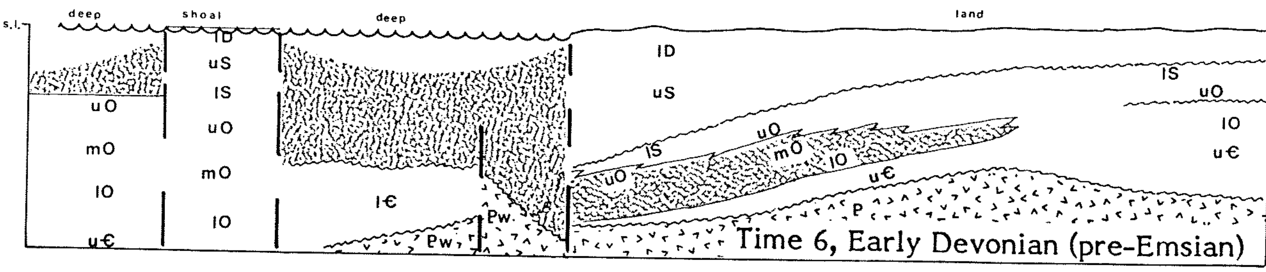


Fig. 17, Cross-section, time-slices, Cambrian to Middle Devonian.





Water

Shallow-water carbonates

Basinal strata, limestone, shale, chert.

Sandstone, siltstone, conglomerate

Proterozoic

Unconformity (subaerial)

Fault

Devonian (D), Silurian (S), Ordovician (O), Cambrian (C), Windermere (Pw), pre-Windermere Proterozoic (P), lower, middle, upper (l, m, u).

Fig. 17, continued.

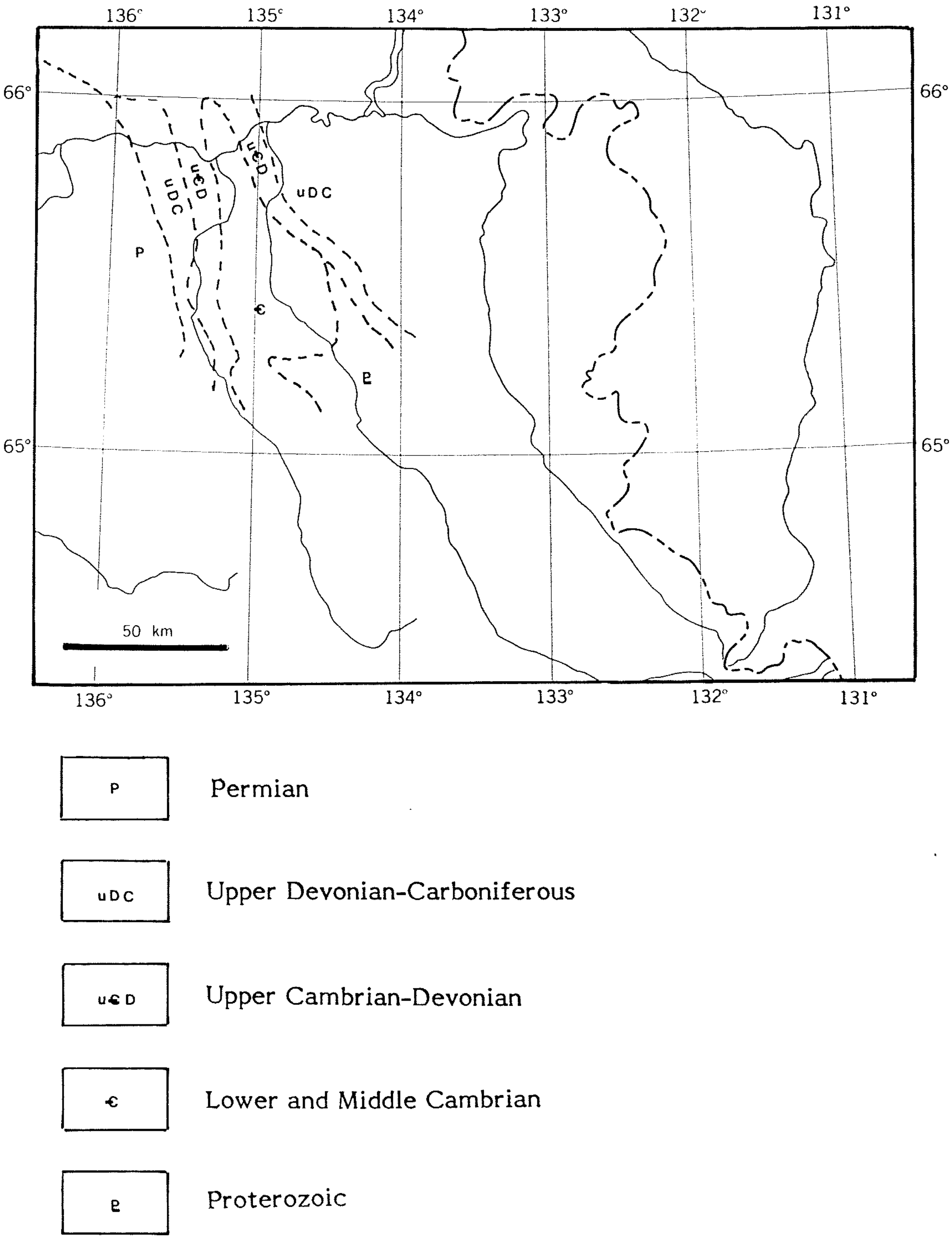


Fig. 19, Pre-Cretaceous geology.

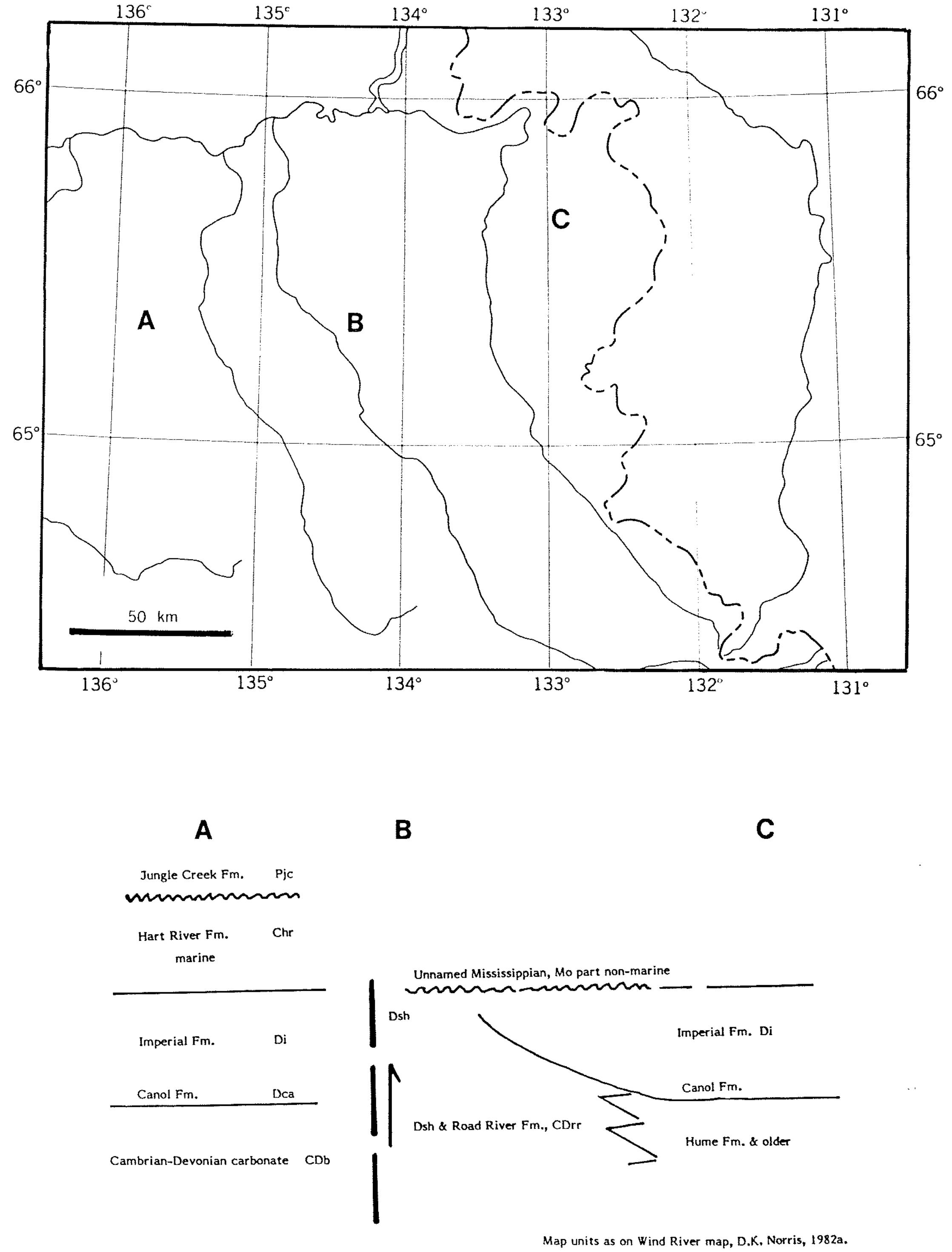


Fig. 18, Evidence for pre-Mississippian erosion.