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STRATIGRAPHY, SEDIMENTOLOGY AND PALYNOLOGY OF THE KOOTENAY-BLAIRMORE TRANSITION IN SOUTHWESTERN ALBERTA AND SOUTHEASTERN BRITISH COLUMBIA

B.D.Ricketts
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Cover

Thin pebble-lenses and scour-lags associated with trough crossbedded sandstones in the Pocaterra Creek Member, Mount Allan.

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STRATIGRAPHY, SEDIMENTOLOGY, AND PALYNOLOGY OF THE KOOTENAY-BLAIRMORE TRANSITION IN SOUTHWESTERN ALBERTA AND SOUTHEASTERN BRITISH COLUMBIA

Abstract

In the Kananaskis region, the transition between the Kootenay and Blairmore groups encompasses the Elk Formation and the overlying Pocaterra Creek Member of the Cadomin Formation. The Pocaterra Creek Member is not recognized in the Fernie region where the Elk Formation is succeeded by undifferentiated conglomeratic strata of the Cadomin Formation.

The Pocaterra Creek Member appears to be the same age as strata at the top of the Elk Formation in the Fernie area. Based on the microfloral assemblage, a Berriasian age was determined for this stratigraphic interval.

Based on sedimentological and palynological criteria, it is suggested that there is no discernible hiatus at the Kootenay-Blairmore transition at Coal Creek (Fernie Basin). Similarly, the transition at Mount Allan and Highwood Pass appears essentially conformable, although a hiatus between the Pocaterra Creek Member and the Kootenay Group probably increases in magnitude southwards toward Cat Creek, where the Cadomin directly overlies Kootenay strata. At all of these localities, the Elk and Cadomin formations represent a northward prograding braid plain and alluvial fan, across which coarse grained sediment was dispersed by braided rivers.

Key words: Pocaterra Creek Member, Berriasian, palynology, alluvial fan, braid plain, braided rivers.

Résumé

Dans la région de Kananaskis, la transition entre les groupes de Kootenay et de Blairmore englobe la formation d'Elk et le membre susjacent de Pocaterra Creek de la formation de Cadomin. Le membre de Pocaterra Creek n'est pas reconnu dans la région de Fernie, où la formation d'Elk est suivie de strates conglomératiques non différenciées qui appartiennent à la formation de Cadomin.

Le membre de Pocaterra Creek semble du même âge que les strates qui coiffent la formation d'Elk dans la région de Fernie. D'après l'assemblage microfloral, on a attribué cet intervalle stratigraphique au Berriasien.

D'après des critères sédimentologiques et palynologiques, on ne discerne pas de discontinuité de sédimentation à la transition Kootenay-Blairmore à Coal Creek (bassin de Fernie). D'une manière semblable, la transition qui se trouve à Mount Allan et à Highwood Pass paraît essentiellement conformable, bien qu'un hiatus entre le membre de Pocaterra Creek et le groupe de Kootenay s'accroîte fort probablement au sud de Cat Creek, de sorte que les strates de la formation de Cadomin recouvrent celles de la formation de Kootenay. A tous ces endroits, les formations d'Elk et de Cadomin représentent une plaine anastomosée et un cône alluvial qui avancent vers le nord, au travers desquels des sédiments à grains grossiers ont été dispersés par des cours d'eau anastomosés.

Mot clés: Membre de Pocaterra Creek, Berriasien, palynologie, cône alluvial, plaine anastomosée, cours d'eau anastomosés.

General background

On a regional basis, the Blairmore Group is generally considered to overlie the Kootenay Group disconformably (Fig. 1). Throughout the southern and central Alberta Foothills and the Foothills of northeastern British Columbia, the base of the Blairmore Group and the laterally equivalent Bullhead Group is defined by prominent, resistant conglomerates of the Cadomin Formation. In southern Alberta, the subjacent Kootenay strata weather recessively and hence the contact between the Blairmore and the Kootenay is readily defined. However, this stratigraphic relationship is not always obvious in individual exposures. This paper discusses two areas, one in southern Alberta and the other in southeastern British Columbia, where the Kootenay-Blairmore transition is complicated by the presence of strata (the Pocaterra Creek Member) that are lithologically similar to the Cadomin Formation but distinct from the Elk Formation (Kootenay Group). In both these areas, sedimentation throughout this transition appears to have been relatively continuous.

Based on their work in the Highwood Pass area, Allan and Carr (1947) proposed the name Pocaterra Creek Member to include all strata with lower Blairmore affinities between the Cadomin Formation and subjacent Kootenay Group. The base of the Pocaterra Creek Member was defined by a conglomerate that, at the type section in Highwood Pass, exhibits subtle differences in grain size and pebble composition compared to the Cadomin Formation conglomerates[1]. At the type section, the Pocaterra Creek conglomerate is finer grained, supposedly lacks green chert pebbles and contains fewer quartzite pebbles. The remaining strata in this unit include sandstone, siltstone and grey, red, and green mudstone beds. Allan and Carr (1947) further noted that the Pocaterra facies is of local importance only and that these strata pinch out some 26 km south of Highwood Pass, beyond which point the Cadomin Formation rests directly on Kootenay beds.

At Ribbon Creek and Mount Allan, Crockford (1949) described a sequence of conglomerates and sandstones in the uppermost part of the Kootenay Group (his Conglomerate member), while at the same time recognizing that this unit was probably equivalent to the (lower Blairmore) Pocaterra Creek Member. The same upper part of Crockford's sequence, above the coal-bearing Kootenay strata, more recently has been formally defined as the Pocaterra Creek Member (Gibson, 1977a, b, 1985a; Hughes and Cameron, 1985). Similarly, Glaister (1959) suggested a correlation of the Pocaterra conglomerates with the upper part of the Elk Formation (Kootenay Group) in the Fernie region. In a subsequent study, which included Fernie, Sparwood and Marten ridges in the Fernie Basin, Gibson (1977a, b, 1985a) included the rocks of this interval in the Pocaterra Creek Member. The Pocaterra Creek Member was recognized only at these three localities.

In a paper on the Cadomin Formation at Flathead Ridge in the Fernie Basin, Ollerenshaw (1981) could find no basis for separating the Cadomin and Pocaterra Creek units using the criteria defined by Allan and Carr (1947), despite the lithological similarity between the Flathead Ridge sequence

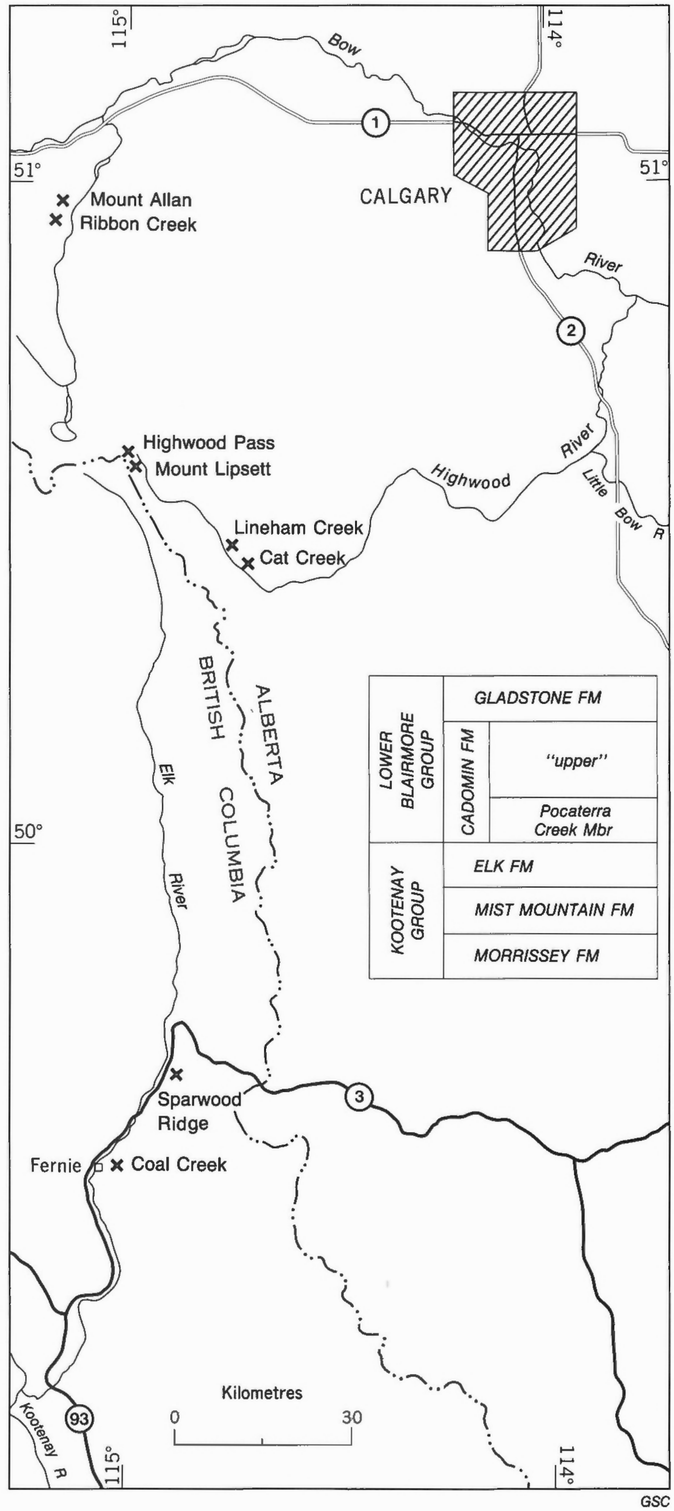

Figure 1. Location of measured sections at Kananaskis and Fernie and summary of stratigraphic units.

[1]Referred to as the basal Blairmore conglomerate by Allan and Carr (1947).

and other strata described by Crockford (1949) and Gibson (1977a). Apparently, conglomerates at the level of the Cadomin Formation in the Flathead Ridge area exhibit considerable compositional variation and several were identified as belonging to the Cadomin Formation. McLean (1982) elevated the Pocaterra to formation status on the basis that it is lithologically distinct from the Cadomin Formation. In the present analysis, this classification is disputed and the Pocaterra is referred to as a member throughout this paper.

Perhaps the most confusing aspect of the Pocaterra Creek Member is its stratigraphic relationship to the Blairmore Group and underlying Kootenay Group. In their original discussion, Allan and Carr (1947) were unable to determine the nature of the Pocaterra - Kootenay contact, but indicated an erosional unconformity was possible because of the abrupt change in lithology between these two units. They further suggested that the pre-Cadomin unconformity, having been recognized in other parts of southern Alberta, also was present above the Pocaterra Creek Member. Crockford (1949), on the other hand, stated that the Kootenay-Blairmore transition at Mount Allan is conformable. Rapson (1965) also considered the possibility that this contact is conformable in the Fernie region, and Gibson (1977a) subsequently extended this idea to the Kootenay Group-Pocaterra Creek Member contact. In further discussions of the pre-Cadomin unconformity, Newmarch (1953), Norris (1964), and McLean (1976, 1977) postulated that the magnitude of the hiatus decreases westward from the southern Alberta Foothills, to the extent that the Cadomin Formation and Kootenay Group may be conformable in the far west. Until recently, paleontological evidence has not been available to either prove or disprove the existence of conformable or unconformable contacts between these units.

In the present study:

(i) Measurement of stratigraphic sections and collection of samples for pollen analysis were undertaken by B.D.R.

(ii) The stratigraphy of the Pocaterra Creek Member, and the sedimentology of the Kootenay-Blairmore transition in the Kananaskis and Fernie areas (Fig. 1) have been examined and interpreted by B.D.R.

(iii) The palynology and biostratigraphy of the Elk-Pocaterra Creek interval were undertaken by A.R.S.

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THE KOOTENAY-BLAIRMORE TRANSITION: KANANASKIS AREA

In this paper, reference is made to the main conglomerate of the Cadomin Formation, which is a resistant, cliff-forming unit that occurs throughout the southern and central Alberta Foothills (see discussion by McLean, 1977). The base of this conglomerate defines the upper Pocaterra Creek Member contact. The contact between the Elk Formation and Pocaterra Creek Member was defined by Gibson (1977a, 1985a) as being where grey, carbonaceous - argillaceous, lithic arenites are overlain by more quartz-rich sandstone lithologies. In the area under consideration, this contact coincides with the base of the lowest conglomerate in the Pocaterra Creek Member, and also overlies the highest occurrence of thin coal beds, "needle" coals or "needle" siltstones.

Measured sections at Mount Allan and Ribbon Creek (figs. 2, 3, 4) are located on the eastern limb of the Mount Allan syncline; sections occur farther south along strike near Highwood Pass. The additional stratigraphic sequence (Pocaterra Creek Member) between the regionally recognized Kootenay Group and Cadomin Formation is thickest (121 m) at Mount Allan, pinching out completely between Lineham and Cat creeks, beyond which point the normal Cadomin directly overlies Kootenay strata (Fig. 2).

Summary of lithologies in the Pocaterra Creek Member

This section describes the general lithologic character of the stratigraphic interval under consideration; more detailed aspects of the sedimentary facies are provided later in the paper.

The proportions of conglomerate, sandstone and mudstone for each measured section in the Kananaskis area are shown in Table 1. Sandstone and mudstone lithologies predominate and occur in subequal proportions; conglomerates are subordinate. Except in the case of the section at Lineham Creek, these proportions remain relatively constant throughout the area. The Lineham Creek section is only 3 m thick and is situated near the pinch-out edge of the Pocaterra Creek Member. There may be a bias toward "high" mudstone percentages because recessive intervals in each section are included in this category; nevertheless, the mudstone values do compare favourably with the Mount Allan section, where a complete sequence of the Pocaterra Creek is exposed.

The basal unit of the Pocaterra Creek is a pebble conglomerate that usually is overlain by crossbedded or parallel laminated litharenites. Except for a few low-angle, planar crossbeds, the conglomerate contains little internal stratification or grain size segregation. Locally, thin lenses of sandstone resemble drape structures on migrating bed forms. The clast-supported framework consists of subrounded to subangular pebbles. Compositional and textural features of the conglomerates are summarized in Table 2. Pebbles consist predominantly of grey and dark grey chert, with subordinate white, pink and pale brown

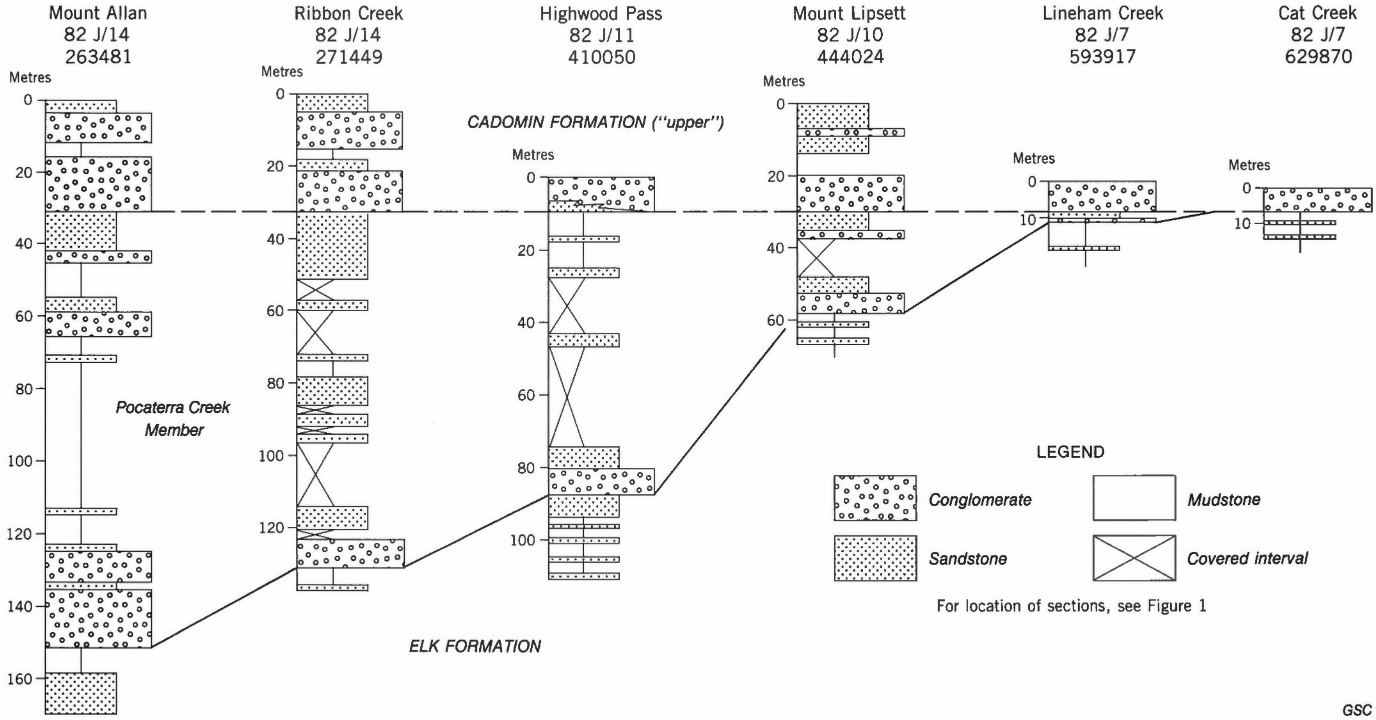


Figure 2. *Schematic representation of measured sections through the Kootenay-Blairmore transition at Kananaskis, covering an approximate paleogeographic distance of 65 km. The Cadomin Formation can be correlated throughout this area and is used as a stratigraphic marker. The Mount Allan section is modified from Hughes and Cameron (1985). An NTS grid reference is given for the top of each section. The base of the Cadomin is used as a datum.*

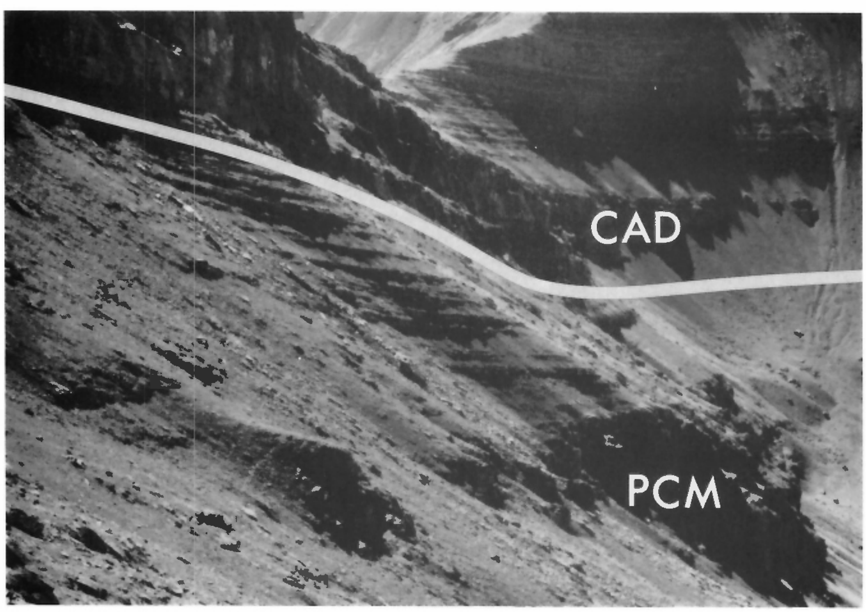


Figure 3. *The principal reference section for the Pocaterra Creek Member, north face of Mount Allan. The lower massive unit is the basal conglomerate-sandstone of the member. The stratigraphic thickness of the Pocaterra Creek Member is 121 m.*

quartzite (quartz arenite), and rare pebbles of grey limestone. A few green chert pebbles occur in most exposures; therefore, the absence of green chert pebbles is no longer a valid criterion for distinguishing between the Pocaterra Creek and upper Cadomin conglomerates. In any one section of the Pocaterra Creek conglomerate, average pebble size (2 cm) is less than that observed in the remainder of the Cadomin Formation (5 cm). Maximum clast sizes also vary widely, for example, at Mount Allan, clasts attain a maximum of 10 cm in the Pocaterra Creek conglomerate, compared to 25 cm in the upper Cadomin. Furthermore, the Pocaterra Creek conglomerate shows a gradual thinning and concomitant fining trend from the Mount Allan exposures south toward Lineham Creek (Fig. 2 and Table 1). Some variation in pebble composition exists, although this variation apparently is less pronounced than that observed in many exposures of the typical Cadomin Formation. Similar variations were observed between Cadomin conglomerates on Flathead Ridge by Ollerenshaw (1981, p. 341).

Sandstones immediately overlying the basal Pocaterra Creek conglomerate are chert-rich litharenites, and contain a variety of crossbed forms and thin, pebble conglomerate lenses. At Ribbon Creek (Fig. 4), the sandstones are medium- to fine-grained, although the incidence of pebble conglomerate and coarse sand lenses increases toward the upper Cadomin Formation. In

TABLE 1

Proportions of the main lithologies composing the Pocaterra Creek Member in the Kananaskis area as a percentage of total thickness

(Recessive intervals at each measured section are included in the Mudstone category.)

Section	% Conglomerate	% Sandstone	% Mudstone
Mount Allan	14	33	53
Ribbon Creek	8	44	48
Highwood Pass	9	35	56
Mount Lipsett	15	45	40
Lineham Creek	14	76	10

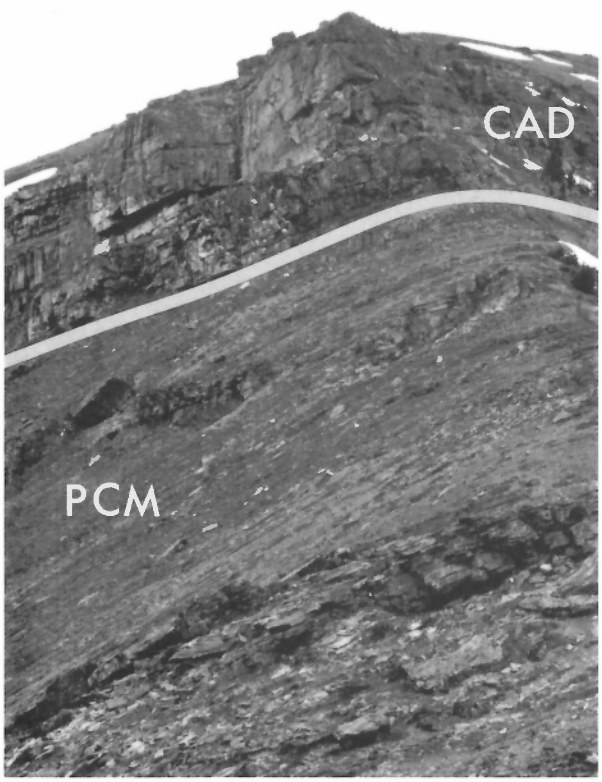


Figure 4. *Pocaterra Creek Member exposed on a ridge above Ribbon Creek. The prominent bluff is the "upper" Cadomin Formation. In the photograph, the basal conglomerate of the Pocaterra Creek Member is located to the lower right. The stratigraphic thickness of the Pocaterra Creek Member is 97 m.*

TABLE 2

Proportions of the principal framework components in the upper Cadomin, Pocaterra Creek Member and Elk conglomerates

[Principal framework components are represented as follows: (a) = black-grey chert, (b) = white quartzite, (c) = green chert.

Average and maximum clast sizes are given for each section.]

	CLASTS	CADOMIN	POCATERRA CREEK	ELK
Mount Allan	a)	40-60%	70-80%	
	b)	30-60%	20-30%	
	c)	5-10%	5%	
	Av. size	5 cm	2 cm	
	Max. size	25 cm	10 cm	
Ribbon Creek	a)	40-50%	80-90%	
	b)	40-50%	10-15%	
	c)	5%	2-3%	
	Av. size	5 cm	2 cm	
	Max. size	12 cm	5 cm	
Highwood Pass	a)	sandy facies	70-80%	80-90%
	b)	no data	20-30%	10-20%
	c)		3-5%	3-5%
	Av. size	2 cm	1-2 cm	
	Max. size	5 cm	3 cm	
Mount Lipsett	a)	40-50%	80-90%	
	b)	40-50%	10-15%	
	c)	5%	-	
	Av. size	5 cm	1 cm	
	Max. size	15 cm	4 cm	
Lineham Creek	a)	50-60%	85-90%	
	b)	30-40%	10-15%	
	c)	5-10%	-	
	Av. size	4 cm	0.5 cm	
	Max. size	10 cm	1 cm	
Cat Creek	a)	50-60%	-	
	b)	30-40%	-	
	c)	5-10%	-	
	Av. size	2 cm		
	Max. size	5 cm		
Coal Creek[1]	a)	50-60%		80-90%
	b)	30-40%		10-20%
	c)	5-10%		3-5%
	Av. size	4 cm		2 cm
	Max. size	10 cm		8 cm

[1]Average for several conglomerates in the Elk.

composition, these sandstones are indistinguishable from thin beds of sandstone interbedded with the conglomerates of the upper Cadomin Formation. Finer grained lithologies in the Pocaterra sequence tend to weather recessively. However, good exposures of grey siltstone, interbedded with red, green, and some grey, shaly mudstones are found at Mount Allan and Highwood Pass. The siltstones and mudstones lack carbonaceous material. Reddish-purple weathering mudstones contain calcareous nodules and a few calcite crusts that probably represent caliche zones. It is these features in the mudrock lithologies that help to distinguish the Pocaterra Creek sequence from the subjacent Kootenay strata and superjacent lower Blairmore rocks.

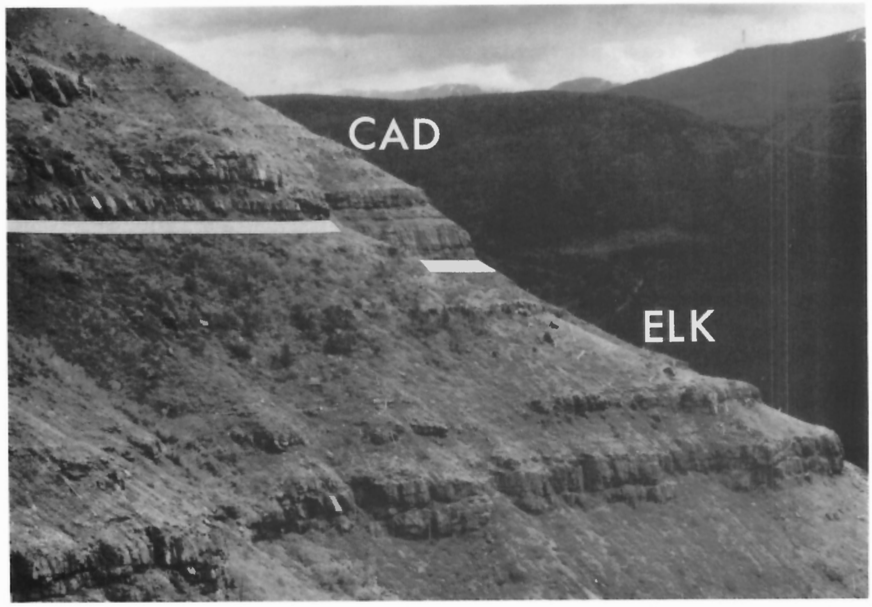


Figure 5. *The Kootenay (Elk Formation) - Cadomin sequence at Coal Creek. Note the fining-upward trends associated with the massive cliff-forming conglomerates. The lowest conglomerate unit is 13-15 m thick and corresponds to the 220 m stratigraphic level in Figure 6.*

Contacts

The basal conglomerate of the Pocaterra Creek sequence overlies the Elk Formation above an erosional contact that locally has a scoured relief of up to 100 cm. However, the abruptness of the Kootenay-Blairmore transition is variable. For example, at Mount Allan, Ribbon Creek, and Highwood Pass, sandstone and thin conglomerate beds of the Elk Formation are similar in composition and sedimentary structures to Pocaterra Creek strata; erosion at the base of conglomerates in the Elk is similar in nature to that at the base of the Pocaterra. Rapson (1965), who conducted a detailed petrographic analysis of this stratigraphic interval, noted that the frequency, thickness and grain size of sandstones and conglomerates increases gradually from the Kootenay into the Blairmore; Rapson also demonstrated the compositional similarity between the coarse clastics in these two groups. The above criteria suggest a relatively continuous succession from the Elk to Pocaterra to Cadomin, although the evidence is by no means unequivocal.

Within this succession, it is the fine grained rather than the coarse grained lithologies that change, namely, from coal-bearing strata in the Elk, to green mudstone and caliche-bearing red mudstone in the Pocaterra Creek Member. Again, these "redbeds" do not provide unambiguous evidence of the nature of the Elk-Pocaterra Creek contact: the redbeds might be part of a continuously evolving stratigraphic sequence, or they could represent a major change in depositional environment after a hiatus.

South of Highwood Pass (Fig. 2), the Pocaterra Creek sequence thins rapidly and the basal conglomerate is in contact with predominantly fine grained Kootenay rocks; the transition here appears to be more abrupt (Mount Lipsett, Lineham Creek).

The upper contact of the Pocaterra Creek Member is always sharp and erosional, and is of a similar nature to the basal contact. The lithological similarity of sandstone and conglomerate units in the upper Cadomin and the top of the Pocaterra Creek, suggests that this transition also is relatively continuous, and that no major disconformity exists.

THE KOOTENAY-BLAIRMORE TRANSITION: FERNIE AREA

Exposures of the Kootenay-Blairmore contact were examined at Coal Creek and Sparwood Ridge (figs. 5, 6). The sequence at Coal Creek is characterized by numerous cliff-forming conglomerate units. In the lower part of the Elk Formation the conglomerates are separated stratigraphically by thin coal beds, carbonaceous shale, siltstone and buff-weathering litharenites. The proportion of coal-bearing strata decreases upward in the Elk Formation, and in this section the uppermost coal beds were found 70 m below the base of the Cadomin; the coal beds are represented by resistant, white-weathering "needle" siltstones in the top 70 m. It should be noted that Gibson (1985a) has documented thin coal beds within 25 m of the base of the Blairmore in additional stratigraphic sections near Coal Creek. Gibson (*op. cit.*) also states that the "needle" siltstone generally occurs in the upper third of the Elk Formation.

As noted in the previous section, the Kootenay-Blairmore contact in parts of the Fernie basin has been placed by Gibson (1977a; 1985a) where grey, carbonaceous sandstone, carbonaceous shale, and coal are succeeded by a thick conglomerate (Fig. 6), overlain by lighter coloured, quartz-bearing, noncarbonaceous sandstone and grey-green mudrocks. The sandstones above the conglomerate also have a green hue and some contain isolated burrows and trails. This conglomerate was correlated by Gibson (1977a) with the Pocaterra Creek conglomerate of the Kananaskis area; the Cadomin conglomerate occurs some 40 m above it. Nowhere do strata between the basal conglomerate and Cadomin contain red mudstone, although prominent redbeds occur above the Cadomin on Morrissey Ridge.

On Sparwood Ridge (Fig. 6), the lowermost Blairmore is defined by a chert-pebble conglomerate that overlies grey sandstone and a few, thin, "needle" siltstone beds. Distinctive, white, quartz sandstones are well exposed above this conglomerate, and below the Cadomin. As was the case in the sequence at Coal Creek, there is no indication that red mudstones were deposited.

The compositional trends of the conglomerates and sandstones are similar to those observed in the Kananaskis area (also documented by Rapson, 1965). Conglomerates near the base of the Elk Formation at Coal Creek consist almost entirely of dark grey chert pebbles that are no more than 1 cm in width. Higher in the Elk, the conglomerates are coarser grained (Table 2) and become progressively richer in rounded, white, quartzite pebbles, a trend that culminates in the thick Cadomin conglomerates, which contain up to 40 per cent white quartzite pebbles and cobbles up to 10 cm. Although these trends apply to the Coal Creek sequence in general, individual conglomerate units in the Kootenay and Blairmore display considerable lateral variation in thickness and composition. Thick conglomerates commonly split into two units, separated by thinly bedded siltstone and fine grained sandstone, the basal Blairmore conglomerate being one example. Some conglomerates in the Elk Formation can be traced for several hundred metres on ridges adjacent to Coal Creek, but will suddenly "lens out", being replaced laterally by crossbedded sandstone. Similar facies variations have been observed at Sparwood Ridge, although at this locality the number of conglomerate units in the Elk Formation is considerably less than at Coal Creek.

The basal contacts of Elk and Blairmore conglomerates are sharp and have erosional reliefs of up to 75 cm. Upper contacts, on the other hand, are more gradational and the conglomerates typically grade into thin sandstones interbedded with siltstones, in some cases forming distinct fining-upward sequences.

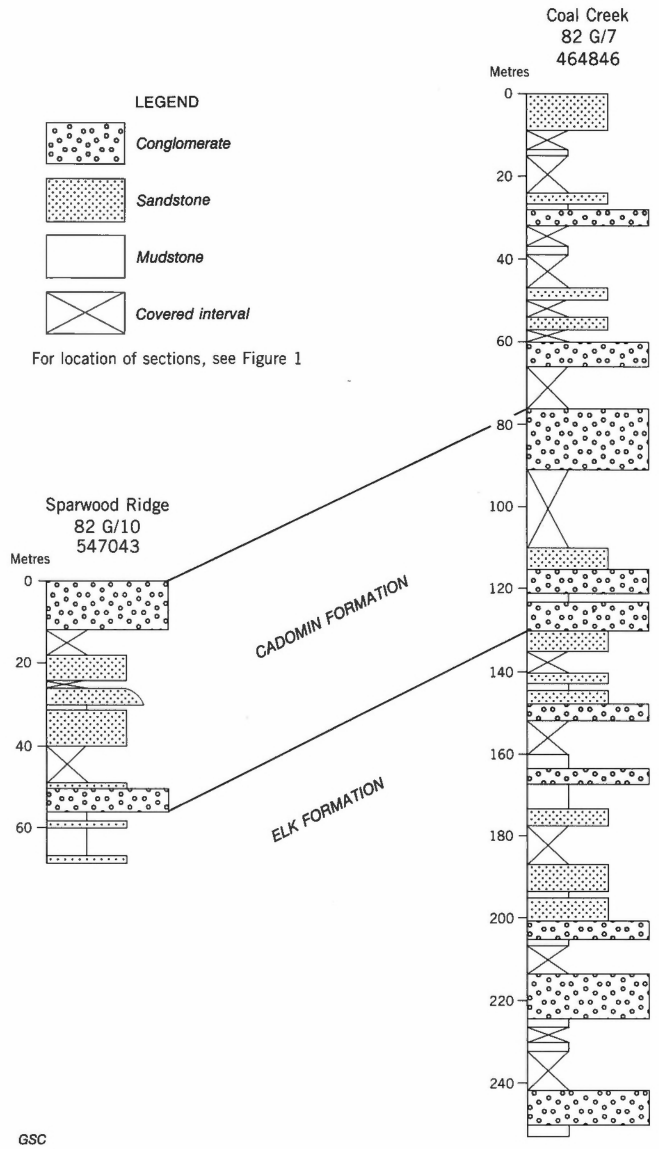


Figure 6. Schematic representation of measured sections at Coal Creek and Sparwood Ridge. An NTS/UTM grid reference is given for the top of each section.

THE STATUS OF THE POCATERRA CREEK MEMBER

Kananaskis area

The following criteria serve to distinguish the sequence of rocks occurring in the stratigraphic interval between the Elk Formation (Kootenay Group) and the Cadomin Formation proper:

(i) A basal conglomerate that is generally finer grained and contains a higher proportion of dark grey coloured chert pebbles than the Cadomin conglomerate

(ii) Sandstones are lighter coloured than Elk sandstones, and lack carbonaceous debris

(iii) The presence of red weathering mudstones, some containing caliche deposits

(iv) A general lack of coaly or carbonaceous lithologies that are typical of the Elk Formation.

Based on the above criteria, the sequence referred to as the Pocaterra Creek Member by Allan and Carr (1947) is a distinct unit in the Mount Allan and Highwood Pass areas. However, sandstones in the Pocaterra Creek are indistinguishable from sandstones in the main Cadomin Formation in terms of their composition and sedimentary structures. Coarse grained lithologies in the Pocaterra Creek have closer affinities with the Cadomin than with the Elk Formation. The principal distinguishing feature between the Pocaterra Creek and the Cadomin in the Kananaskis area is the presence of red mudstones in the former unit. The Pocaterra-Cadomin sequence is considered, on lithologic and stratigraphic grounds, to represent relatively continuous sedimentation. The Pocaterra Creek is, therefore, treated as a member of the Cadomin Formation rather than as a separate formation.

The Pocaterra Creek sequence at Kananaskis has a wedge-shaped geometry and was interpreted by Allan and Carr (1947) to be an erosional remnant. Alternatively, the general southward thinning and fining trends of the basal Pocaterra Creek conglomerate can also be interpreted as primary depositional features. In the present study, the

Pocaterra Creek Member is viewed as a (localized) precursor to the Cadomin conglomerate and is locally conformable with the Cadomin. The magnitude of the hiatus between the Kootenay Group and Pocaterra Creek Member increases from Mount Allan south toward the depositional edge of the Pocaterra near Lineham Creek (Fig. 2); the disconformity is at a maximum where Cadomin conglomerate rests directly upon Kootenay strata at Cat Creek.

Fernie area

At Coal Creek, the stratigraphic sequence encompassing the Elk Formation and lower Blairmore Group exhibits considerable lateral and vertical variation in both coarse and fine grained facies; correlation of individual conglomerate units is difficult and at present no single unit can be used as a lithostratigraphic marker.

The nature of the Kootenay-Blairmore transition in the Fernie area is quite variable (Gibson, 1985a; and pers. comm.). At Coal Creek, the sequence appears to be continuous and conformable, whereas at Flathead and Morrissey ridges, the transition is abrupt and may be disconformable. In the Coal Creek section, two thick conglomerates occur above the Kootenay-Blairmore contact (85 m and 120 m, in Fig. 6); both conglomerates are similar in their composition, clast size and sedimentary structures, and there is little to distinguish between them. The intervening strata include green shales and sandstones, but lack red mudstone which, in the Kananaskis area, is the principal feature used to distinguish between the Cadomin and Pocaterra Creek. In fact, at Morrissey Ridge the redbeds occur above the Cadomin. Furthermore, the distinctive, white, quartz sandstones that occur at Sparwood Ridge are not seen at Coal Creek and thus cannot be used as a general criterion for separating the Cadomin and the Pocaterra Creek.

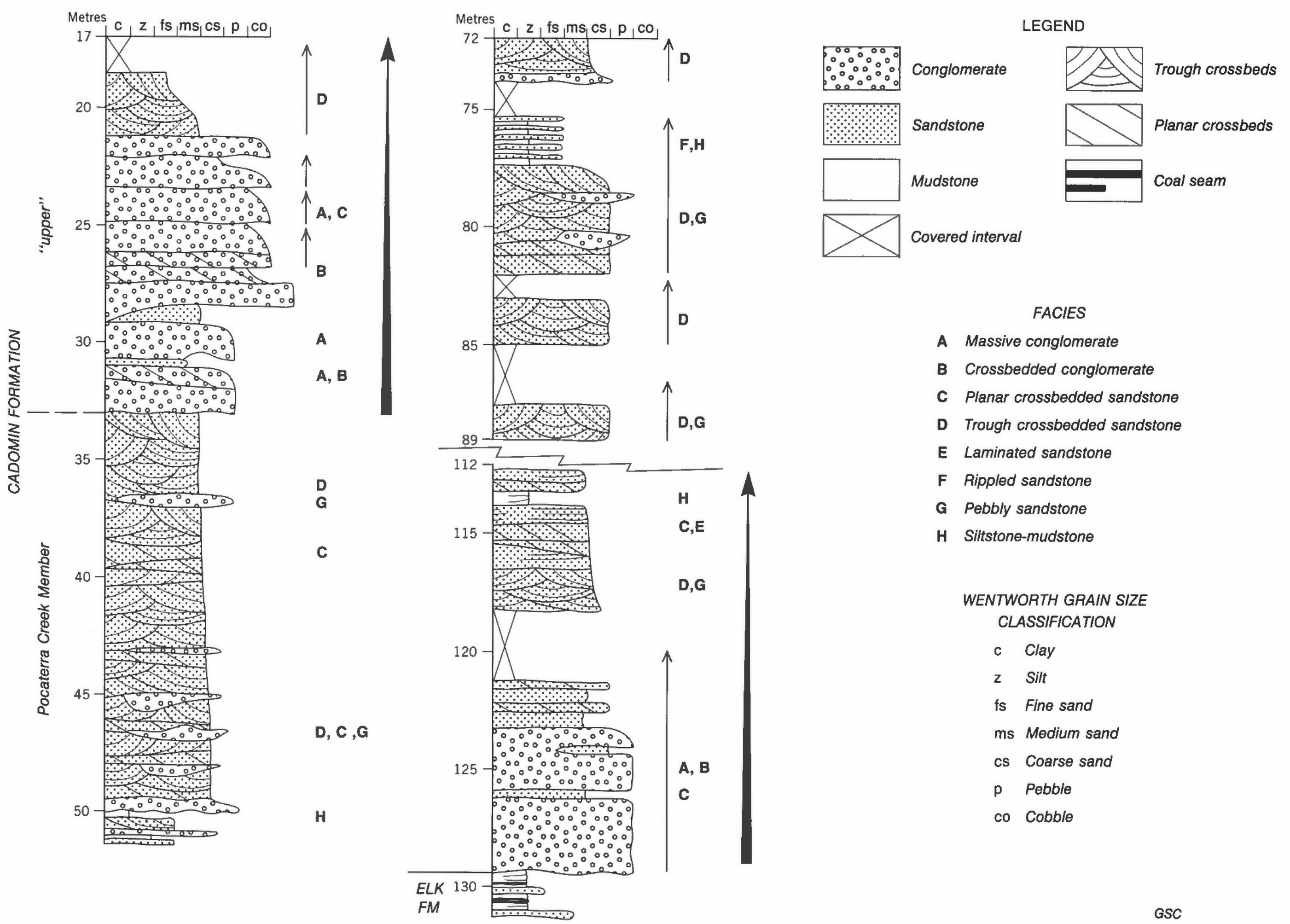


Figure 7. Detail of sedimentary facies and fining-upward sequences in representative segments of the Ribbon Creek section. Stratigraphic intervals (metres) correspond to those in Figure 2. The small arrows represent second-order, fining-upward cycles, and the large arrows first-order cycles. The Wentworth grain size classification is used. The lithofacies are described in Table 3.

On this basis, the name Pocaterra Creek is here considered inappropriate for basal Blairmore Group strata in the Fernie region (i.e. the basal 40 m). This stratigraphic interval is therefore included in the Cadomin Formation. At Coal Creek, the top of the Cadomin is placed (albeit somewhat arbitrarily) at the top of a thick chert-pebble conglomerate (about 80 m in Fig. 6), 55 m above the top of the Elk Formation.

The type section of the Pocaterra Creek Member

The type section is located at Highwood Pass, atop a ridge above the headwaters of Pocaterra Creek (Allan and Carr, 1947). Unfortunately, the section immediately underlies the footwall of the Lewis Thrust, and has been tectonically thickened by small, upright, isoclinal folds. The corrected thickness of this section is 75 m (Allan and Carr measured 112 m). Generally, fine grained lithologies are poorly exposed in the type section, although some calcite nodule-bearing, maroon mudstones are located near the top of the member. Therefore, a reference section is proposed, located on the eastern ridge of Mount Allan; here a complete 121 m thick section of the Pocaterra Creek Member is exposed on the east limb of the Mount Allan Syncline (115°12'00"W; 50°58'30"N). This section has been measured in detail by Hughes (1975).

SEDIMENTOLOGY OF THE KOOTENAY-BLAIRMORE TRANSITION

The sedimentology of the Kootenay (Elk Formation)-Blairmore transition in two areas, Ribbon Creek and Coal Creek (figs. 7, 8), is discussed below. For reasons discussed earlier, the Elk and Cadomin (including the Pocaterra Creek Member) are considered to be conformable in these areas. The Kootenay is generally regarded as representing deposition on a broad coastal plain (Jansa, 1972; Gibson, 1977a; 1985a). Strata of the lower Kootenay Mist Mountain Formation are interpreted as lower deltaic plain deposits that were transitional with upper deltaic or alluvial plain environments. The overlying, conglomeratic Elk Formation represents a part of the alluvial plain that was closer to the sediment source and may include sediments deposited at the fringe of an alluvial fan (Gibson, 1977a, 1985a). Individual conglomerate units in the Elk were considered by Gibson to be indicative of braided streams. Sedimentological features of the Cadomin Formation have been summarized by McLean (1977) who interpreted these conglomerates as humid-region, alluvial fan and pediment deposits. McLean rejected an arid-region type of alluvial fan because of the lack of debris flow deposits, although it is now recognized that debris flow may also occur in the proximal parts of humid fans (see Rust and Koster, 1984).

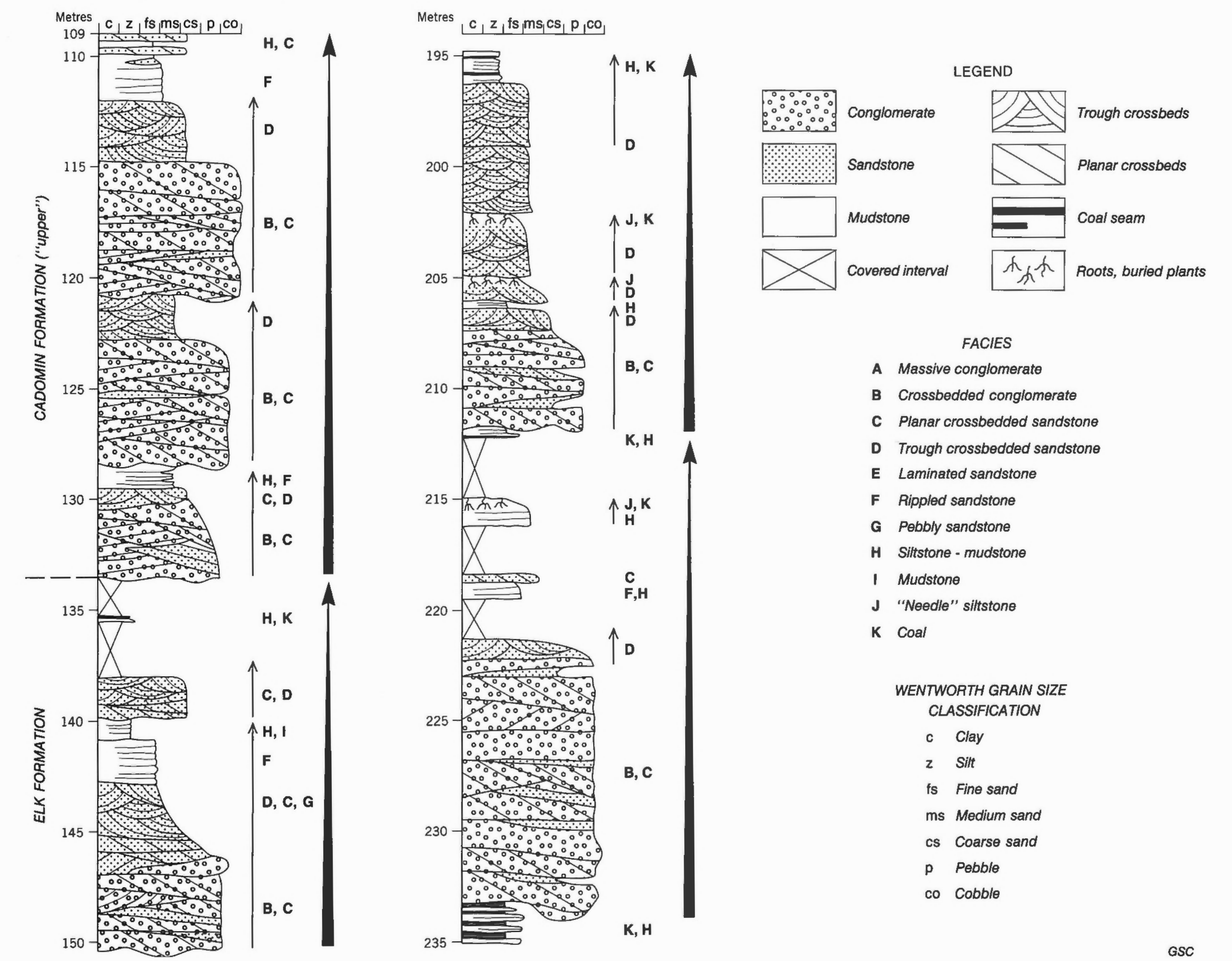


Figure 8. *Sedimentary facies and fining-upward sequences in representative segments of the Coal Creek section. Stratigraphic intervals correspond to those in Figure 6. The lithofacies are described in Table 3.*

Principal lithotypes and sedimentary facies

Four principal lithotypes are recognized:

(i) thick conglomerates;
(ii) sandstones and some interbedded siltstones;
(iii) red mudstone-caliche; and
(iv) coal-bearing, fine grained rocks.

Within each lithotype, a variety of sedimentary facies are identified, each defined by its relatively homogeneous composition and sedimentary structures. The facies (summarized in Table 3) are similar to those described by Miall (1977, 1978) and Rust (1978). However, use of their facies codes has been avoided because this coding system has so far been designated for braided fluvial deposits only, although the system may eventually be extended to include other fluvial types. More important, however, is the risk of introducing a bias toward *braided* in the interpretation of a sequence, if such codes are used, especially when the evidence is equivocal. A major problem with classification schemes like those of Miall (*op. cit.*) and Rust (*op. cit.*) is that certain genetic connotations become entrenched, despite the intentions of those authors otherwise. To some extent, the classification scheme itself becomes a form of interpretive model.

Thick conglomerate units

Average pebble sizes for Elk Formation and Cadomin Formation conglomerates are listed in Table 2. All of the conglomerates possess a clast-supported framework. Two styles of bedding occur: large-scale, planar crossbedded pebble conglomerates (facies B), which are particularly well developed at Coal Creek, and massive bedded conglomerates (facies A). Planar crossbeds occur as single sets or as a series of superposed sets, generally between 50-120 cm thick, but locally up to 4 m thick (Fig. 9). Individual sets can be traced several tens of metres laterally (in the direction of foreset dip) or may only extend a few metres, and are truncated by a succeeding crossbed set, or are overlain by a thin sandstone (Fig. 10). One crossbed set in an Elk Formation conglomerate at Coal Creek was traced laterally for about 100 m; here, local discordances in foreset strata and thin sandstone drapes resemble reactivation surfaces. Foreset strata usually are 10 to 30 cm thick, exhibit grading normal and parallel to foreset contacts, and dip between 10 and 20° to the lower set contact. Some planar crossbed sets have a distinctly coarser grained basal lag, one or two pebbles thick. Most conglomerate units show a tendency to split laterally into two units that are separated by sandstone or interbedded sandstone and siltstone, 1 to 2 m thick, but may coalesce in the downdip direction (Fig. 9): the intervening fine grained deposits thus have a lenticular shape several tens to hundreds of metres long.

TABLE 3

Sedimentary facies in the Cadomin, Pocaterra Creek, and upper part of the Elk Formation

	FACIES	DESCRIPTION
A	Massive Conglomerate	Clast-supported, tabular bedded, chert-pebble conglomerate. Vague parallel stratification or non-stratified. Crude imbrication.
B	Crossbedded Conglomerate	Large, planar-tabular crossbed sets up to 4 m thick. Individual foresets graded, dipping 10-20°. Toesets tangential or abutting.
C	Crossbedded Sandstone	Planar crossbed sets, up to 120 cm thick, generally 5-60 cm thick, fine-coarse grained, locally pebbly.
D	Crossbedded Sandstone	Trough crossbed sets, 5-60 cm thick, fine-coarse grained, locally pebbly. Commonly festooned.
E	Laminated Sandstone	Horizontal - subhorizontal laminae, medium-fine grained. Parting lineation. Also contains a few small trough crossbeds or ripples.
F	Rippled Sandstone	Asymmetric current ripples, 1-2 cm amplitude. Straight crested and linguoid. Includes climbing ripples.
G	Pebbly Sandstone	Trough-shaped, scour-and-fill structures, com-monly having a basal layer of pebbles.
H	Siltstone - Mudstone	Thin interbeds of siltstone and mudstone or shale, a few centimetres thick. Local ripple and trough crossbeds in siltstones. A few thin, sandy stringers.
I	Mudstone	Red, green, and purple mudstones; mottled weathering. Rarely contain root structures. Red varieties have rubbly weathering calcite nodules and crusts.
J	"Needle" Siltstone	White-weathering, case hardened, highly carbonaceous sandy siltstone with needle-like algal structures. Commonly have complex root systems associated with overlying coal beds.
K	Coal	Thin coal beds (few centimetres) and shaly coals. Includes "needle" coals.

Figure 9. A thick conglomerate unit from the Elk Formation on the north side of Coal Creek. Note the large-scale planar crossbedding (facies B) and thin sandstone lenses (facies C). The conglomerate unit is split toward the top left of the picture by a (recessive) wedge of siltstone. The cliff on the right is 7 m high. Facies letters used are from Table 3.

Figure 10. Elk Formation conglomerates interstratified with thin sandstone lenses, on the north side of Coal Creek.

Massive bedded conglomerates appear to have a tabular geometry with dimensions similar to the B facies. In some beds, vague subhorizontal layering occurs - such beds tend to be coarser grained than the associated planar crossbeds, and have a greater component of cobbles. The A facies appears to be more common in the Cadomin conglomerates than in Elk conglomerates, particularly in some of the coarse cobble beds in exposures at Mount Allan and Ribbon Creek.

Sandstones and siltstones

Litharenites occur as thin beds interlayered with grey siltstones and mudstones, or as thick (20-25 m) units, for example at the top of the Pocaterra Creek Member at Ribbon Creek (Fig. 7). Sandstones are well exposed at Ribbon Creek and display abundant trough crossbeds (facies D) and planar crossbeds (facies C, Fig. 11). Facies C types generally are well sorted, lack grit or basal pebble lags, and are associated with subhorizontally laminated sandstones (E facies, Fig. 12) that contain parting lineations. Trough crossbedded sandstones, on the other hand, commonly are associated with thin, chert-pebble lags or lenses, as shown in Figure 13 (similar to the Se facies of Rust, 1978). Sandstone beds may be overlain abruptly by siltstone and mudstone, or show fining-upward trends. Fining-upward sequences also show a sequence of sedimentary structures, for example from base to top:

$\pm C \rightarrow D(G) \rightarrow F \rightarrow E \rightarrow H, K$ (Fig. 7)

Climbing ripples are present locally in the upper, finer parts of such sequences. Trough crossbeds commonly are oversteepened, and form small ball-and-pillow structures during soft-sediment deformation (Fig. 14). In the Pocaterra Creek sequence at Ribbon Creek, there is a general increase in the coarse (chert) sand and pebble component toward the top of the member.

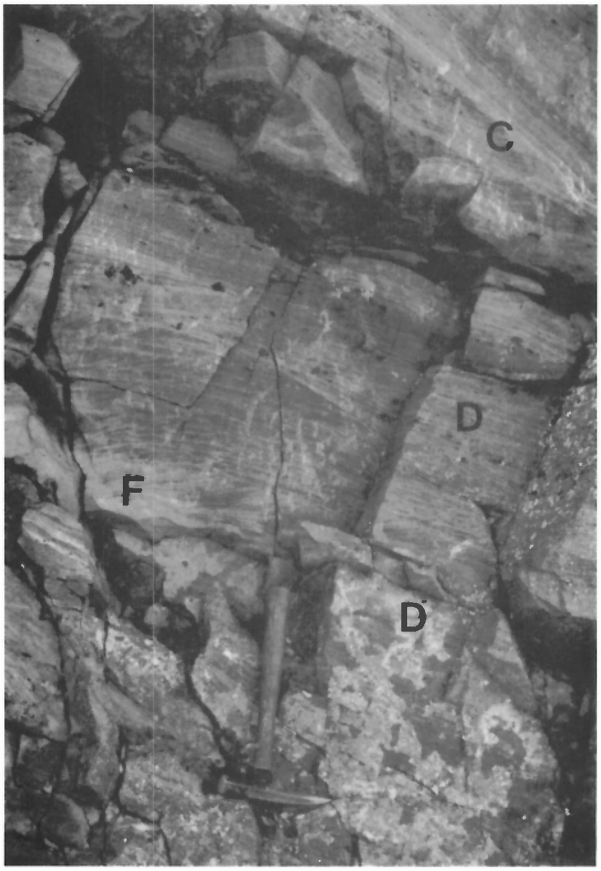


Figure 11. *Trough (D) and planar (C) crossbedded sandstone facies in the Pocaterra Creek Member, Ribbon Creek. The set of climbing ripples (F) above the hammer was scoured by trough crossbedded sandstone. A few black chert pebbles line the bases of trough scours. Facies letters used are from Table 3.*

Red mudstone

Red, green, and purple mudstones (facies I) are well exposed at Mount Allan in the Pocaterra Creek Member. Upper contacts of beds are relatively abrupt, however lower contacts tend to be less distinct where mudstone grades into the subjacent siltstone or sandstone. Weathering of the mudstones is characteristically rubbly. Calcareous nodules are common near the tops of the beds and, in places, nodules have coalesced to form highly irregular calcitic layers (Fig. 15). Vague root structures also were found in one of these beds.

Coal-bearing strata

These lithologies are found only in the Elk Formation at Coal Creek and consist of thin (a few cm) coals and "needle" coals (facies K) interbedded with fine grained sandstone, siltstone, and mudstone or shale of facies H. Distinctive, light grey, resistant "needle" siltstones of facies J (Gibson, 1977a, p. 782, 1985a) are common in the upper part of the Elk Formation in both the Kananaskis and Fernie areas and provide a useful means of distinguishing this formation from the Cadomin when exposure of coal units is poor. Well developed plant structures also are common in facies H and J (Fig. 16). The needle structures (see Gibson, 1977a, Plate II, and 1985a) are considered by Pearson and Grieve (1980) and Kalkreuth (1982) to be of algal origin.

Figure 12. *Subhorizontal, laminated sandstone (facies E) from the Pocaterra Creek Member, Ribbon Creek.*

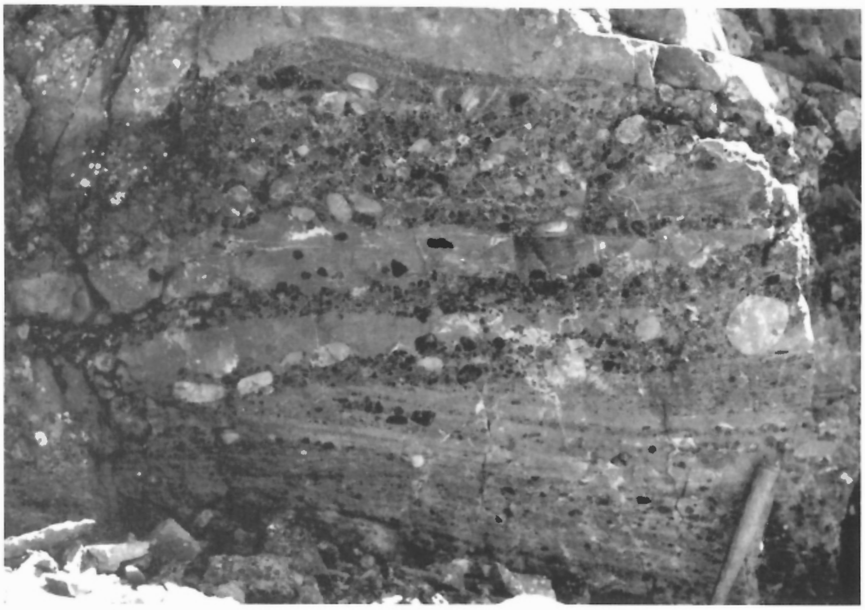


Figure 13. Thin pebble-lenses and scour-lags associated with trough crossbedded sandstones in the Pocaterra Creek Member, Mount Allan. Note the abundance of white quartzite pebbles; the cobble above the hammer handle is 10 cm across.

Figure 14. Oversteepened trough crossbeds in Pocaterra Creek Member sandstone, Mount Allan. Note the detached ball-and-pillow structure at top centre of photograph. The lens cap indicates stratigraphic top.

INTERPRETATION OF LITHOTYPES

A major clue in interpreting these rocks is the presence of thick conglomerates with clast supported frameworks. Fabric and bedforms in the conglomerates indicate high-energy, bed load transport of sediment and the most likely analogy is a braided river system. Some modern meandering rivers do have a gravel component with a clast-supported framework (e.g. Jackson, 1976), although this lithology is usually restricted to lag concentrates (Rust, 1978).

The conglomerates represent deposition in the principal active channels. The large-scale planar crossbeds are interpreted as large transverse gravel bars that had dimensions similar to many transverse structures in modern braided rivers; for example, the Donjek River (Williams and Rust, 1969) and Kicking Horse River (Hein and Walker, 1977). Crossbed set thickness and internal organization also are similar to some examples of Pleistocene fluvial gravels (Eynon and Walker, 1974; Vondra and Burggraf, 1978). Transverse bar development probably took place during periods of stream flooding, with growth being initiated at sites of basal pebble lag accumulation; a phenomenon that has been observed in modern gravel bars (Hein and Walker, 1977). Fluctuations in bar growth are indicated by reactivation surfaces, and, where the surfaces are draped by thin sandstone layers, growth may have occurred during successive periods of flooding. The preservation of these bar forms also depends upon the rate at which the falling-stage takes place (Blodgett and Stanley, 1980; Williams and Rust, 1969). For example, during a slow falling-stage, bar dissection occurs as the degree of exposure increases and the bar surface is transected by small subsidiary channels (corresponding to the second- and third-order channels of Williams and Rust, 1969). In the rock record this is seen as

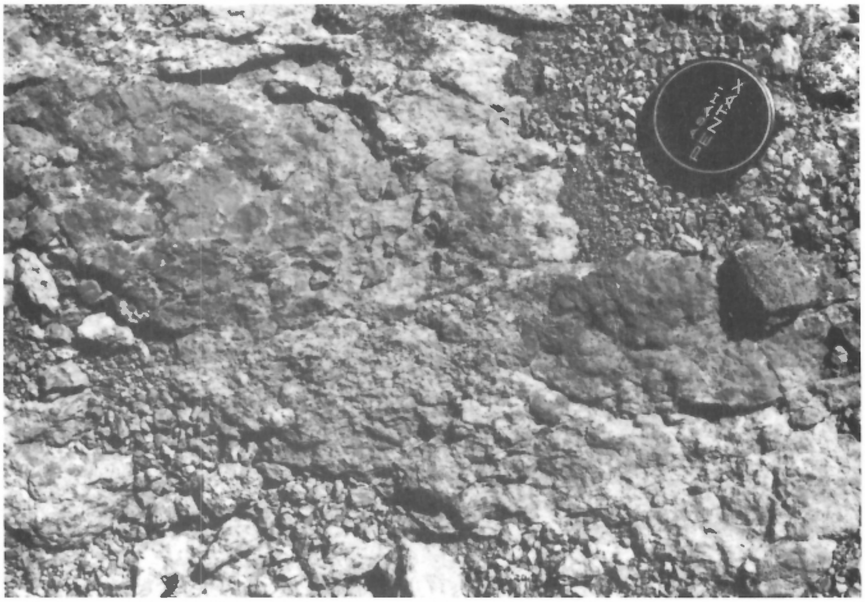


Figure 15. *Rubbly weathered, nodular calcite crust, or caliche, in one of the numerous purple-red mudstone units of the Pocaterra Creek Member, Mount Allan.*

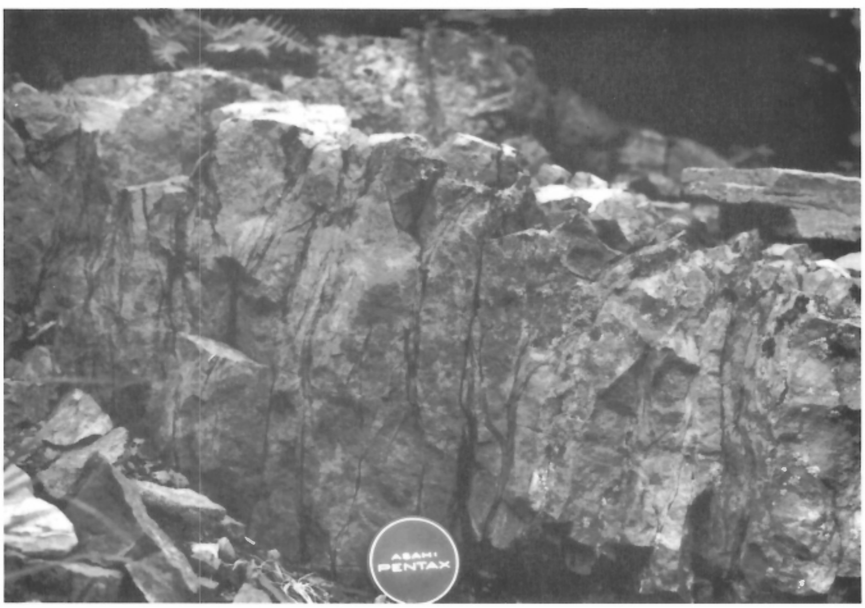


Figure 16. *Resistant, white weathering silt- to fine sand-sized sandstone with distinctive plant structures in their position of growth. The mode of preservation and preferential silicification of these beds is believed to have resulted from rapid burial of plants by volcanic ash mixed with terrigenous silt and fine sand. The upper part of this bed contains needle siltstone. Upper part of the Elk Formation, Coal Creek.*

planar crossbed sets of limited lateral extent, with set truncations commonly draped by thin sandstones; some of the ripple crossbedded sandstones may represent the bar-edge sand wedges of Rust (1972). A rapid falling-stage, on the other hand, is more likely to leave bar structures intact, and this may account for the laterally extensive Gp crossbed sets in the Elk and Cadomin.

The massive and horizontally bedded conglomerate units (facies A) are interpreted as poorly stratified, longitudinal bars. Hein and Walker (1977) have suggested that these bed forms develop under higher sediment discharge rates than do transverse bars (downstream growth is faster than aggradation and slip faces cannot develop), and this suggestion is supported by the present study on the evidence of the coarser grade of pebbles seen in several massive conglomerates, especially in the Cadomin Formation.

Sandstones in the Elk and Cadomin strata represent relatively lower energy sediment transport, although stream flow was sometimes capable of transporting pebbles. The two dominant facies (planar and trough crossbedded) resulted from deposition in active, subsidiary channels of lower competence than the main gravel-bearing channels. Occasional upper flow regime plane-bed conditions produced horizontally laminated sandstone with parting lineations (facies E).

The nodular, red weathering mudstones are interpreted as caliche deposits and thus are indicative of extended periods of subaerial exposure under semiarid conditions. Calcareous nodules and crusts formed during periods of evaporation and desiccation alternating with brief influxes of freshwater and resultant leaching. The lack of carbonaceous material and paucity of root structures in the mudstones indicate that plant growth was minimal during caliche formation.

Thin, coaly beds in the Elk Formation are interbedded with dirty sandstone and siltstone and represent accumulation in swamps or shallow ponded areas. During Elk times, the region in general was covered by a gymnosperm-dominated flora, although locally ferns were a more important component. Periods of coal accumulation were brief and floodwaters laden with fine sand and silt frequently inundated the swamps.

Cyclicity

Cyclic, fining-upward sequences have been documented in modern and ancient braided systems (Miall, 1977, 1978), in both gravel-dominated (Rust, 1978) and sand-dominated (Cant, 1978) rivers. In the examples from the Elk and Cadomin presented herein, three orders of cyclicity are recognized:

(i) A first-order coarsening- and thickening-upward cycle involving the complete sequence; the transition from the Elk Formation to the Cadomin Formation at Coal Creek displays a gradual decrease in coal-bearing strata, a concomitant increase in crossbedded sandstone and siltstone lithologies, and a gradual increase in the average clast size in the conglomerates. Similar trends are seen in the Ribbon Creek section.

(ii) First-order, fining-upward conglomerate-sandstone-siltstone cycles, in which the base of the conglomerate is scoured. In the Elk Formation these cycles culminate in thin coal and "needle" coal beds, and in the Pocaterra Creek Member they terminate in siltstone and red mudstone-caliche beds.

(iii) The smallest second-order cycles involve single sandstone or conglomerate beds that fine upward to pebbly sandstone, siltstone or mudstone. The most common facies sequence is

$$(C)D \rightarrow F \rightarrow H \rightarrow \pm K$$

and resembles fining-upward cycles commonly seen in meandering river deposits. The D facies may be pebbly, and planar crossbedded sandstones can occur below or above the D facies.

DISCUSSION AND GENERAL PALEOENVIRONMENTAL INTERPRETATIONS

In the Ribbon Creek and Coal Creek areas the sequence containing the Cadomin Formation (including the Pocaterra Creek Member) and the upper part of the Elk Formation is interpreted as the product of a system of braided streams and adjacent floodplains. The cyclicity of the conglomerates, sandstones and mudrocks (including the coals) resembles the Donjek model for braided streams (Miall, 1977; Williams and Rust, 1969). Major channels are represented by the thick conglomerate units. The channels were gravel-dominated and the formation of large longitudinal and transverse bars was a characteristic feature. General observations indicate that longitudinal bars (facies A) become more common, and that clast size increases concomitantly in the upper parts of this sequence (the coarsest pebble grades are found in the Cadomin). These features may indicate steeper stream gradients and resultant higher energy flow conditions. Subsidiary channels were characterized by crossbedded sands and pebble sands (facies C, D). The adjacent floodplain only received sediment during periods of flooding.

In the Elk-Cadomin sequence, the general vertical trend toward coarser grained lithologies and the loss of coaly beds suggests sediment transport conditions of increasing energy. To account for this trend, and for the repetition of the conglomerate-sandstone-coal sequences (first-order fining-upward cycles) a comparison is made with a prograding, humid, alluvial fan, braid plain depositional setting, as suggested by McLean (1977) for the Cadomin Formation. Good examples of this environment include modern fans in Alaska (Boothroyd and Nummedal, 1978), the Kosi River in Nepal (Gole and Chitale, 1966), and a more ancient analogue in the Precambrian Van Horne Sandstone (McGowen and Groat, 1971).

In the alluvial fan, braid plain setting, aggradation within the major gravel-dominated channels, and periodic flooding onto the adjacent floodplain, resulted in a decrease in the local stream gradient. At some point in this cycle, possibly during a flood stage, the channels shifted laterally to a previously inactive part of the fan that had a steeper gradient. The abrupt, commonly eroded contacts between conglomerate units and subjacent finer grained lithologies, in the Elk and Cadomin, are probably a direct result of these rapid lateral shifts in channel flow. The first-order cycles in the Elk Formation thus represent channel avulsion in the more distal parts of the fans, with the inactive floodplain regions subsequently becoming heavily vegetated. The Cadomin conglomerate cycles, on the other hand, represent a more proximal setting. The increase in longitudinal bars in the Cadomin conglomerates is comparable to trends in some modern Alaskan alluvial fans, where longitudinal bars are characteristic of proximal fan environments, and transverse bars are more common in the lower gradient, down-fan settings (Boothroyd and Nummedal, 1978).

Within this general setting, the Pocaterra Creek Member is viewed as a local precursor to the regionally more extensive Cadomin. The Pocaterra Creek Member represents an early phase of braid plain development, which culminated in deposition of the main Cadomin conglomerate. In the Kananaskis area, the wedge-shaped geometry of the Pocaterra Creek is readily apparent from Figure 2, and between Cat Creek and Mount Allan, this represents a paleogeographic distance of 65 km. If the Pocaterra Creek Member had its thickest development at Mount Allan, and the fan also was symmetrical about this location, the fan could have attained a width of 130 km prior to the main phase of Cadomin deposition.

At Kananaskis, during the early phase of alluvial sedimentation, the lack of accumulated organic debris in the Pocaterra Creek Member could indicate that only scattered patches of vegetation were present; spores from a sample of the member in Highwood Pass indicate that moisture-dependent ferns persisted, at least locally, in this member. This contrasts with the coal-bearing Elk Formation, which we suggest represents a forested, downslope alluvial plain environment and which, together with the thick coal-bearing strata lower in the Kootenay Group, indicates deposition in humid and temperate regions[1]. However, red mudstone and caliche in the Pocaterra Creek Member are more indicative of semiarid conditions. Similar conclusions were reached by Gibson (1977a, 1985a) and Ollerenshaw (1981) regarding red and maroon mudstone units in the Fernie area. Did these more arid conditions result from climatic changes of regional extent, or did they reflect local changes in weather patterns (for example, as rain shadows that developed during progressive uplift of the Rocky Mountains)?

In the southern and central Alberta Foothills, the Cadomin is overlain conformably by the lower member of the Gladstone Formation, which also contains some maroon and red mudstones, and shows a distinct lack of coal-bearing strata (Norris, 1964; McLean, 1982). North of the Bow River, however, carbonaceous debris becomes an increasingly important component of the lower Gladstone (McLean, *op. cit.*). The Gething Formation, which also overlies and partly intertongues with the Cadomin in northeastern British Columbia (Stott, 1968), also contains abundant, thick coal measures and, like the Kootenay Group, probably represents relatively humid conditions. Therefore, temperate conditions generally prevailed during Kootenay and lower Blairmore times, although there appears to have been some variation in the degree of aridity between southern and northern "Alberta", the south being more arid than the northern region.

[1]The terms tropical, temperate, etc., refer to positions of latitude and not to amounts of precipitation or degree of aridity.

BIOSTRATIGRAPHY OF THE KOOTENAY AND BLAIRMORE GROUPS

Because the Blairmore and Kootenay groups of southwestern Alberta and southeastern British Columbia are primarily of continental origin, considerable difficulty has been encountered in determining their ages. The following discussion highlights only the major developments in the determination of the ages of these groups. The reader is referred to Gussow (1960) for a detailed account although it should be noted that the present authors do not agree with Gussow's conclusions.

Kootenay Group

The occurrence of *Titanites occidentalis* Frebold, in the Morrissey Formation near Fernie, British Columbia, has been used to fix the maximum age of the Kootenay as Late Portlandian (Frebold, 1954, 1957). Apart from the occurrence of *Titanites*, the next closest documented age relating to the base of the Kootenay Group is the Early Oxfordian age of beds in the upper part of the Fernie Formation (Frebold, 1957).

Subsequent to the initial report of *Titanites* from the base of the Kootenay, Bell (1956) published a comprehensive study on the Kootenay and overlying Blairmore floras. The evidence gained by Bell from the Kootenay flora, through comparison with the Wealden of northwest Europe and England, was only sufficiently precise to assign a Neocomian - Barremian age for the Kootenay, although he personally favored Barremian rather than Neocomian. No evidence was found by Bell to suggest that the Kootenay flora could be divided into subfloras. However, without knowing whether Bell's plant localities encompassed the entire Kootenay Group, the significance of this observation is uncertain.

Rouse (1959) concluded that a Late Jurassic rather than Early Cretaceous age was more appropriate for the microflora recovered from the roof shales of coals near Fernie, within what is now the Mist Mountain Formation, based on a comparison with the known Jurassic and Early Cretaceous microfloral assemblages. A similar conclusion was reached by Pocock (1964) in his study of samples from what are now the Mist Mountain and Morrissey formations at Grassy Mountain, Alberta. Sweet (1972) suggested the possibility of an Early Cretaceous age for the uppermost part of the Mist Mountain Formation on Sparwood Ridge, British Columbia, based on the presence of *Schizosporis reticulatus* Cookson and Dettmann, 1959. Subsequently, Sweet (in Gibson, 1977a, 1979, 1985a) also indicated a probable Early Cretaceous age for the uppermost part of the Mist Mountain Formation and for the overlying Elk Formation. These inferences of an Early Cretaceous age do not necessarily conflict with the Late Jurassic ages determined by Rouse and Pocock, as the samples these authors studied came from stratigraphically lower horizons.

In the same relative stratigraphic position as the Kootenay Group (i.e. between the Fernie and Cadomin formations), the Minnes Group of northeastern British Columbia and northwestern Alberta ranges from Tithonian to late Valanginian in age (Stott, 1981).

Blairmore Group

Arguments concerning the age of the Blairmore Group in southwestern Alberta derive from two sources: the nonmarine fossils recovered from localities within the area; and from inferred correlations with marine intercalations that occur in outcrop farther to the north. McLean and Wall (1981) reviewed the critical arguments relating to the age of the Blairmore Group in the Foothills of central Alberta and concluded that the Moosebar Member of the Malcolm Creek Formation is Early Albian. The Moosebar Member directly overlies the Gladstone Formation, which in turn overlies the Cadomin Formation. Farther north, the upper part of the Gething Formation, which also overlies the Cadomin Formation, is dated as Aptian by Gibson (1985b).

Bell (1956) presented arguments for either or both an Aptian and a Barremian age for the megaflora from the lower part of the Blairmore Group, whereas Berry (1929) previously had considered the same flora to be late Aptian or Albian in age. The arguments of both these authors were dependent upon the assumed age of comparable floras elsewhere in North America. There are no published palynological reports on the Blairmore Group of southern Alberta. Pocock (1962), Singh (1964) and Vagvolgyi and Hills (1969) document microfloras from the broadly correlative Mannville Group. Singh (1964) assigned a Barremian to Middle Albian and Vagvolgyi and Hills (1969) an Early to Middle Albian age to their respective intervals of study. Pocock (1962) considered the basal Deville Member of the Lower Mannville to be of Berriasian to Valanginian age and the overlying Quartz sand member to be Barremian in age. Recently, these age assignments were revised upward by Pocock (1980), who now contends that there are no Cretaceous strata older than Aptian underlying the Western Canadian Plains.

Summary

From previous reports, it is possible to conclude that the Kootenay-Blairmore transition is not older than Portlandian and is probably not younger than Aptian in age.

SPORE AND POLLEN ASSEMBLAGES FROM THE ELK-POCATERRA CREEK INTERVAL

Well preserved assemblages were recovered from samples of mudstone, shale and bituminous coal (high to medium volatile) from sections of the Elk-Pocaterra Creek interval at Coal Creek, Highwood Pass and Cat Creek (one sample) (see Table 4). The number of samples obtainable for palynological analysis from this interval was limited by the dominance of coarse clastic units, and the recessive nature in outcrop sections of the more finely grained rocks. Three samples, from fine grained sandstone and siltstone interbeds within the overlying Cadomin Formation in the Coal Creek section, proved to be barren.

In this study, it was found that bisaccate pollen (mostly *Alisporites* spp. but with a few occurrences of *Podocarpidites* spp. and *Vitreisporites* sp.) dominate the assemblages found in samples of the Elk Formation from 31 to 121 m below the base of the Cadomin Formation at Coal Creek, in contrast to the predominance of spores in sample C-92963, from 13 m below the Cadomin Formation (Fig. 17). Noticeable in figures 17, 18 and 19 is the apparently abrupt increase in the relative abundance and diversity of schizaeaceous spores and the relative abundance of *Gleicheniidites* toward the top of the Elk-Pocaterra Creek interval. This floristic change can be interpreted as an extension of the trend toward a higher percentage and greater diversity of spores initiated lower in the section, which would suggest a more or less conformable sequence. For a more definitive argument on the degree of conformity, the reader is referred to the sedimentological analysis earlier in this report.

It is of note that the three samples from the Coal Creek section with the highest relative abundance of bisaccate pollen (Fig. 17; C-092957, C-092959 and C-092960) occurred in association with the "needle" siltstones (C-092957, C-092959) or contained "needles" of coal (C-092960).

In addition to those taxa and morphological groups listed in figures 17, 18 and 19, and discussed under **Systematic Palynology,** several occurrences were recorded of specimens referrable to *Laevigatosporites*, *Lycopodiumsporites*, *Neoraistrickia*, *Stereisporites*, and *Verrucosisporites*.

TABLE 4

Localities and stratigraphic horizons of samples processed for palynology

(The base of the Cadomin Formation is used as a datum. The figures in brackets indicate stratigraphic position below this datum and figures without brackets define the position above the datum.)

	G.S.C. Locality No.	Position (Metres)
1.	Coal Creek Section (49°30'N, 114°59'W).	
	C-092965	116
	C-092964	102
	C-092968	92
	C-092963	(13)
	C-092966	(31)
	C-092967	(32)
	C-092962	(38)
	C-092961	(39)
	C-092960	(64)
	C-092972	(76)
	C-092959	(94)
	C-092958	(96)
	C-092957	(101)
	C-092956	(121)
2.	Highwood Pass Section (50°35'N, 115°01'W).	
	C-092979	41
	C-092978	(7)
	C-092977	(37)
	C-092974	(53)
	C-092973	(71)
3.	Cat Creek Section (50°25'N, 114°43'W).	
	C-092969	(3)

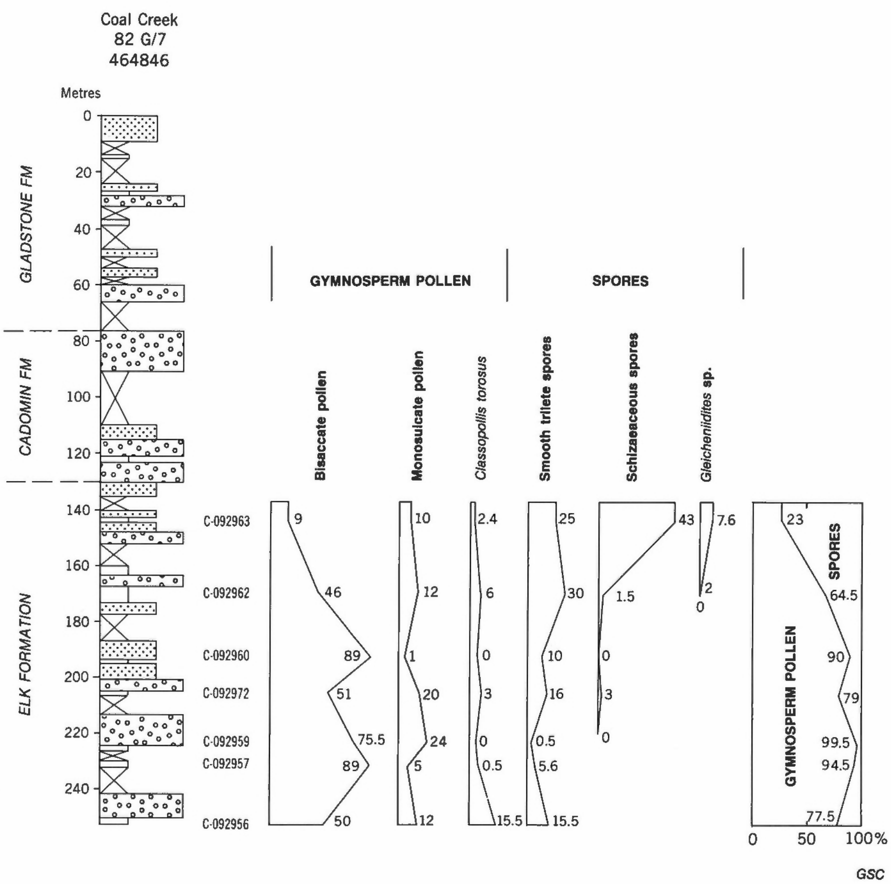


Figure 17. Relative abundance diagram for the seven countable palynological samples from the Elk Formation, Coal Creek section.

SYSTEMATIC PALYNOLOGY

Most of the species figured on plates 1 to 4, and discussed in the following section, are selected from the assemblages recovered from the upper part of the Elk Formation and the Pocaterra Creek Member of the Cadomin Formation, because of their biostratigraphic significance. A few longer ranging species are included, to provide a record of these species from the Kootenay Group and contiguous strata.

No new taxa or combinations are proposed. The intent of the abbreviated discussions given for each species is to point out possible taxonomic ambiguities, which might affect the biostratigraphic meaning of the species. Selected occurrences are given as a means of referencing the papers used in determining the biostratigraphic significance of the species.

The species discussed below are grouped into three categories: spores, gymnosperm pollen, and algal structures. Within each category the species are listed alphabetically.

SPORES

Biretisporites potoniaei
Delcourt and Sprumont, 1955

Plate 1, figure 1

Remarks. For synonymy, see Delcourt, Dettmann and Hughes (1963).

Occurrence. Early Cretaceous (for details see Singh, 1971).

Ceratosporites sp.

Plate 1, figure 9

Remarks. This species is comparable to *Ceratosporites* sp. in McIntyre and Brideaux, 1980, from the Valanginian of Northern Canada.

Cicatricosisporites sp. cf. *C. aralica*
(Bolkhovitina) Brenner, 1963

Plate 1, figures 2-4

Remarks. The specimens seen in this study differ from those described by Bolkhovitina (1961) in having more or less straight sides, rather than convex sides. As did Brenner (1963), we accept the spores of *Ruffordia goepperti* (Dunk.) Seward, 1913 illustrated by Couper (1958) as synonymous with *C. aralica*. In addition, *C. purbeckensis* Norris (1969) also appears to be conspecific with *C. aralica*. A closely similar species, *C. hughesi* Dettmann, 1963, appears to differ in having more fusion of the ribs on the radials.

Occurrence (selected). C. aralica is known from the Lower Cretaceous of the USSR (Bolkhovitina, 1961); the Lower Cretaceous, Wealden of England (Couper, 1958, and referred to as *Ruffordia goepperti*); and the Potomac Group, U.S.A. (Brenner, 1963). *C. purbeckensis* has been reported from the Lower, Middle and Upper Purbeck of England, Suites B and C (Norris, 1969).

Cicatricosisporites australiensis
(Cookson) Potonié, 1956

Plate 1, figures 5, 6

Remarks. C. australiensis is characterized by the proximal and distal ribs running parallel to the equatorial outline. Specimens that conform to *C. australiensis* in the above characteristic, as well as in general size, shape, and rib morphology, were found both with ribs of medium width (Pl. 1, fig. 5), which conform to the width originally described for *C. australiensis*, and with finer ribs (Pl. 1, fig. 6). Although both forms have been combined into one species, it is recognized that they may, in fact, be separate species.

Occurrence. C. australiensis has been widely reported from the Early Cretaceous (see Singh, 1971) and from the Late Jurassic by some authors (see Brideaux and Fisher, 1976).

Cicatricosisporites sp. cf. *C. grabowensis*
Döring, 1965

Plate 1, figures 7, 8

Remarks. Except for their smaller size, the specimens observed in this study conform closely to *C. grabowensis*.

Occurrence. *C. grabowensis* was described from the Wealden of Germany (Döring, 1965) and was reported by Brideaux and Fisher (1976) from the Upper Jurassic of Arctic Canada.

Concavissimisporites punctatus
(Delcourt and Sprumont) Brenner, 1963

Plate 1, figures 12, 13

Remarks. *C. punctatus*, as originally described, encompasses spores 30 to 50 mμ in diameter with an intramicroreticulate to intragranulate ornament (Delcourt and Sprumont, 1955). The wall was described by Delcourt et al. (1963) as having an undulose appearance and not as punctate. It is in the sense of Delcourt et al. (1963) that *C. punctatus* is used in this paper.

Bolkhovitina (1961) considered *C. punctatus* to be synonymous with *Concavissimisporites* (*Lygodium*) *asper* (Bolkhovitina) Pocock, 1962. However, the larger size of *C. asper* appears to provide a basis for separating these species.

Brenner (1963) included microrugulate to granular specimens, 38 to 73 mμ in diameter, within *C. punctatus*. Relatively large specimens in this species were also included by Pocock [1962, 54 (62) 66 mμ; 1964, 72 mμ] and Singh (1964; 55-75 mμ). Those described by Pocock were granular or verrucate, and those by Singh, subgranulose. *Lygodium granulatum* Ivanova, 1961, described as being 57.5 to 60 mμ in diameter and granular, would seem to be a more appropriate species to encompass the larger, more granular spores described by Pocock (1962, 1964), Brenner (1963), and Singh (1964). *Lygodium granulatum* was transferred to *Maculatisporites* by Döring (1964) (see *Maculatisporites granulatus* for further discussion of this species).

Occurrence. Early and early Late Cretaceous. For further details see Srivastava (1975), but note that the Bathonian record given by Srivastava is considered to be in error, and that the uppermost Jurassic record of Burger (1966) is considered to be of *Maculatisporites granulatus* rather than *C. punctatus*.

Convolutriletes sp. cf. *C. rousei*
Pocock, 1970

Plate 1, figure 18

Occurrence. *C. rousei* was described from the Jurassic of Western Canada by Pocock (1970).

Deltoidospora psilostoma Rouse, 1959

Remarks. See Rouse (1959, Pl. 12, figs. 7, 8) for photographs of this species.

Occurrence. Kootenay Group (Rouse, 1959), Jurassic to Upper Cretaceous of Western Canada (Pocock, 1962).

Densoisporites velatus
Weyland and Krieger, 1953

Plate 1, figure 14

Remarks. For synonymy, see Döring (1965).

Occurrence. Jurassic to Cretaceous (for further details, see Döring, 1965).

Echinatisporis varispinosus
(Pocock) Srivastava, 1975

Plate 1, figures 19, 20

Remarks. This species occurs most commonly in the literature as *Acanthotriletes varispinosus* Pocock, 1962. Dörhöfer (1979) placed *Acanthotriletes varispinosus* in synonymy with *Selaginella aculeata* Verbitskaya, 1962, and substituted a new name, *Apiculatisporis verbitskayae*, for the latter species. A similar, if not conspecific, species, *Ceratosporites parvus*, was described by Brenner (1963).

Occurrence. Cretaceous of North America (see Srivastava 1975; Brenner, 1963 under *Ceratosporites parvus*). Lower Cretaceous of Europe (Dörhöfer, 1977, 1979; Kemp, 1970, under *Ceratosporites* sp. cf. *C. parvus*).

Foraminisporis dailyi
(Cookson and Dettmann) Dettmann, 1963

Plate 1, figure 17

Remarks. For partial synonymy and description, see Dettmann, 1963. We also consider *Lycopodiacidites triangularis* Brenner, 1963, as probably synonymous with this species.

Occurrence. Upper Mesozoic of Australia (Dettmann, 1963); possibly in Potomac Group, Maryland (Brenner, 1963); Lower Cretaceous (Valanginian) of Europe (Dörhöfer, 1979); and Lower Cretaceous of Alberta (Singh, 1971).

Foraminisporis wonthaggiensis
(Cookson and Dettmann) Dettmann, 1963

Plate 1, figures 15, 16

Remarks. For synonymy and description, see Dettmann (1963). The specimens observed in this study differ from those described by Dettmann (1963) in having spines on the proximal surface as large or larger than those on the distal surface (compare Pl. 1, figs. 15 and 16 with Dettmann, 1963, Pl. 14, figs. 19-28).

Occurrence. See Singh (1971) for occurrences. Dörhöfer (1979) indicates a Berriasian to Valanginian range in Europe.

Gleicheniidites senonicus Ross, 1949

Plate 1, figure 21

Occurrence. Worldwide, Jurassic to Cretaceous (Singh, 1971).

Ischyosporites punctatus
Cookson and Dettmann, 1958

Plate 1, figures 10, 11

Occurrence. Upper Jurassic to Albian of Canada and Australia (Singh, 1971).

Impardecispora minor
(Pocock) Venkatachala, Kar and Raza, 1968

Plate 2, figure 7

Remarks. The specimens observed in this study lack sculpture elements bordering the laesurae.

Occurrence. Lower Mannville and stratigraphic equivalents (Pocock, 1962); and throughout the Mannville Group, except for the Deville Member (Singh, 1964).

Impardecispora uralensis
(Bolkhovitina) Venkatachala, Kar and Raza, 1968

Plate 3, figure 1

Occurrence. Barremian to Albian, USSR (Bolkhovitina, 1961).

Impardecispora sp. A

Plate 2, figures 5, 6, 9, 10

Remarks. The specimens included in *Impardecispora* sp. A are similar in general morphology to *Trilobosporites sphaerulentus* Phillips and Felix, 1971, differing from *T. sphaerulentus* in being smaller (48-56 mμ as opposed to 75-95 mμ). Specimens with and without sculpture bordering the laesurae are included in this species.

Occurrence. *Trilobosporites sphaerulentus* is known from the Albian of Louisiana (Paden Phillips and Felix, 1971).

Maculatisporites granulatus
(Ivanova) Döring, 1964

Plate 2, figures 1, 2

Remarks. In this paper, *Maculatisporites granulatus* is distinguished from *Concavissimisporites punctatus* by its larger size and more distinct granules. We consider that specimens included in *C. punctatus* by Pocock (1962, 1964), Brenner (1963), Singh (1964), and Burger (1966) are referable to *M. granulatus*.

Occurrence. Widespread reports from the Lower Cretaceous and uncommon records from the uppermost Jurassic (Pocock, 1962, 1964; Brenner, 1963; Singh, 1964, Döring, 1965; and Burger, 1966).

Maculatisporites microverrucatus
Döring, 1964

Plate 2, figure 3

Occurrence. Berriasian-Valanginian of Europe; Late Jurassic to Early Cretaceous of North America (Dörhöfer, 1979).

Maculatisporites parkinii
(Pocock) Dörhöfer, 1979

Plate 2, figure 4

Remarks. For synonymy, see Dörhöfer (1979) and Singh (1964). The overall size and shape, and the fine, evenly distributed granules of the specimens seen in this study compare well with *Concavisporites parkinii* as described in Pocock (1962), whereas the exine is thinner (1.5-2.5 mμ as compared to 3-4 mμ) in the specimens observed in this study.

Occurrence. See above references for occurrences.

Osmundacidites major Döring, 1965

Plate 2, figure 11

Occurrence. Wealden A (Döring, 1965).

Pilosisporites brevibaculatus
Döring, 1965

Plate 2, figure 8

Occurrence. Wealden G, Germany (Döring, 1965).

Pilosisporites trichopapillosus
(Thiergart) Delcourt and Sprumont, 1955

Plate 2, figures 12, 13

Remarks. For synonymy, see Döring, 1965. The specimens from sample C-92963 (Pl. 2, fig. 12) conform closely to *P. trichopapillosus*. The commonly shorter and more sparsely distributed spines seen on specimens in sample C-92979 (Pl. 2, fig. 13) is treated herein as intraspecific variation, although the option exists of assigning these specimens to another species.

Occurrence. Widely reported from the Lower Cretaceous with occasional records from the Upper Jurassic (for details see Brenner, 1963; Döring, 1965; and Singh, 1971).

Trilobosporites aornatus Döring, 1965

Plate 3, figure 9

Remarks. *Matonisporites phlebopteroides* Couper, 1958, which ranges from Jurassic to Cretaceous in age, is similar to *T. aornatus* in having an unsculptured wall and a thickened exine at the radials. It is distinct from *T. aornatus* in that the differentially thickened exine does not extend appreciably toward the poles.

Occurrence. Upper Malm (?) to Wealden, Zone A of Germany (Döring, 1965); Berriasian to lowest lowermost Valanginian (Dörhöfer 1979).

Trilobosporites sp. cf *T. bernissartensis*
(Delcourt and Sprumont) Potonié, 1956

Plate 3, figure 5

Remarks. The specimens representing this species are most similar to those described as *T. bernissartensis* by Burger (1966), a species which also had a primary and superimposed secondary ornament. This characteristic was not recorded by Delcourt and Sprumont (1955), Couper (1958), nor Döring (1965) in their descriptions of *T. bernissartensis.*

Occurrence. *T. bernissartensis* in Burger (1966) was recorded from pollen zones R to U, and possibly to pollen zone X. *T. bernissartensis* (s.l.) is known from the Late Jurassic and Early Cretaceous (Döring, 1966).

Trilobosporites canadensis
Pocock, 1962

Plate 3, figures 6-8

Remarks. Venkatachula et al. (1968) transferred this species to *Impardecispora*. Because of its apparently close affinity with *T. bernissartensis* (see below) it seems preferable to retain *Trilobosporites canadensis* within *Trilobosporites* (s.s.).

As noted by Pocock (1962), one end of the range of variation ascribed to *T. canadensis* approaches that of *T. bernissartensis* [compare Pocock 1962, Pl. 4, fig. 67, with the holotype of *T. bernissartensis* refigured by Delcourt et al. 1963, Pl. 43, figs. 11 and 12 and to the specimen in Pl. 43, fig. 13 (*op. cit.*)]. Likewise, the specimen in Delcourt et al. (1963, Pl. 43, fig. 14) bears a close resemblance to the holotype of *T. canadensis* (Pocock 1962, Pl. 4, fig. 63). Therefore, it can be concluded that in both Europe and North America a similar range of variation occurs within the *T. canadensis-T. bernissartensis* complex, and that this range of variation indicates an overlap in the circumscription of these species.

In this study, specimens very similar to the holotype of *T. canadensis* were recorded (Pl. 3, fig. 8) as well as those tending toward *T. bermissartensis* (Pl. 3, fig. 6). For the purposes of this paper, this entire range of variation was included within *T. canadensis*, as specimens most similar to this species dominated the assemblage.

Occurrence. *T. canadensis* was reported from the Lower Mannville by Pocock (1962) and is known from the Berriasian and Valanginian of Europe (Dörhöfer, 1979).

Trilobosporites sp. cf. *T. granulatus*
Döring, 1965

Plate 3, figure 12

Remarks. A comparison of the illustrated specimens with *T. granulatus* is based on the overall similarity in the general shape of these spores and the form of the radial thickenings. *T. granulatus* is slightly smaller (50-73 mµ compared to 76 mµ in diameter for the specimen in Pl. 3, fig. 12) and has more precisely formed granules than the specimens recovered in this study.

Occurrence. *T. granulatus* was reported from the upper Malm, and questionably from the Wealden A, by Döring (1965), and from the lower Berriasian by Dörhöfer (1979).

Trilobosporites hannonicus
(Delcourt and Sprumont) Potonié, 1956

Plate 3, figures 10, 11

Occurrence. Wealden of Belgium (Delcourt and Sprumont, 1955); Deville and Ellerslie members, McMurray Formation of Alberta (Singh, 1964).

Trilobosporites obsitus Norris, 1969

Plate 3, figures 2-4

Remarks. The specimens assigned to this species closely compare to those figured by Norris (1969, Pl. 106, figs. 7, 8). *T. bernissartensis* (Delcourt and Sprumont) Potonié, 1956, appears to have a close affinity with *T. obsitus*. The knob-like apical thickenings of the exine, and more prominent proximal versus distal ornament in *T. obsitus*, appear to provide a basis for maintaining *T. obsitus*, as a separate species from *T. bernissartensis*.

Occurrence. Upper Purbeck, Zone C (Norris, 1969); late Berriasian to early Valanginian (Dörhöfer, 1979).

GYMNOSPERM POLLEN

Callialasporites obrutus
Norris, 1969

Plate 4, figure 6

Occurrence. Late Jurassic to Early Cretaceous, suites A through C in England (Norris, 1969).

Classopollis torosus
(Reissinger) Couper, 1958

Plate 4, figure 9

Occurrence. The range of *Classopollis* is given in Srivastava (1978) as Late Triassic to Turonian.

Ephedripites multicostatus
Brenner, 1963

Plate 4, figure 3

Occurrence. Potomac Group, Maryland (Brenner, 1963); mid-Atlantic outer continental shelf, Berriasian to Turonian (Bebout, 1981); western north Atlantic, Berriasian (?) to Hauterivian (?) (Habib, 1977).

Ephedripites sp. cf *E. patapscoensis*
Brenner, 1963

Plate 4, figure 4

Remarks. The single specimen observed (Pl. 4, fig. 4) appears to lack the knob-like structures at the ends of the grain described by Brenner for *E. patapscoensis*.

Occurrence. Potomac Group, Maryland, subzone B of Zone II (Brenner, 1963).

Eucommiidites troedssonii Erdtman, 1948

Plate 4, figure 2

Occurrence. Jurassic to Cretaceous (Singh, 1971).

ALGAL STRUCTURES

Tetranguladinium conspicuum
Yu Jingxian, Guo Zhengying, and Mao Shaozhi, 1983

Plate 4, figure 5

Remarks. As an orthographic correction '*conspicus*' has been changed to '*conspicuum*' *fide* J. Jansonius (pers. comm.). This form of algae was called a fossil conjugate in Tschudy and Scott (1969, Pl. 2-1) and was referred to as *Horologinella* sp. by Sweet (1978).

Occurrence. Early Cretaceous of China (Yu Jingxian et al., 1983); Late Cretaceous (Tschudy and Scott, 1969; Sweet, 1978).

Botryococcus sp.

Plate 4, figure 8

Remarks. Both Burger (1966) and Norris (1969) noted a significant increase in the occurrence of *Botryococcus* in the Early Cretaceous as compared to the Late Jurassic.

Occurrence. *Botryococcus* ranges from Ordovician to Recent (Traverse, 1955).

Schizosporis reticulatus
Cookson and Dettmann, 1959 emend. Pierce, 1976

Plate 4, Figure 10

Remarks. For synonymy and description, see Pierce (1976).

Occurrence. Worldwide, Berriasian to Cenomanian-Turonian or possibly Maastrichtian, based on 20 published records (Pierce, 1976).

Sigmopollis sp.

Plate 4, figure 7

Occurrence. Norris (1969) reports *Sigmopollis callosus*, which differs from *Sigmopollis* sp. in being rugulate, from his Zone C.

Schizophacus rugulatus
(Cookson and Dettmann) Pierce, 1976

Plate 4, figure 11

Remarks. The specimens from Canada (Pocock, 1962; and this paper) appear to be more coarsely sculptured than those originally described by Cookson and Dettmann (1959) and Dettmann (1963).

Occurrence. Uppermost horizons of Upper Mesozoic strata in Australia (Dettmann, 1963); Mannville Group (Pocock, 1962).

Schizophacus spriggii
(Cookson and Dettmann) Pierce, 1976

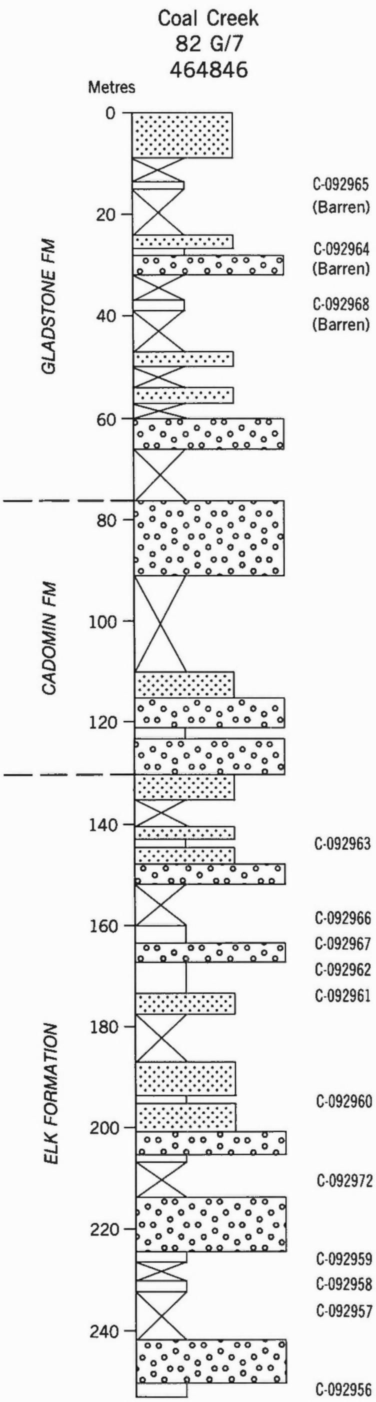
Plate 4, figure 1

Remarks. The size of specimens recovered in this study (95-130 mμ maximum dimension, 10 specimens) approaches that given by Cookson and Dettmann (1959) for this species (75-125 mμ) and is less than that of *Schizophacus grandis* (Pocock) Pierce, 1976 (153 mμ maximum; Pocock, 1962) although the two species are otherwise quite similar.

Occurrence. *Schizophacus spriggii* occurs in the Upper Mesozoic of Australia (Dettmann, 1963) and Lower Mannville to Lower Colorado of Alberta (Pocock, 1962). *Schizophacus grandis* occurs in the Quartz sand member; Lower Mannville (Pocock, 1962).

Based on the similarities between the assemblages recovered, the following sample horizons are probably more or less correlative: C-092979 from the Pocaterra Creek Member, Highwood Pass Section; C-092963 from the top of the Elk Formation, Coal Creek Section; and, to a lesser extent, C-092969 from the Pocaterra Creek Member, Cat Creek Section (Fig. 20). Although the low number of samples might seem to make the above conclusion questionable, no stratigraphically lower horizons have yielded similar assemblages (Sweet, unpublished data; Gibson, 1985a, 1985b), which adds strength to the argument.

If one accepts the above conclusion and the placement of the formational boundaries as correct, one implication is that the Pocaterra Creek Member of the Cadomin Formation at Highwood Pass is correlative with the upper Elk beds at Coal Creek. It is generally conceded that the Pocaterra Creek Member is lithologically part of the Cadomin Formation (Gibson, 1977a, 1981, 1985a; McLean, 1977; and this paper) and that no major time break occurs between the Pocaterra Creek Member and the main part of the Cadomin Formation. Therefore, a second implication of the above correlation is support for a more or less continuous sedimentological record between the Elk Formation and the Cadomin Formation in the Fernie region. This situation would be comparable to the possibility suggested by Stott (1981) of little or no hiatus between the Bickford and Cadomin formations in the Carbon Creek basin and western Foothills of northeastern British Columbia.



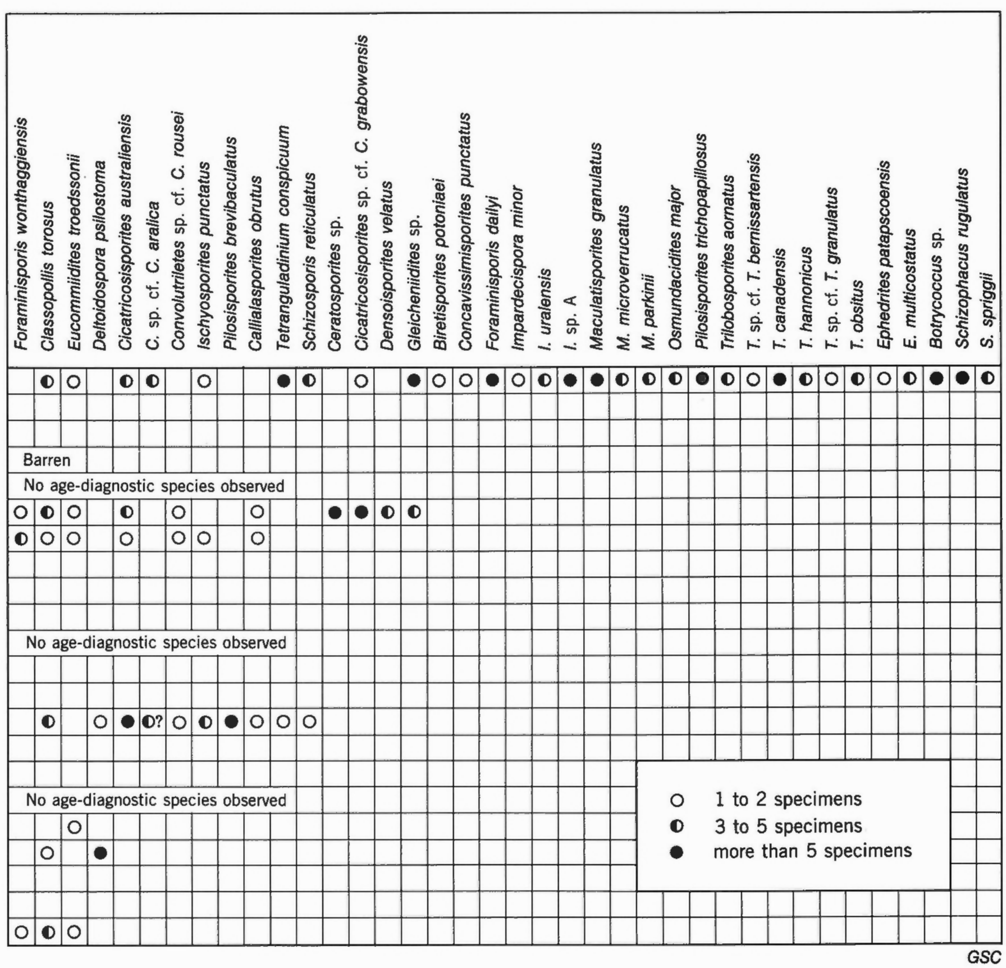


Figure 18. *Range chart of selected palynomorphs from the Coal Creek Section, southeastern British Columbia.*

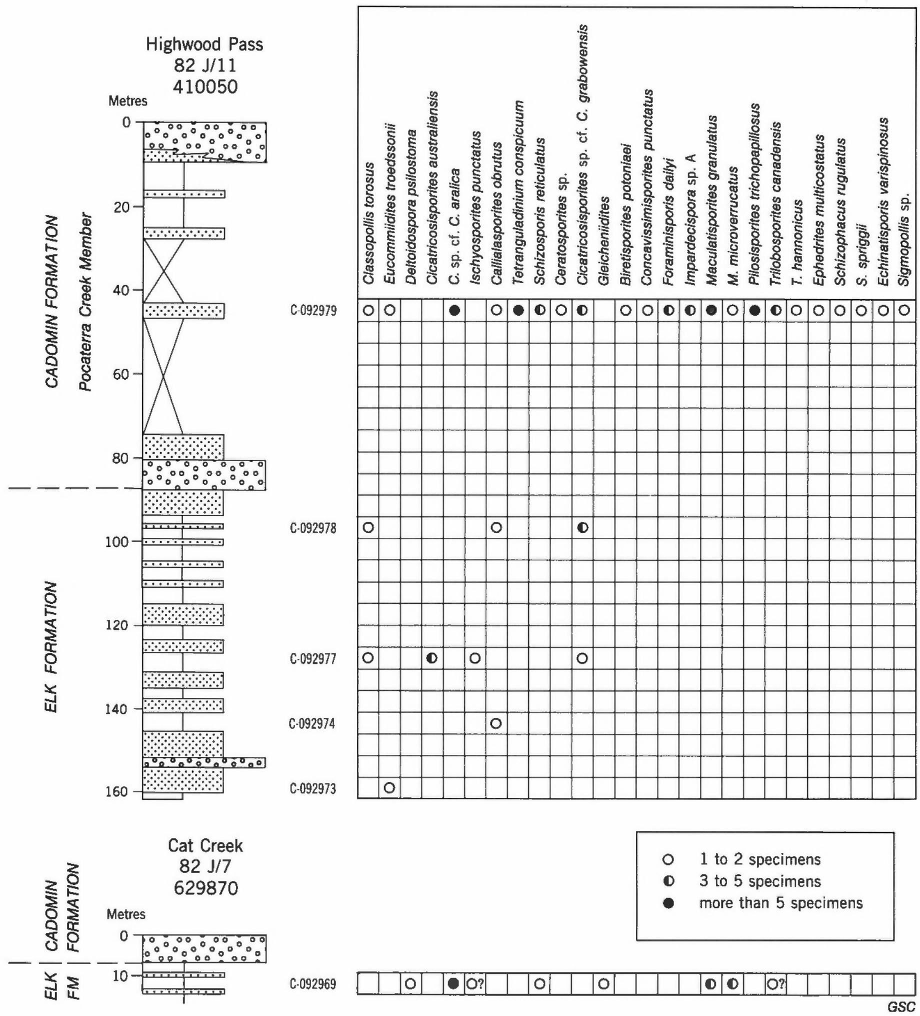


Figure 19. *Range chart of selected palynomorphs from the Highwood Pass section and one sample from Cat Creek, southwestern Alberta.*

PALEOENVIRONMENTAL SIGNIFICANCE OF ASSEMBLAGES

The flora from the Elk-Pocaterra Creek interval is comparable to that in assemblages described by Herngreen and Chlonova (1981) from the Lower Cretaceous, Boreal microfloral province. The Boreal microfloral province occurs throughout North America, Europe and Asia (excluding India), and is typified by abundant bisaccate pollen and abundant spores with a high degree of diversity. This assemblage is contrasted by Herngreen and Chlonova with a pre-Albian, West African-South American microfloral province, typified in part by a dominance of *Classopollis* and considered to represent a warmer and drier climate than that of the Boreal province.

A parallel argument is presented by Vakhrameev (1981), who suggests that a low content of *Classopollis* (1-10%), within the Jurassic and Cretaceous of the USSR, indicates a temperate and/or humid climate. Alternatively, Vakhrameev observes that a high relative abundance of *Classopollis* occurs most commonly in association with indicators of arid to semiarid conditions in subtropical to tropical areas. Using Vakhrameev's arguments, the overall low relative abundance of *Classopollis* in the samples examined during this study, and indeed throughout much of the Kootenay Group (unpublished data, A.R. Sweet), would suggest a temperate and/or humid climate for this stratigraphic interval.

The increased relative abundance and diversity of schizaeaceous spores and *Gleicheniidites* at the top of the sections (figs. 17, 18, 19) suggests a possible warm temperate, but more likely subtropical to tropical, humid regional climate for the uppermost part of the Elk-Pocaterra Creek interval. These inferences are compatible with and lend support to the humid, temperate to subtropical environment for the Cadomin Formation proposed by McLean (1977) and as interpreted in this paper, based on sedimentological arguments.

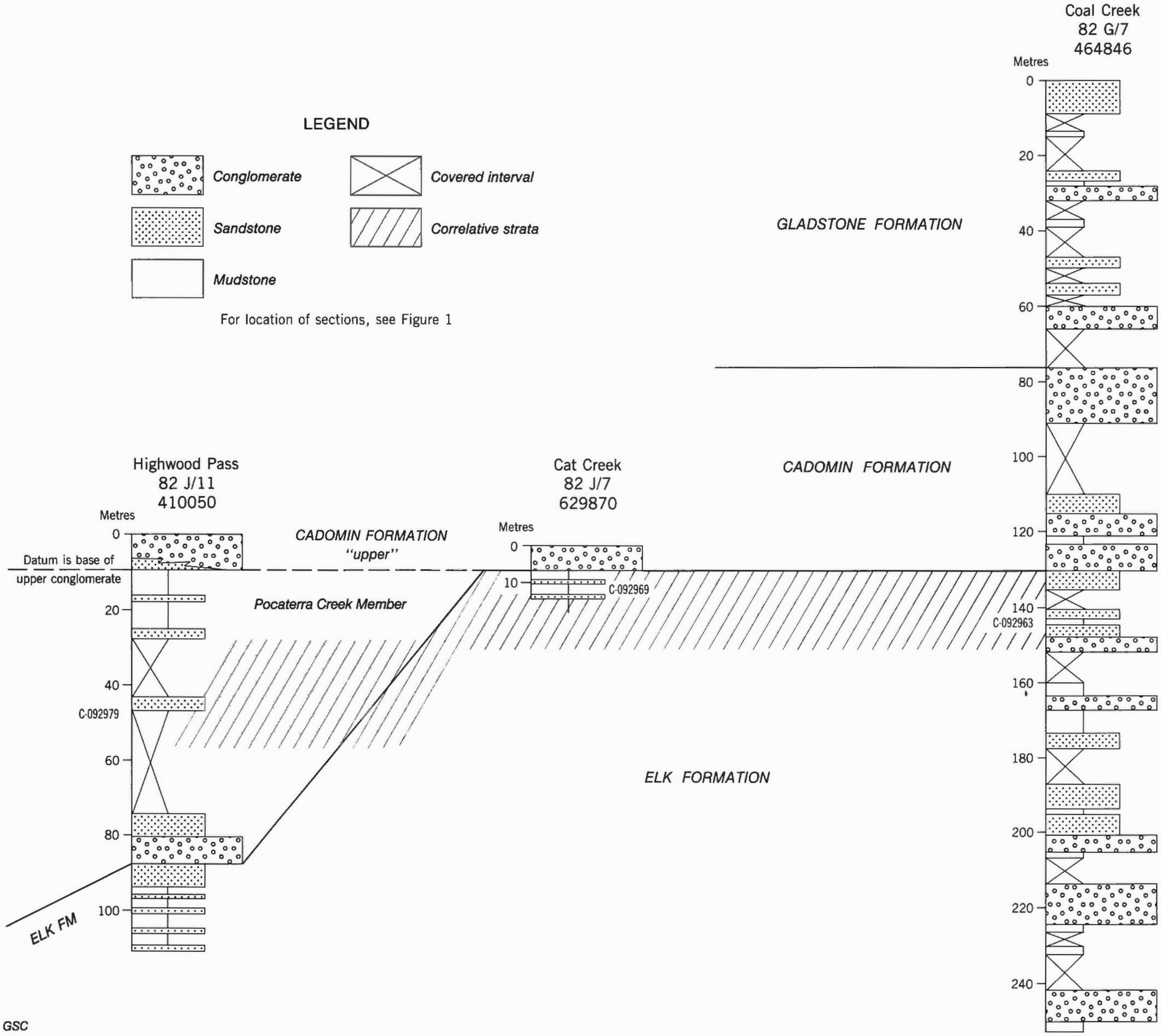


***Figure 20.** Correlation diagram based on palynological results.*

AGE OF ELK - POCATERRA CREEK MICROFLORAL ASSEMBLAGE

Five lines of evidence support a Berriasian age for the microflora of the Elk - Pocaterra Creek interval:

1. The microfloras of the Jurassic - Cretaceous boundary interval in Europe have been extensively documented through the work of Couper (1958), Burger (1966), Döring (1965, 1966), Norris (1969), Dörhöfer (1977, 1979) and Dörhöfer and Norris (1977).

Figure 21 summarizes the ranges of species common to both northwestern Europe and the Elk - Pocaterra Creek interval. In Figure 21, the zonations established by Norris, Burger, and Döring have been correlated according to Herngreen et al. (1980, Text-fig. 6). The correlation of the zonations by Dörhöfer (1977, 1979) with the zonations of the authors listed above follows Dörhöfer (1979, Text-fig. 2). Although the correlations between the various zonations in Herngreen et al. (1980, Text-fig. 6) are similar to those of Dörhöfer (1979, Text-fig. 2), the placement of the Tithonian-Berriasian boundary differs significantly in these papers. Dörhöfer (1979) shows the boundary at the base of Norris's (1969) Zone B and the correlative zones of Döring and Burger, whereas Herngreen et al. place the Tithonian-Berriasian boundary at the top of Zone B and the correlative zones. Contributing to the above discrepancy in the placement of the Jurassic-Cretaceous boundary are two factors: uncertainty exists as to the correct placement of the Jurassic-Cretaceous boundary relative to the stage boundaries in the Tethyan Realm, as compared to those in the Boreal Realm; and problems exist in correlating between the marine and nonmarine sections of Europe. The reader is referred to Jeletzky (1973) and Casey (1973) for a discussion of these problems. For the purpose of this paper Berriasian will be used in the broader sense of Dörhöfer (1979) to include Zone B of Norris (1969).

Of the species listed in Figure 21, five [*Cicatricosisporites australiensis, Densoisporites velatus, Maculatisporites granulatus* (or synonymous species), *Pilosisporites trichopapillosus*, and *Trilobosporites bernissartensis*] are known to range from pre-Berriasian to post-Berriasian strata. However, fifteen species [*Cicatricosisporites grabowensis, C. purbeckensis, Concavissimisporites punctatus, Echinatisporis varispinosus, Foraminisporis dailyi, F. wonthaggiensis, Maculatisporites microverrucatus, Pilosisporites brevibaculatus, Schizophacus spriggii, Schizosporis reticulatus, Sigmopollis callosus, Trilobosporites aornatus, T. canadensis, T. granulatus*, and *T. obsitus*] are known only from Berriasian or younger strata. The presence of these species in the Elk - Pocaterra Creek interval argues for a post-Jurassic age. In contrast, the Jurassic microfloras reported by Pocock (1962, 1964, 1970) and Rouse (1959) from the Kootenay Group, Mist Mountain and Morrissey formations, differ from those of the Elk - Pocaterra Creek interval in that they lack any of the above species that are restricted to the Cretaceous.

2. Hughes's (1981) summary of the entrance levels for his various biorecords of cicatricose spores would suggest that the first entry of spores similar to *Cicatricosisporites purbeckensis* (*C.* sp. cf. *C. aralica* of this paper), together with an absence of *Appendicisporites* (as in the Elk - Pocaterra Creek interval), are indicative of an Early Berriasian age.

3. Microfloral assemblages were documented from the Valanginian and Hauterivian of Europe by Millioud (1967) and from the Early and Middle Valanginian (age based on *Buchia* spp.) of the District of Mackenzie, Canada, by McIntyre and Brideaux (1980). The Elk-Pocaterra Creek assemblages differ from those of the Valanginian and Hauterivian in possessing a diverse suite of *Trilobosporites* and *Impardecispora*, and in lacking *Appendicisporites, Aequitriradites* and *Triporoletes*. These differences suggest a pre-Valanginian age for the Elk - Pocaterra Creek interval.

4. A further argument for a pre-Valanginian age for the Elk-Pocaterra Creek interval is the fact that most of the species listed in Figure 21 were recovered only from the top portion of the sections (see figs. 18 and 19). Lower in the sections, a less diverse assemblage was recovered (figs. 18, 19), more reminiscent of the uppermost Jurassic as exemplified by the assemblage of Zone A, Norris (1969). A similar change in diversity was recorded by Dörhöfer (1979) between his Zone II and his Zone III. It should be stressed, however, that a Berriasian rather than a Jurassic age is favoured for the entire Elk-Pocaterra

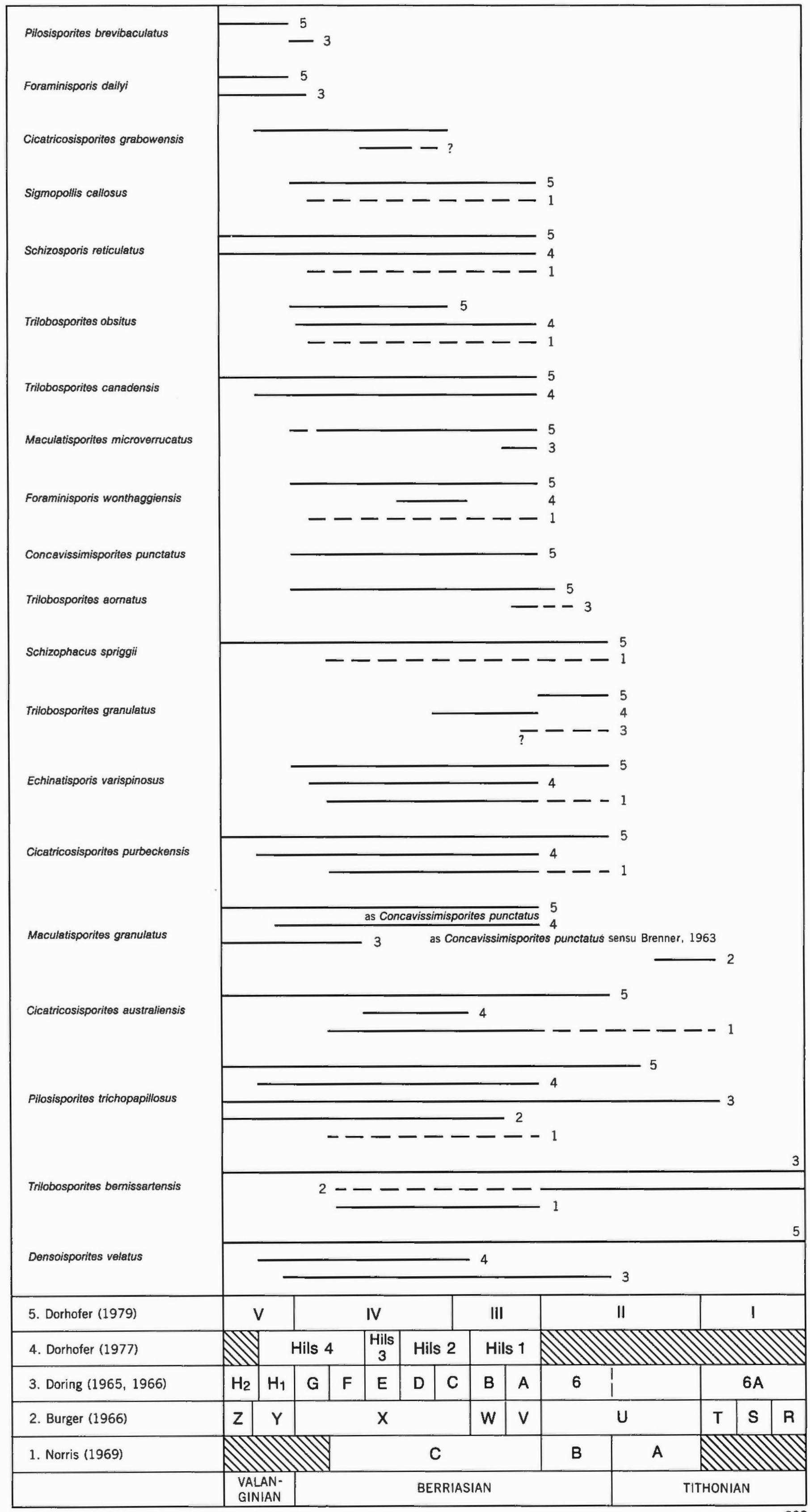


Figure 21. European stratigraphic ranges of species found in the Elk-Pocaterra Creek interval.

Creek interval, based on the presence of *Schizosporis reticulatus* well below the stratigraphic interval reported on in this paper.

5. The floristic changes referred to above, which have also been the subject of previous publications, are considered by Herngreen and Chlonova (1981) to be part of a worldwide change in spore and pollen assemblages near the Jurassic-Cretaceous boundary. If the floristic change noted within the sections studied for this report is part of this worldwide floristic event near the Jurassic-Cretaceous boundary, as seems likely, then a pre-Valanginian age for the Elk-Pocaterra Creek interval has additional support.

SUMMARY AND CONCLUSIONS

1. The Pocaterra Creek Member of the Cadomin Formation can be retained as an identifiable unit only in the Kananaskis region.

2. Based on the similarity of microflora, the Pocaterra Creek Member in the Kananaskis area appears to be the same age as strata at the top of the Elk Formation in the Fernie area.

3. Based on lithological and palynological criteria, it is considered that there is no discernible hiatus associated with the Kootenay-Blairmore transition at Coal Creek (Fernie Basin area). Similarly, the transition at Mount Allan and Highwood Pass appears essentially conformable, although a hiatus between the Pocaterra Creek Member and Kootenay Group probably increases in magnitude southwards toward Cat Creek, where the Cadomin directly overlies Kootenay strata.

4. The Pocaterra Creek Member represents a local precursor to the regionally extensive, coarse grained Cadomin deposits.

5. The Kananaskis and Fernie regions were major depocentres for alluvial fan, braid plain and pediment sedimentation in early Cretaceous times. At these two localities, the Elk Formation and Cadomin Formation (including the Pocaterra Creek Member) represent a prograding coastal plain and alluvial fan, wherein coarse sediment was dispersed mainly by braided rivers.

6. Both the Elk Formation and the Pocaterra Creek Member were deposited in warm temperate to subtropical, humid, regional climatic conditions with local arid conditions occurring periodically during the deposition of the Pocaterra Creek Member. The degree of aridity changed from humid during early Kootenay times, becoming progressively less humid during Elk times so that the thickness and number of coals decreased. The progression culminated in the lower Blairmore where local accumulation of red mudstone and caliche took place under semiarid conditions.

7. The Elk Formation and the Pocaterra Creek Member of the Cadomin Formation are certainly younger than Jurassic and most probably are of Berriasian age.

8. In a regional context, a Berriasian age for the Elk Formation implies that the main episode of pre-Cadomin coal formation occurred earlier in southeastern British Columbia and southwestern Alberta than in northeastern British Columbia, as coal-bearing strata at the top of the Minnes Group are of middle to late Valanginian age (Stott, 1981). Indeed, if one assumes more or less continuous deposition throughout the Elk-Cadomin interval, then the above age differences also imply that the Cadomin conglomerate is diachronous. The diachroneity of this stratigraphic unit is consistent with the interpretation advanced by Gibson (1977a, 1985a) and Hamblin and Walker (1979) of a northwards prograding clastic wedge.

REFERENCES

Allan, J.A. and Carr, J.L.
1947: Geology of the Highwood-Elbow area, Alberta; Alberta Research Council Report 49.

Anan-Yorke, R. and Stelck, C.R.
1978: Microfloras from Upper Albian *Neogastroplites* Zone, Sikanni Chief River, Northeastern British Columbia; in Western and Arctic Canadian Biostratigraphy, C.R. Stelck and B.D.E. Chatterton (eds.); Geological Association of Canada, Special Paper 18, p. 473-493.

Bebout, J.W.
1981: An informal palynologic zonation for the Cretaceous System of the United States mid-Atlantic (Baltimore Canyon area) outer continental shelf; Palynology, v. 5, p. 159-194.

Bell, W.A.
1956: Lower Cretaceous floras of Western Canada; Geological Survey of Canada, Memoir 285, 331 p.

Berry, E.W.
1929: The Kootenay and Lower Blairmore floras; National Museum of Canada, Bulletin 58, p. 28-54.

Blodgett, R.H. and Stanley, K.O.
1980: Stratification, bedforms and discharge relations of the Platte braided river system, Nebraska; Journal of Sedimentary Petrology, v. 50, p. 139-148.

Bolkhovitina, N.A.
1961: Fossil and contemporaneous spores of the Family Schizaeaceae. Translation of Iskopaemye i souremenniye spory semeystva Schizeynykh; Moskva, Akademiia Nauk SSSR, 176 p.

Boothroyd, J.C. and Nummedal, D.
1978: Proglacial braided outwash: a model for humid alluvial-fan deposits; in Fluvial Sedimentology, A.D. Miall (ed.); Canadian Society of Petroleum Geologists, Memoir 5, p. 641-668.

Brenner, G.J.
1963: The spore and pollens of the Potomac Group of Maryland; Maryland Department of Geology, Mines and Water Resources, State of Maryland Bulletin 27, 215 p.

Brideaux, W.W. and Fisher, M.J.
1976: Upper Jurassic - Lower Cretaceous dinoflagellate assemblages from Arctic Canada; Geological Survey of Canada, Bulletin 259, 53 p.

Burger, D.
1966: Palynology of the uppermost Jurassic and lowermost Cretaceous strata in the eastern Netherlands; Leidse Geologische Mededelingen, v. 35, p. 209-276.

Cant, D.J.
1978: Development of a facies model for sandy braided river sedimentation; comparison of the South Saskatchewan River and the Battern Point Formation; Fluvial Sedimentology, A.D. Miall (ed.); Canadian Society of Petroleum Geologists, Memoir 5, p. 627-639.

Casey, R.
1973: The ammonite succession at the Jurassic-Cretaceous boundary in eastern England; in The Boreal Lower Cretaceous, R. Casey and P.F. Rawson (eds.); Geological Journal, Special Issue No. 5, Seel House Press, Liverpool, p. 193-266.

Couper, R.A.
1958: British Mesozoic microspores and pollen grains, a systematic and stratigraphic study; Palaeontographica, Abteilung B, v. 103, p. 75-179.

Crockford, M.B.B.
1949: Geology of the Ribbon Creek area, Alberta; Alberta Research Council Report 52.

Delcourt, A.F., Dettmann, M.E., and Hughes, N.F.
1963: Revision of some Lower Cretaceous microspores from Belgium; Palaeontology, v. 6, p. 282-292.

Delcourt, A.F. and Sprumont, G.
1955: Les spores et grains de pollen du Wealdien du Hainaut; Mémoires de la Société Belge de Géologie (Bruxelles), v. 5, 73 p.

Dettmann, M.E.
1963: Mesozoic microfloras from southeastern Australia; Royal Society of Victoria, v. 77, 148 p.

Dörhöfer, G.
1977: Palynologie und Stratigraphie der Bückeberg - Formation (Berriasium - Valanginium) in der Hilsmalde (NW-Deutschland); Geologisches Jahrbuch, Reihe A, v. 42, p. 3-122.

1979: Distribution and stratigraphic utility of Oxfordian to Valanginian miospores in Europe and North America; American Association of Stratigraphic Palynologists, Contributions Series, No. 5B, p. 101-132.

Dörhöfer, G. and Norris, G.
1977: Discrimination and correlation of highest Jurassic and lowest Cretaceous terrestrial palynofloras in northwest Europe; Palynology, v. 1, p. 79-93.

Döring, H.
1964: Trilete Sporen aus dem Oberen Jura und dem Wealden Norddeutschlands; Geologie, v. 13, no. 9, p. 1099-1129.

1965: Die sporen paläontologische Gliederung des Wealden im Westmecklenburg (Struktur Werle); Geologie, v. 14, p. 1-118.

1966: Sporenstratigraphischer Vergleich zwischen dem Wealden Norddeutschlands und Südenglands; Geologie, v. 55, p. 102-129.

Doyle, J.A.
1969: Cretaceous angiosperm pollen of the Atlantic Coastal Plain and its evolutionary significance; Journal of the Arnold Arboretum, v. 50, p. 1-33.

Eynon, G. and Walker, R.G.
1974: Facies relationships in Pleistocene outwash gravels, southern Ontario: a model for bar growth in braided rivers; Sedimentology, v. 21, p. 43-70.

Frebold, H.
1954: Stratigraphic and palaeogeographic studies in the Jurassic Fernie Group, Alberta; Alberta Society of Petroleum Geologists, News Bulletin, v. 2, p. 1-2.

1957: The Jurassic Fernie Group in the Canadian Rocky Mountains and Foothills; Geological Survey of Canada, Memoir 287, 197 p.

Gibson, D.W.
1977a: Sedimentary facies in the Jura-Cretaceous Kootenay Formation, Crowsnest Pass area, southwestern Alberta and southeastern British Columbia; Bulletin of Canadian Petroleum Geology, v. 25, p. 767-791.

1977b: The Kootenay Formation of Alberta and British Columbia - a stratigraphic summary; Geological Survey of Canada, Paper 77-1A, p. 95-97.

1979: The Morrissey and Mist Mountain Formations - newly defined lithostratigraphic units of the Jura-Cretaceous Kootenay Group, Alberta and British Columbia; Bulletin of Canadian Petroleum Geology, v. 27, p. 183-208.

1985a: Stratigraphy, sedimentology and depositional environments of the coal-bearing Jurassic-Cretaceous Kootenay Group, Alberta and British Columbia; Geological Survey of Canada, Bulletin 357.

1985b: Stratigraphy and sedimentology of the Gething Formation, Carbon Creek Coal basin, northeastern British Columbia; Geological Survey of Canada, Paper 80-12.

Glaister, R.P.
1959: Lower Cretaceous of southern Alberta and adjoining areas; American Association of Petroleum Geologists, Bulletin, v. 43, p. 590-640.

Gole, C.V. and Chitale, S.V.
1966: Inland delta building activity of Kosi River; Journal of the Hydraulics Division; Proceedings of the American Society of Civil Engineers, v. 92, p. 111-126.

Gussow, W.C.
1960: Jurassic-Cretaceous boundary in Western Canada and Late Jurassic age of the Kootenay Formation; Royal Society of Canada, Transactions, v. 54, p. 45-64.

Habib, D.
1977: Comparison of Lower and Middle Cretaceous palynostratigraphic zonations in the western North Atlantic; in Stratigraphic Micropaleontology of Atlantic Basin and Borderlands, F.M. Swain (ed.); Elsevier Scientific Publishing Company, Amsterdam, p. 341-368.

Hamblin, A.P. and Walker, R.G.
1979: Storm-dominated shallow marine deposits: the Fernie-Kootenay (Jurassic) transition, southern Rocky Mountains; Canadian Journal of Earth Sciences, v. 16, p. 1673-1690.

Hein, F.J. and Walker, R.G.
1977: Bar evolution and development of stratification in a gravelly braided river, Kicking Horse River, British Columbia; Canadian Journal of Earth Sciences, v. 14, p. 562-570.

Herngreen, G.F.W. and Chlonova, A.F.
1981: Cretaceous microfloral provinces; Pollen et Spores, v. 23, p. 441-556.

Herngreen, G.F.W., Van Hoeken-Klinkenberg, P.M.J. and De Boer, K.F.
1980: Some remarks on selected palynomorphs near the Jurassic-Cretaceous boundary in the Netherlands; IV International Palynological Conference, Lucknow (1976-1977), v. 2, p. 357-367.

Hughes, J.D.
1975: Correlation and cyclicity analysis of the Jurassic-Cretaceous Kootenay Formation near Canmore, Alberta; Unpublished MSc Thesis, University of Alberta, 191 p.

Hughes, J.D. and Cameron, A.R.
1985: Lithology, depositional setting, and coal-rank depth relationships in the Jurassic-Cretaceous Kootenay Group at Mount Allan, Cascade Coal Basin, Alberta; Geological Survey of Canada, Paper 81-11, 41 p.

Hughes, N.F.
1981: Jurassic-Cretaceous boundary palynology in Europe; The Palaeobotanist, v. 28-29, p. 316-323.

Jackson, R.G.
1976: Large scale ripples of the lower Wabash River; Sedimentology, v. 23, p. 593-624.

Jansa, L.F.
1972: Depositional history of the coal-bearing Upper Jurassic-Lower Cretaceous Kootenay Formation, southern Rocky Mountains; Geological Society of America, Bulletin, v. 83, p. 3199-3222.

Jeletzky, J.A.
1973: Biochronology of the marine boreal latest Jurassic, Berriasian and Valanginian in Canada; in The Boreal Lower Cretaceous, R. Casey and P.F. Rawson (eds.); Geological Journal Special Issue No. 5, Seel House Press, Liverpool, p. 41-80.

Kalkreuth, W.D.
1982: Rank and petrographic composition of selected Jurassic-Lower Cretaceous coals of British Columbia, Canada; Bulletin of Canadian Petroleum Geology, v. 30, p. 112-139.

Kemp, E.M.
1970: Aptian and Albian Miospores from Southern England; Palaeontographica, Abteilung B, v. 131, p. 73-143.

McGowen, J.H. and Groat, C.G.
1971: Van Horne Sandstone, west Texas: an alluvial fan model for mineral exploration; University of Texas, Bureau of Economic Geology, Report of Investigations 72.

McIntyre, D.J. and Brideaux, W.W.
1980: Valanginian miospore and microplankton assemblages from the northern Richardson Mountains, District of Mackenzie, Canada; Geological Survey of Canada, Bulletin 320, 57 p.

McLean, J.R.
1976: Cadomin Formation: eastern limit and depositional environment; Geological Survey of Canada, Paper 76-1B, p. 323-327.

1977: The Cadomin Formation: stratigraphy, sedimentology and tectonic implications; Bulletin of Canadian Petroleum Geology, v. 25, p. 792-827.

1982: Lithostratigraphy of the Lower Cretaceous coal-bearing sequence, Foothills of Alberta; Geological Survey of Canada, Paper 80-29.

McLean, J.R. and Wall, J.H.
1981: The Early Cretaceous Moosebar Sea in Alberta; Bulletin of Canadian Petroleum Geology, v. 29, p. 334-377.

Miall, A.D.
1977: A review of the braided-river depositional environment; Earth Science Review, v. 13, p. 1-62.

1978: Lithofacies types and vertical profile models in braided river deposits: a summary; in Fluvial Sedimentology, A.D. Miall (ed.); Canadian Society of Petroleum Geologists, Memoir 5, p. 597-604.

Millioud, M.E.
1967: Palynological study of the type localities at Valangin and Hauterive; Review of Paleobotany and Palynology, v. 5, p. 155-167.

Newmarch, C.B.
1953: Geology of the Crowsnest Coal basin; British Columbia Department of Mines, Bulletin 33.

Norris, D.K.
1964: The Lower Cretaceous of the southeastern Canadian Cordillera; Bulletin of Canadian Petroleum Geology, v. 12, p. 512-535.

Norris, G.
1969: Miospores from the Purbeck beds and marine Upper Jurassic of southern England; Palaeontology, v. 12, p. 574-620.

Ollerenshaw, N.C.
1981: Cadomin Formation, Flathead Ridge vicinity, southeastern British Columbia; Geological Survey of Canada, Paper 81-1A, p. 341-347.

Paden Phillips, P. and Felix, C.J.
1971: A study of lower Middle Cretaceous spores and pollen from the southeastern United States; I. Spores; Pollen et Spores, v. 13, no. 2, p. 279-348.

Pearson, D.E. and Grieve, D.A.
1980: Elk Valley coalfield; in Geological Fieldwork, 1979; Ministry of Energy, Mines and Petroleum Resources, British Columbia, Paper 1980-1, p. 91-96.

Pierce, S.T.
1976: Morphology of *Schizosporis reticulatus* Cookson and Dettmann, 1959; Geoscience and Man, v. 15, p. 25-33.

Pocock, S.A.J.
1962: Microfossil analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canada Plains; Palaeontographica, Abteilung B, v. 111, p. 1-95.

1964: Palynology of the Kootenay Formation at its type section; Bulletin of Canadian Petroleum Geology, Special Guidebook Issue, Flathead Valley, v. 12, p. 500-512.

1970: Palynology of the Jurassic sediments of Western Canada, Part 1, Terrestrial Species; Palaeontographica, Abteilung B, v. 130, p. 12-136.

1980: Palynology at the Jurassic-Cretaceous boundary in North America; IV International Palynological Conference, Lucknow (1976-1977), v. 2, p. 377-385.

Rapson, J.E.
1965: Petrography and derivation of Jurassic-Cretaceous clastic rocks, southern Rocky Mountains, Canada; American Association of Petroleum Geologists, Bulletin, v. 49, p. 1426-1452.

Rouse, G.E.
1959: Plant microfossils from Kootenay coal-measures strata of British Columbia; Micropaleontology, v. 5, p. 303-324.

Rust, B.R.
1972: Structure and process in a braided river; Sedimentology, v. 18, p. 221-245.

1978: Depositional models for braided alluvium; in Fluvial Sedimentology, A.D. Miall (ed.); Canadian Society of Petroleum Geologists, Memoir 5, p. 605-625.

Rust, B.R. and Koster, E.H.
1984: Coarse alluvial deposits; in Facies Models, second edition, R.G. Walker (ed.); Geoscience, Canada Reprint Series 1, p. 53-69.

Singh, C.
1964: Microflora of the Lower Cretaceous Mannville Group, east-central Alberta; Research Council of Alberta, Bulletin 15, 239 p.

1971: Lower Cretaceous microfloras of the Peace River area, northwestern Alberta; Research Council of Alberta, Bulletin 28, v. 1, 300 p.

Srivastava, S.K.
1975: Miospores from the Fredericksburg Group (Albian) of the southern United States; Paléobiologie continentale, v. 6, 119 p.

1978: Cretaceous spore-pollen floras: a global evaluation; Biological Memoirs, v. 3, p. 1-130.

Stott, D.F.
1968: Lower Cretaceous Bullhead and Fort St. John Groups, between Smoky and Peace rivers, Rocky Mountain Foothills, Alberta and British Columbia; Geological Survey of Canada, Bulletin 152, 279 p.

1981: Bickford and Gorman Creek, two new formations of the Jurassic-Cretaceous Minnes Group, Alberta and British Columbia; Geological Survey of Canada, Paper 81-1B, p. 1-9.

Sweet, A.R.
1972: Palynologic study of coals and associated clastics of the Kootenay Formation, Crowsnest area; Geological Survey of Canada, Paper 72-1B, p. 23.

1978: Palynology of the lower part, type section, Tent Island Formation, Yukon Territory; in Current Research, Part B, Geological Survey of Canada, Paper 78-1B, p. 31-37.

Traverse, A.
1955: Occurrence of the oil forming alga *Botryococcus* in lignites and other Tertiary sediments; Micropaleontology, v. 1, p. 343-350.

Tschudy, R.H. and Scott, R.A.
1969: Aspects of Palynology; New York, Wiley - Interscience, p. 510.

Vagvolgyi, A. and Hills, L.V.
1969: Microflora of the Lower Cretaceous McMurray Formation, northeast Alberta; Bulletin of Canadian Petroleum Geology, v. 17, p. 155-181.

Vakhrameev, V.A.
1981: Pollen *Classopollis*: indicator of Jurassic and Cretaceous climates; The Palaeobotanist, v. 28-29, p. 301-307.

Vondra, C.F. and Burggraf, D.R. Jr.
1978: Fluvial facies of the Plio-Pleistocene Koobi Fora Formation, Karari Ridge, East Lake Turkana, Kenya; in Fluvial Sedimentology, A.D. Miall (ed.); Canadian Society of Petroleum Geologists, Memoir 5, p. 511-529.

Williams, G.L.
1975: Dinoflagellate and spore stratigraphy of the Mesozoic-Cenozoic, offshore eastern Canada; Geological Survey of Canada, Paper 74-30, p. 107-161.

Williams, P.F. and Rust, B.R.
1969: The sedimentology of a braided river; Journal of Sedimentary Petrology, v. 39, p. 649-679.

Yu Jingxian, Guo Zhengying, and Mao Shaozhi
1983: Cretaceous palynological assemblages from the district south of the Songhua River; Professional Papers of Stratigraphy and Palaeontology, Chinese Academy of Geological Sciences, Geological Publishing House, Peking, China, no. 10, p. 1-117.

PLATE LEGENDS

The reference numbers given for the figured specimens include: a GSC locality number prefixed by a C; a preparation and slide number prefixed by a P; stage co-ordinates (Leitz Ortholux Microscope 646202); and a GSC type number.

All specimens are magnified 750 X and were photographed in bright field illumination. Figured specimens are stored in the type collection of the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada, K1A OE8.

PLATE 1

Figure	1.	*Biretisporites potoniaei*, C-92963, P2391-9d, 33.3x118.3, GSC 68192.
Figures	2-4.	*Cicatricosisporites* sp. cf. *C. aralica*.
	2, 3.	C-92963, P2391-9a, 41.4x119.5, GSC 68193.
	4.	C-92979, P2391-22b, 33.2x110.8, GSC 68194.
Figures	5, 6.	*Cicatricosisporites australiensis*
	5.	C-92978, P2391-21b, 29.5x110.1, GSC 68195.
	6.	C-92962, P2391-8b, 20.3x114.8, GSC 68196.
Figures	7, 8.	*Cicatricosisporites* sp. cf. *C. grabowensis* C-92962, P2391-8b, 25.3x114.3, GSC 68197.
Figure	9.	*Ceratosporites* sp., C-92962, P2391-8c, 23.3x126.3, GSC 68198.
Figures	10, 11.	*Ischyosporites punctatus*, C-92963, P2391-9q, 28.2x113.0, GSC 68199.
Figures	12, 13.	*Concavissimisporites punctatus*, C-92963, P2391-9d.
	12.	20.8x121.4, GSC 68200.
	13.	28.3x110.2, GSC 68201.
Figure	14.	*Densoisporites velatus*, C-92962, P2391-8c, 38.4x122.8, GSC 68202.
Figures	15, 16.	*Foraminisporis wonthaggiensis*, C-92961, P2391-7a, 17.0x115.3, GSC 68203.
Figure	17.	*Foraminisporis dailyi*, C-92963, P2391-9c, 27.9x116.2, GSC 68204.
Figure	18.	*Convolutriletes* sp. cf. *C. rousei*, C-92962, P2391-8c, 26.5x117.6, GSC 68205.
Figures	19, 20.	*Echinatisporis varispinosus*, C-92979, P2391-22a, 14.2x115.4, GSC 68206.
Figure	21.	*Gleicheniidites senonicus*, C-92963, P2391-9f, 13.2x120.3, GSC 68207.

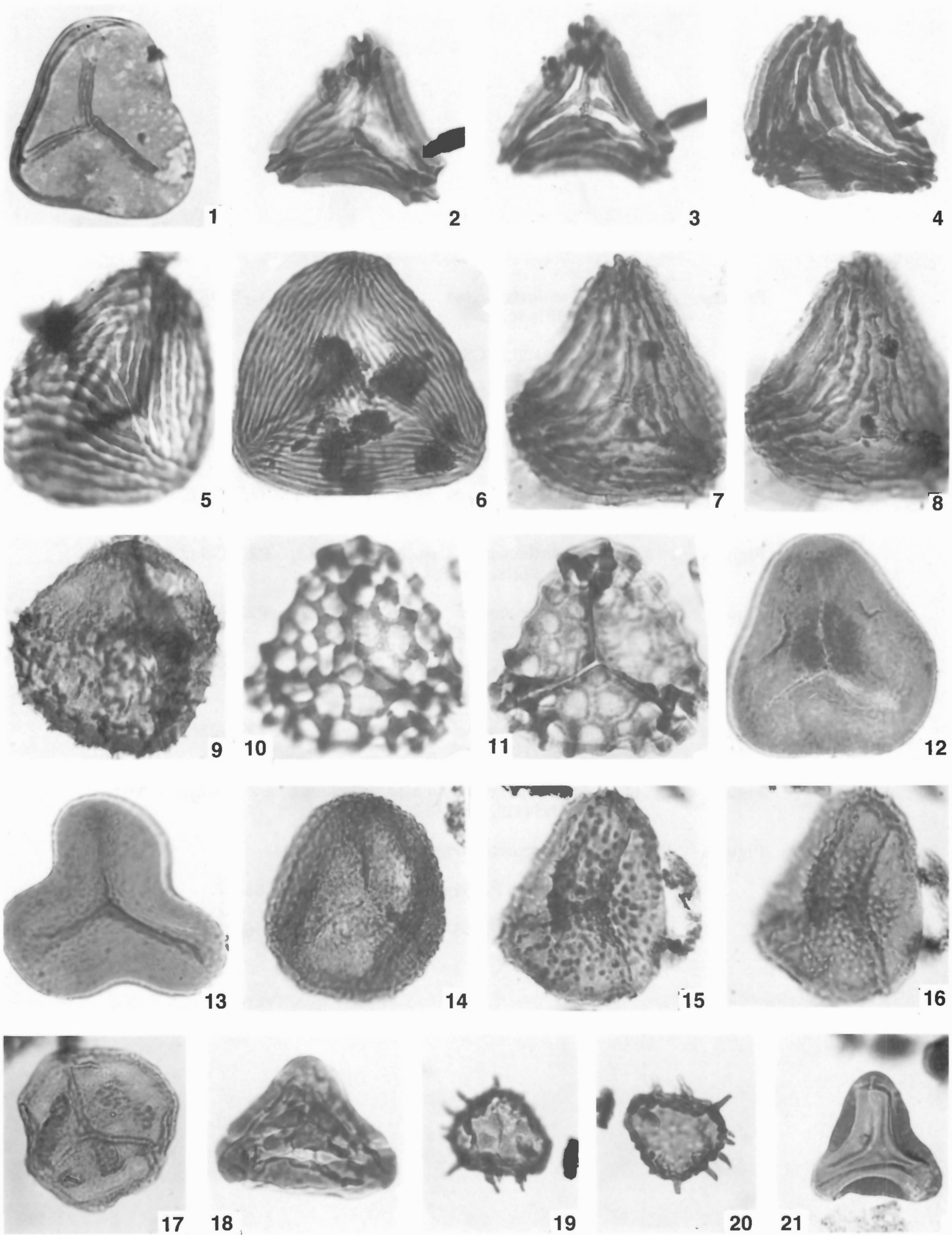

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PLATE 2

Figures	1, 2.	*Maculatisporites granulatus*, C-92963, P2391-9c.
	1.	38.2x120.7, GSC 68208.
	2.	25.1x125.5, GSC 68209.
Figure	3.	*Maculatisporites microverrucatus*, C-92963, P2391-9c, 38.4x125.8, GSC 68210.
Figure	4.	*Maculatisporites parkinii*, C-92963, P2391-9d, 35.8x124.8, GSC 68211.
Figures	5, 6.	*Impardecispora* sp. A, C-92963, P2391-9c, 24.6x122.8, GSC 68212.
Figure	7.	*Impardecispora minor*, C-92963, P2391-9r, 28.6x115.8, GSC 68213.
Figure	8.	*Pilosisporites brevibaculatus*, C-92959, P2391-5b, 17.8x108.8, GSC 68214.
Figures	9, 10.	*Impardecispora* sp. A, C-92979, P2391-22c, 36.8x110.4, GSC 68215.
Figure	11.	*Osmundacidites major*, C-92963, P2391-9q, 29.0x111.2, GSC 68216.
Figures	12, 13.	*Pilosisporites trichopapillosus*.
	12.	C-92963, P2391-9c, 24.3x121.6, GSC 68217.
	13.	C-92979, P2391-22b, 26.2x116.3, GSC 68218.

PLATE 2

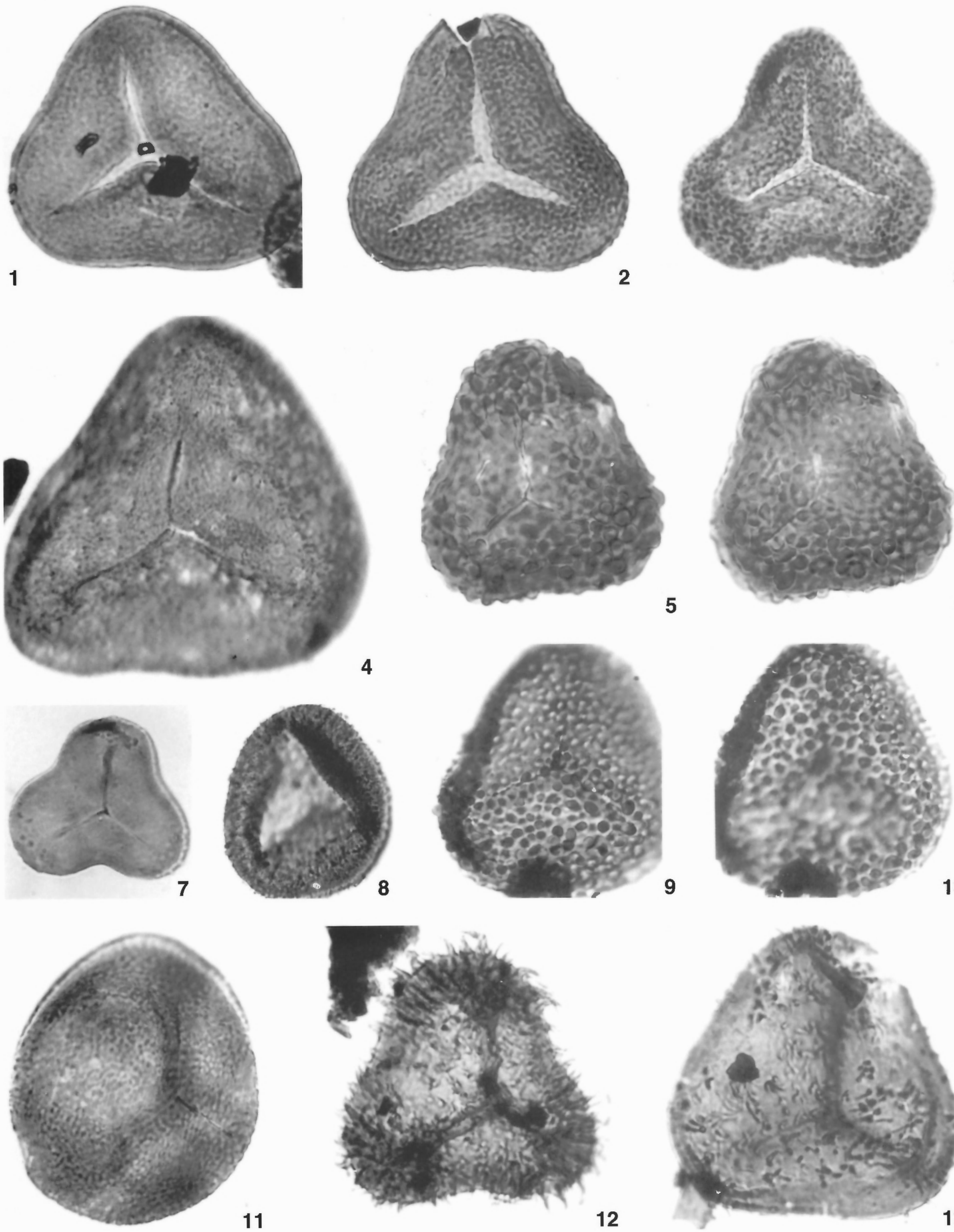

PLATE 3

Figure	1.	*Impardecispora uralensis*, C-92963, P2391-9q, 31.6x115.1, GSC 68219.
Figures	2-4.	*Trilobosporites obsitus*, C-92963.
	2, 3.	2391-9q, 15.2x112.6, GSC 68220.
	4.	2391-9d, 23.4x113.8, GSC 68221.
Figure	5.	*Trilobosporites* sp. cf. *T. bernissartensis*, C-92963, P2391-9q, 26.2x111.6, GSC 68222.
Figures	6-8.	*Trilobosporites canadensis*, C-92963.
	6.	P2391-9c, 28.4x117.8, GSC 68223.
	7.	P2391-9d, 23.1x121.9, GSC 68224.
	8.	P2391-9d, 11.8x118.6, GSC 68225.
Figure	9.	*Trilobosporites aornatus*, C-92963, P2391-9q, 33.2x115.3, GSC 68226.
Figures	10, 11.	*Trilobosporites hannonicus*, C-92963, P2391-9q.
	10.	15.8x111.2, GSC 68227.
	11.	22.2x118.2, GSC 68228.
Figure	12.	*Trilobosporites* sp. cf. *T. granulatus*, C-92963, P2391-9k, 11.4x112.5, GSC 68229

PLATE 3

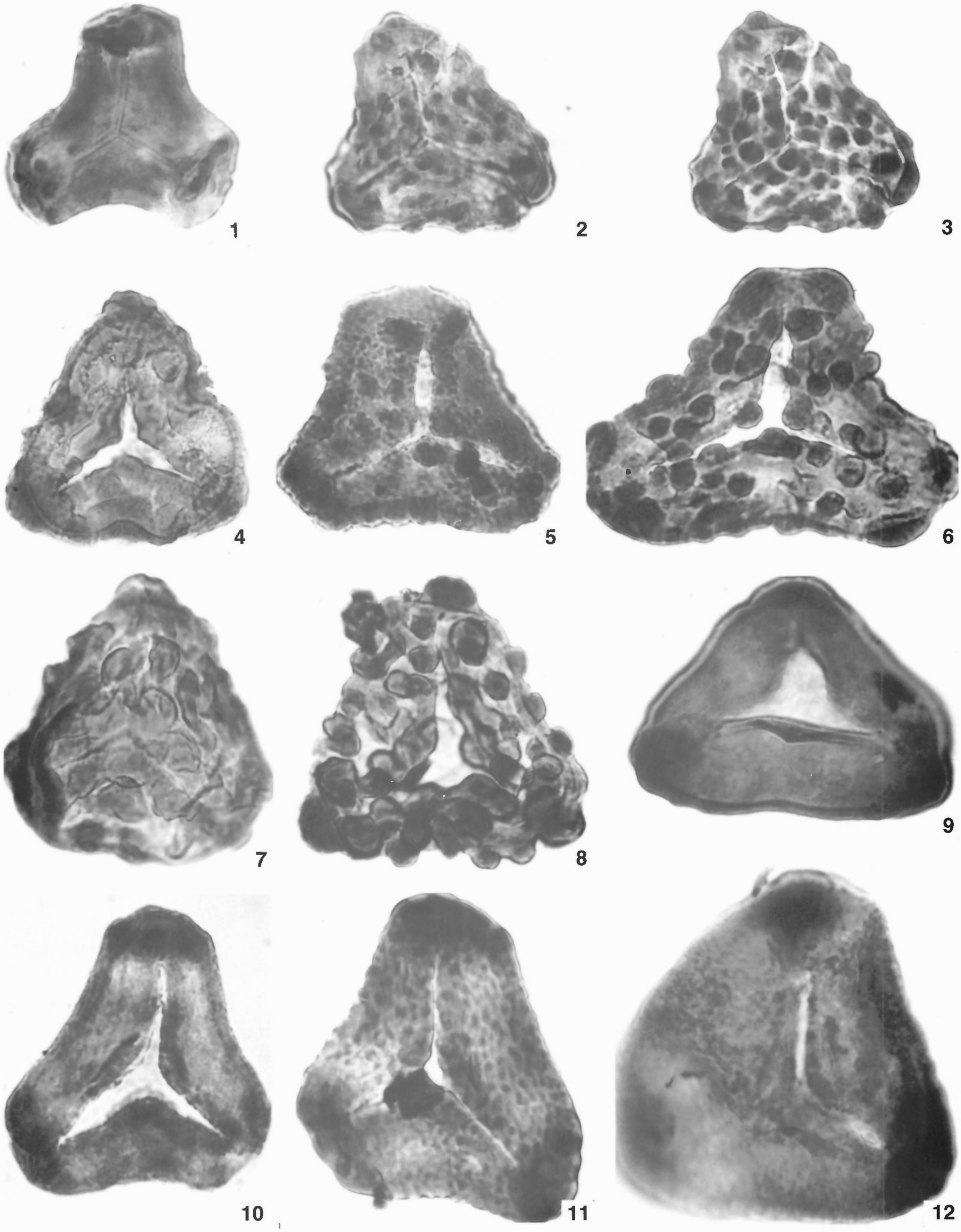

PLATE 4

Figure

1. *Schizophacus spriggii*, C-92963, P2391-9j, 11.7x120.0, GSC 68230.

2. *Eucommiidites troedssonii*, C-92959, P2391-5b, 14.8x114.7, GSC 68231.

3. *Ephedripites multicostatus*, C-92963, P2391-9f, 20.2x122.2, GSC 68232.

4. *Ephedripites* sp. cf. *E. patapscoensis*, C-92963, P2391-9e, 28.3x118.3, GSC 68233.

5. *Tetranguladinium conspicuum*, C-92979, P2391-22c, 41.3x118.0, GSC 68822.

6. *Callialasporites obrutus*, C-92962, P2391-8b, 19.5x109.7, GSC 68823.

7. *Sigmopollis* sp., C-92979, P2391-22d, 30.6x114.5, GSC 68824.

8. *Botryococcus* sp., C-92963, P2391-9r, 24.3x113.3, GSC 68825.

9. *Classopollis torosus*, C-92962, P2391-8d, 33.3x121.2, GSC 68826.

10. *Schizosporis reticulatus*, C-92963, P2391-9j, 32.3x120.4, GSC 68827.

11. *Schizophacus rugulatus*, C-92963, P2391-9d, 31.0x115.7, GSC 68828.

PLATE 4